U. S. Department
of Transportation
Federal Railroad
Administration

# North Carolina "Sealed Corridor" Phase I
## U.S. DOT Assessment Report

**Report to Congress**

Office of Railroad Development

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# Executive Summary

In response to a request in the Senate Report 107-38 accompanying the Department of Transportation and Related Agencies Appropriations Act, 2001, 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 2000 in terms of "Lives Saved." The analysis concludes that five lives were saved during the study period and that this positive benefit of the Sealed Corridor improvements will grow as vehicle volume, trains frequency and train speeds increase.

The North Carolina Department of Transportation (NC DOT) plays a prominent role among States pursuing High-Speed Ground Transportation (HSGT) development. The State contains much of the designated "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. 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, 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 "Sealed Corridor" consists of 216 grade crossings, 44 of which are private crossings. Phase I of the implementation plan for the corridor addresses 100 crossings between Charlotte and Greensboro. Fifty-two of the 100 crossings have been improved and/or closed. The research documented in this report assesses the safety benefits of the improvements made to the highway-rail intersections from March 1995 to September 2000.

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 as part of Phase I. Some of the improvements include non-standard devices such as traffic channelization and four-quadrant gates. The progress is described in terms of safety benefits. Crash data were examined through December 2000 to ensure any incidents that may have occurred at crossings improved through September 2000 would be included. This report also contains an analysis and evaluation of whether the resulting reduction in accidents is sustainable through the year 2010 when the State expects that train speeds along the corridor should 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 2000; 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. Further predictions are then completed by reviewing the reduction in risk of the entire Phase I project with all 100 crossings improved and/or closed. The resulting risk reduction that can be anticipated through the year 2010 is then calculated at operating train speeds of 110 mph along the corridor.

## Conclusions

### At least five 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) through December 2000 that each specific crossing had been improved. The sum of these results was then calculated over all of the crossings that were improved. This resulted in an estimate of 5.8, or, conservatively, 5 lives saved as a result of the 52 improvements implemented through December 2000.

The "modified U.S. DOT accident prediction formula" 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 estimates were accumulated for corridor-wide results. This method estimated that the improvements implemented through 2000 are reducing fatalities by approximately 1.3 each year, or over one life saved each year. This correlates well with the results derived from the "fatal crash analysis method", thus providing FRA confidence in the benefits of the improvements to date.

## The accident reduction result is sustainable.

In order to estimate future accident reduction rates, the second of the above methods was used to ensure increases in train and vehicle exposure over time are considered in the analysis. By the year 2010, NC DOT projects 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 three conditions: (1) all 100 Phase I crossings have been treated (build), (2) no additional crossings are treated (i.e. only 52 of the 100 crossings have been treated, partial build) and (3) the baseline that would have existed if none of the Phase I crossings had been treated (no build). The graph shows the influence of the improvements, which were initiated in March 1995, on reducing the annual fatalities through the year 2000. In the build case, the improvements at the remaining 48 crossings in Phase I were assumed to be implemented in 2002, resulting in a further reduction in annual fatalities. The gradual increase in traffic volume and train frequency from 2002 through 2010 is expected to increase annual fatalities under all three conditions. Finally, the increase in train speed to 110 mph assumed to occur in 2010 would further increase all fatality rates.

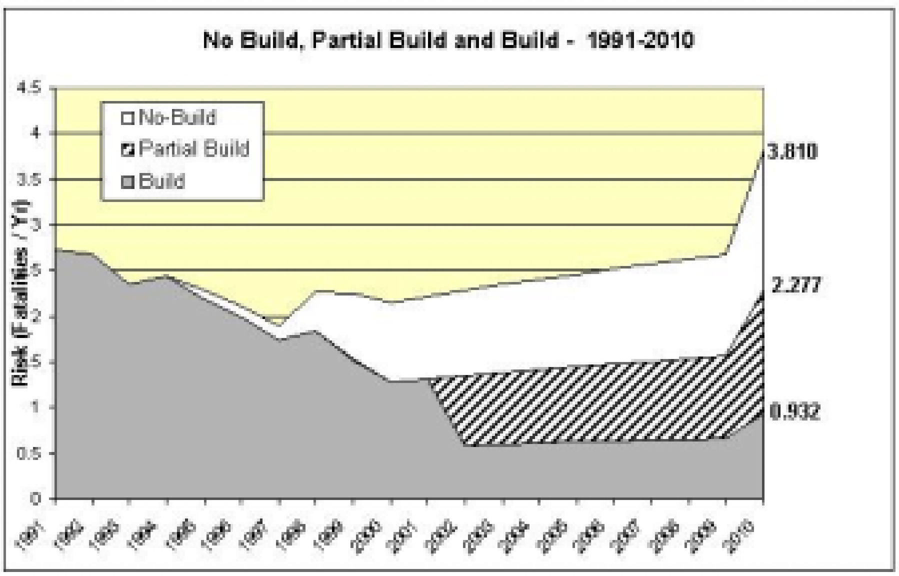


**Figure 1. Build, Partial Build, No Build Risk Calculations from 1991 through 2010 Using the Modified U.S. DOT Formula**

As can be seen in Figure 1, the difference in annual fatalities (the number of lives saved per year) under all three conditions (build, partial build, and no build) would continue to increase throughout the period to 2010. By 2010 the fatality rate resulting from the full treatment of the 100 crossings along the Phase I corridor would be 75 percent lower than the no build condition. Furthermore, if there were no more improvements implemented beyond the calendar year 2000, the annual fatalities in 2010 would still be 40 percent lower than the no build condition.

**Further conclusions**

- The benefit/cost ratio of improvements at crossings with previously experienced fatalities is high. For example, the fatal crash analysis showed that this ratio would be 40:1 for the ten crossings in Phase I with a history of fatal crashes, and 22:1 for the Sugar Creek Road crossing, where five years of post-improvement "after" data is available.
- A detailed analysis was not performed on the additional 116 crossings on the "Sealed Corridor" that are planned to be improved in Phases II, III, and IV. A simple extrapolation of the results of Phase I suggests that approximately 5.5 lives per year would be saved by implementing all phases of the Sealed Corridor program.
- The crossings along the Phase I portion of 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, US Code. This suggests that similar plans for corridor grade crossing improvements be given serious consideration in connection with high-speed rail upgrades in these corridors.
- The implementation of the North Carolina "Sealed Corridor" initiative is a demonstration of non-standard corridor highway-railroad grade crossing improvements. As the rest of this demonstration is implemented it should be monitored to serve as a basis for assessing the potential impact of similar programs in other corridors.

**Acknowledgements**

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# 1.0 BACKGROUND

## 1.1 Introduction

The purpose of this report is to document the benefits of the State of North Carolina's Phase I "Sealed Corridor" Program and the improvements completed through September 2000 at highway-rail grade crossings. A Fatal Crash Analysis method and a modified U.S. DOT Accident Prediction Formula were employed utilizing crash histories and fatalities from 1987 through December 2000. Benefits were estimated for the treatments used along this portion of the "Sealed Corridor" through December 2000 in terms of "Lives Saved." This report documents an assessment of the benefits resulting from a portion, 52 crossings, of the Phase I "Sealed Corridor" Program that have been improved through September 2000. This report also contains an analysis and evaluation of whether the resulting reduction in crashes is sustainable through the year 2010 when train speeds along the corridor are projected to achieve 110 mph and all 100 crossings have been treated and/or closed.

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 21$^{st}$ Century (TEA-21). As a result of this legislation and other initiatives, 10 high-speed rail passenger service corridors have been designated in the United States. High-speed rail operations on these and other emerging corridors could eventually result in train speeds above 110 mph. In creating a high-speed rail corridor in a growing state such as North Carolina, a greater exposure of vehicles to trains and higher train speeds will impact safety. The goal is to attain this improvement in passenger rail service while reducing the risk to both rail and highway users.

Recognizing that these risks must be addressed if high-speed rail service is to be realized, the FRA has developed guidelines for the installation of motorist warning and train protection devices at grade crossings on the designated high-speed rail corridors. In summary, the FRA Guidelines 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. Also, in 1998, the FRA finalized new track safety standards. In these new rules, the 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.

North Carolina plays a prominent role among states pursuing HSGT development. The State houses much of the designated SEHSR which connects Washington, D.C., Raleigh and Charlotte, with extensions south to Columbia, SC and Jacksonville, FL, and southwest to Greenville, SC, Atlanta and Macon, GA (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.


**Figure 2. Southeast High Speed Rail Corridor**

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 with sidings with approximately one crossing per mile. The route carries 35 freight trains per day with approximately 6 daily passenger trains. It has a mix of public and private crossings, the route contains both urban as well as rural environments 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.

The highway-rail grade crossings along the Phase I portion of the NC DOT "Sealed Corridor" are not atypical of the designated HSR corridors. Crossing consolidation activities are very beneficial to other HSR corridors and the applications of non-standard warning devices have interested most of the other corridors. Some of the other HSR corridors, e.g., Florida, are experimenting with innovative devices, also. We believe the results of the assessment study of the NC DOT "Sealed Corridor" Phase I program are transferable to most, if not all, designated HSR corridors nationwide. The experiences found along the "Sealed Corridor" in North Carolina are similar to freight corridors across the country and these techniques and innovations can be applied to these types of corridors as well.

## 1.2 Background on the NC DOT "Sealed Corridor" Initiative

The Feasibility Study for the SEHSR Corridor summarizes the findings of planning efforts for the corridor and provides recommendations for further action. Between Charlotte and Raleigh, the evaluation determined that the existing North Carolina Railroad (NCRR) through Greensboro was the most cost-effective route. Recognizing that improved safety must accompany improved service, the State of North Carolina instituted 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 progress made and benefits achieved in North Carolina as documented in this report hold great promise for continued high-speed rail corridor development in the future and serve as a formula for other States to follow.

In 1997, North Carolina was ranked 14th nationally for train/vehicle collisions. Norfolk Southern Corporation's main railroad line between Greensboro and Charlotte operates over the North Carolina Railroad and is host to high levels of freight traffic, with up to 35 daily freight trains moving over the Phase I portion of the corridor. In addition, six passenger trains currently use this route daily and the projections are to increase the frequency to 23 passenger trains by the year 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 2000, 154 crashes, involving 51 injuries and 34 fatalities have occurred on the corridor. Before crossing closures began under the "Sealed Corridor" program, there were 216 public and private crossings between Charlotte and Raleigh over a distance of 173.3 miles. NC DOT's comprehensive corridor approach includes evaluation of each crossing to determine the appropriate treatments. Approximately $10.3 million in Federal funds and $1.97 million in State funds have been received for crossing safety improvements along this corridor through FY 2001. The project has been funded through a partnership between the Federal Railroad Administration and the Federal Highway Administration (see Table 1). Federal and NC DOT dollars for safety are supplemented with in-kind services from Norfolk Southern Corporation and CSX Transportation. While providing the majority of the funding, U.S. DOT has empowered NC DOT and the railroad industry to think "outside the box" and develop solutions that enhance the existing warning devices at crossings and follow through with innovative, clear-minded approaches.

**Table 1. Sealed Corridor Crossing Safety Funding**

| Fiscal Year | Source | Amount | Proposed Sealed Corridor Phase |
|---|---|---|---|
| 1995 | Section 1010, ISTEA | $ 203,000 | Phase I – Charlotte-Greensboro |
| 1996 | Section 1010, ISTEA | $ 450,000 | Phase I – Charlotte-Greensboro |
| 1996 | Next Generation High Speed Rail/Section 1036, ISTEA | $750,000 | Phase I – Charlotte-Greensboro |
| 1997 | Section 1010, ISTEA | $ 750,000 | Phase I – Charlotte-Greensboro |
| 1997 | Next Generation High Speed Rail/Section 1036, ISTEA | $ 2,000,000 | Phase I – Charlotte-Greensboro |
| 1998 | Section 1010, ISTEA | $ 330,000 | Phase II – Greensboro-Cary |
| 1998 | Next Generation High Speed Rail | $ 2,000,000 | Phase II – Greensboro-Cary |
| 1998 | State Funding | $ 890,000 | Phase I – Charlotte-Greensboro |
| 1999 | Section 1103, TEA-21 | $ 590,000 | China Grove TSS Implementation |
| 1999 | Section 1103, TEA-21 | $ 410,000 | Phase I – Charlotte-Greensboro |
| 1999 | Next Generation High Speed Rail | $ 1,000,000 | Phase III – Raleigh-Cary/Phase II – Greensboro-Cary |
| 2000 | Section 1103, TEA-21 | $ 750,000 | Phase II – Greensboro-Cary/Crossing Inventory |
| 2000 | Next Generation High Speed Rail | $ 400,000 | Phase II – Greensboro-Cary |
| 2000 | State Funding | $ 639,000 | Phase III – Raleigh-Cary/Phase II – Greensboro-Cary |
| 2001 | Next Generation High Speed Rail | $699,000 | Phase IV Raleigh to Charlotte |
| 2001 | State Funding | $445,000 | To be determined |
| | **Total** | **$12,306,000** | |

As stated earlier, the NC DOT "Sealed Corridor" includes 216 grade crossings, 44 of which are private crossings. Phase I of the implementation plan for the corridor between Charlotte and Greensboro addresses 100 crossings. This assessment report documents benefits achieved in terms of "Lives Saved" through a fatal crash analysis method and determines the reduction in fatalities and risk through a modified U.S. DOT Accident Prediction Formula at all crossings that have been treated through September 2000. Fifty-two of the 100 crossings within the Phase I portion of the "Sealed Corridor" program have been improved and/or closed as of September 2000. The analyses documented in this report focus on the treated highway-rail crossings within the Phase I portion of the NC DOT "Sealed Corridor" program, and determine future reduction in risk for the total Phase I corridor through 2010.

The planned corridor improvements have been broken into four phases, based on location:

- Phase I — E. 36th Street, Charlotte northeastwards to S. 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
- Phase IV — Private Crossing Safety Improvement (PCSI) program, 44 private crossings between Charlotte and Raleigh

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

## 1.3 Objectives

The objectives of this assessment report are twofold:

Determine the “Lives Saved” through December 2000 along the NC DOT “Sealed Corridor” Phase I program, and

Determine whether the planned treatments for the entire Phase I corridor provide a sustainable crash reduction condition through 2010.

The analyses described in this assessment report discuss pre-treatment fatalities, estimated pre-treatment risk and benefits in the post-treatment condition in terms of “Lives Saved”. A prediction of the reduction in risk (fatalities/year) is also developed for the entire Phase I “Sealed Corridor” through the year 2010. Risk is the product of the probability of an event occurring, and the severity of that event. The units of these terms vary greatly from study to study. In this assessment report, the probability is defined as the predicted number of grade crossing crashes along a certain set of crossings per year. The severity is defined in terms of fatalities (both on the train and highway vehicle) per crash. So the risk in this study is defined as predicted fatalities per year. Theoretically, there are approximately three times as many injuries for every fatality at highway-rail crossings. By not including the injuries, the overall results of the benefit/cost analysis of “Lives Saved” are very conservative.

A point to keep in mind is that risk as stated above 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 - 1 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.

The organization of the report is as follows. Chapter 2 presents two representative grade crossings where fatal crashes have occurred historically and summarizes all 10 crossings within Phase I that had fatal crashes during the time period, 1987 through 2000. Fatal crash histories and specific in-situ conditions are reviewed. Findings are produced to determine the pre-treatment fatalities and the post-improvement “Lives Saved” through December 2000. Chapter 2 also describes the modified U.S. DOT Accident Prediction Formula, the assumptions used within the formula and its results through December 2000. The final section of Chapter 2 describes results if all of the Phase I crossings are treated as proposed by the NC DOT and train speeds increase to 110 mph in the year 2010. For the 2010 analysis three scenarios are developed ”Build”, “Partial Build” (through 2000) and “No-Build” and the Phase I “Sealed Corridor” risks are compared. Chapter 3 provides findings and conclusions of the assessment of the NC DOT “Sealed Corridor” Phase I program. Specific costs and effectiveness of the warning devices employed are discussed. Chapter 3 presents a trend analysis of the two methods used in the pre-treatment condition as well as actual and predicted “Lives Saved” and risk reduction in the post-treatment condition for the treated crossings. Finally, Chapter 3 summarizes results and develops conclusions.

## 1.4 Description of “Sealed Corridor” Program Activities

Using modified standard technologies, the NC DOT plans to protect railroad operations and motorists at every crossing by closing redundant crossings and by using traffic channelizaton devices (sometimes referred to as median barriers), longer gate arms, four quadrant gates and other innovative signage and traffic control devices at the crossings that remain.

A map of the Phase I corridor between Greensboro and Charlotte with the locations of the 52 treated crossings is shown in Figure 3. Phase I “Sealed Corridor” Improved Crossings Through September 2000. The corridor consists of railroad tracks that belong to the North Carolina Railroad Company[2] (Norfolk

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[2] The state of North Carolina owns the railroad through this company.

Southern Corporation operates through freight service and provides local freight service by trackage rights via a 15-year lease), and CSX Transportation, Inc.

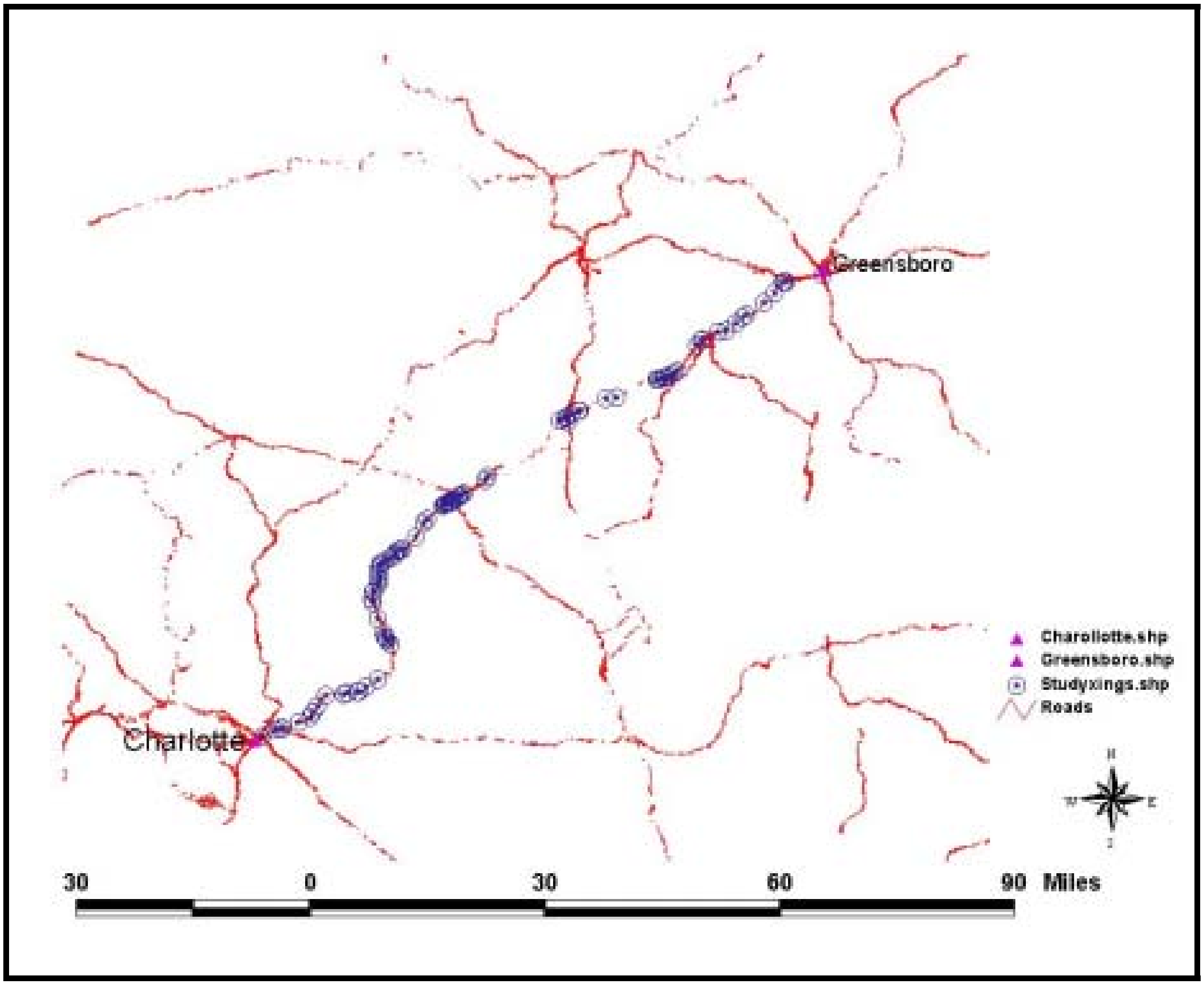


**Figure 3. Phase I "Sealed Corridor" Improved Crossings Through September 2000**

Table 2 describes in detail the specific 52 crossings and improvements that are analyzed in this report. Identifying criteria such as milepost along the railroad, cross-street name, type of crossing improvement used and the date of construction are shown in the table.

**Table 2. Phase I Completed Improvements Through September 2000**

| Milepost | Road Name | Type Crossing | Upgrade* | Construction Date |
|---|---|---|---|---|
| 334.91 | Mildred Avenue | Public | CL | 10/28/98 |
| 335.66 | Julian Road | Public | CL | 11/5/97 |
| 335.49 | D Avenue | Public | CL | 05/17/99 |
| 350.28 | C Avenue | Public | CL | 04/15/99 |
| 335.20 | Klumac Rd./ SR-2541 | Public | LG | 09/13/00 |
| 334.97 | Vance Avenue | Public | CL | 10/20/98 |
| 334.85 | Lumber Street | Public | CL | 1/13/98 |
| 335.2 | E. Harrison St | Public | CL | 04/15/99 |
| 334.61 | Crawford Street | Public | CL | 10/20/98 |
| 334.45 | Knox Street | Public | CL | 4/1/96 |
| 334.20 | E. Monroe St./ SR-1703 | Public | LG/TCD | 09/19/00 |
| 333.3 | Henderson Street | Public | VE | 08/01/98 |
| 332.94 | E. 11th St. | Public | 4Q | 9/9/00 |
| 330.18 | Long Ferry Rd/SR-2120 | Public | LG | 10/11/00 |
| 329.76 | Elm St | Public | CL | 07/18/94 |
| 356.30 | Corban Ave | Public | TCD | 6/1/98 |
| 363.95 | Hickory Ridge Rd./ SR-1138 | Public | TCD | 05/17/00 |
| 364.12 | Robinson Church Rd./ SR-1166 | Public | LG | 5/17/00 |
| 365.24 | Caldwell Rd./ SR-1173 | Public | TCD | 6/1/98 |
| 365.24 | Millbrook Rd/SR-1182 | Public | LG | 12/01/00 |
| 367.00 | Stroup Farm Rd | Private | LG | 10/28/97 |
| 370.71 | Hickory Grove Rd./ SR-2853 | Public | 4Q | 7/20/99 |
| 372.19 | Orr Rd. | Public | LG | 10/28/97 |
| 374.02 | Sugar Creek Rd. | Public | 4Q/TCD | 8/95 & 6/98 |
| 374.39 | W. Craighead Rd. | Public | 4Q | 3/17/95 |
| 374.87 | E. 36th St. | Public | 4Q | 05/16/00 |
| 321.32 | Old Linwood Road/SR-1104 | Public | GS | 4/1/96 |
| 318.68 | Prospect Dr. | Public | 4Q | 2/9/00 |
| 313.09 | Turner Rd./ SR-2005 | Public | TCD | 6/1/98 |
| 311.99 | Lower Lake Rd./ SR-2020 | Public | LG | 4/12/00 |
| 306.83 | Boyles Street | Public | CL | 12/15/95 |
| 306.22 | Loftin Street | Public | CL | 12/15/95 |
| 306.11 | Fisher Ferry Rd. | Public | 4Q | 1/17/00 |
| 305.97 | Salem St./ NC-109 | Public | 4Q | 4/12/00 |
| 305.60 | College Street | Public | CL | 5/24/96 |
| 300.73 | Prospect Ave. | Public | 4Q | 11/4/99 |
| 295.76 | Scientific St./ SR-1332 | Public | LG | 8/8/00 |
| 291.67 | Marckey Rd./ SR-1549 | Public | 4Q | 2/2/99 |
| 290.12 | Hill Top Rd./ SR-1424 | Public | 4Q | 9/2/97 |
| 284.10 | S. Elm St. | Public | 4Q | 01/31/00 |
| 336.24 | Henderson Grove Rd./ SR-1526 | Public | LG | 01/08/00 |
| 338.19 | Peach Orchard Lane/SR2545 | Public | CL | 1/31/97 |
| 338.66 | Peeler Rd./ SR-2538 | Public | TCD | 6/1/98 |
| 340.07 | Webb Rd./ SR-3490 (SR-1500) | Public | TCD | 6/1/98 |
| 344.18 | Bostian Rd./ SR-1221 | Public | CL | 11/8/99 |
| 347.28 | E. 22nd St.SR-1254 | Public | LG/TCD | 10/11/00 |
| 348.06 | Ebenezer Rd | Public | CL | 3/13/00 |
| 349.38 | East C Street | Public | CL | 4/12/99 |
| 349.1 | Plymouth St | Public | CL | 04/15/99 |
| 355.12 | McGill Ave | Public | 4Q | 2/22/00 |
| 355.31 | Misenheimer Dr. | Public | CL | 11/8/99 |
| 296.99 | Pendleton St. | Private | TCD | 8/7/1997 |

*Note: 4Q - Four quadrant gates, TCD – Traffic Channelization Devices, LG - Long gates, CL – Closure, VE – Video Enforcement, GS – Grade separation

## 1.5 Treatment Techniques

### 1.5.1 Closings

In addition to the more traditional approach of using funds for new warning devices at crossings, NC DOT is directing funds to crossing consolidation projects, including closing those crossings identified as redundant in "Traffic Separation Studies" (TSS). TSSs are comprehensive engineering studies used on a corridor-wide basis to evaluate crossings and the surrounding highway network within a community. NC DOT introduced a new process for conducting the TSS, documenting the approach in 1995 to establish a thorough and consistent process to be used throughout the State. The new process is proactive and prioritizes safety and risk-reduction. It specifies the sequence of decisions and activities from bringing consultants and relevant stakeholders into the planning phase through the final implementation. The TSS is a comprehensive evaluation of traffic patterns and road usage for an entire municipality or region. Part of the study determines if any of the public crossings should be closed or grade separated (bridged) to improve safety.

The South End TSS, completed as a set in 1999, includes the cities and towns of Charlotte, China Grove, Harrisburg, Landis and Kannapolis. An example of this closure activity can be found in Figure 4. The figure shows the Ebenezer Road crossing before and after closure in Kannapolis, NC. Another study was completed in 1999 for the Town of Wake Forest. More TSSs are currently being implemented in Claremont, Conover, Hickory, Hildebrand, Longview and Newton. As indicated earlier on page 7, Phase IV of the "Sealed Corridor" will apply Federal dollars to address private crossings that are closure candidates.

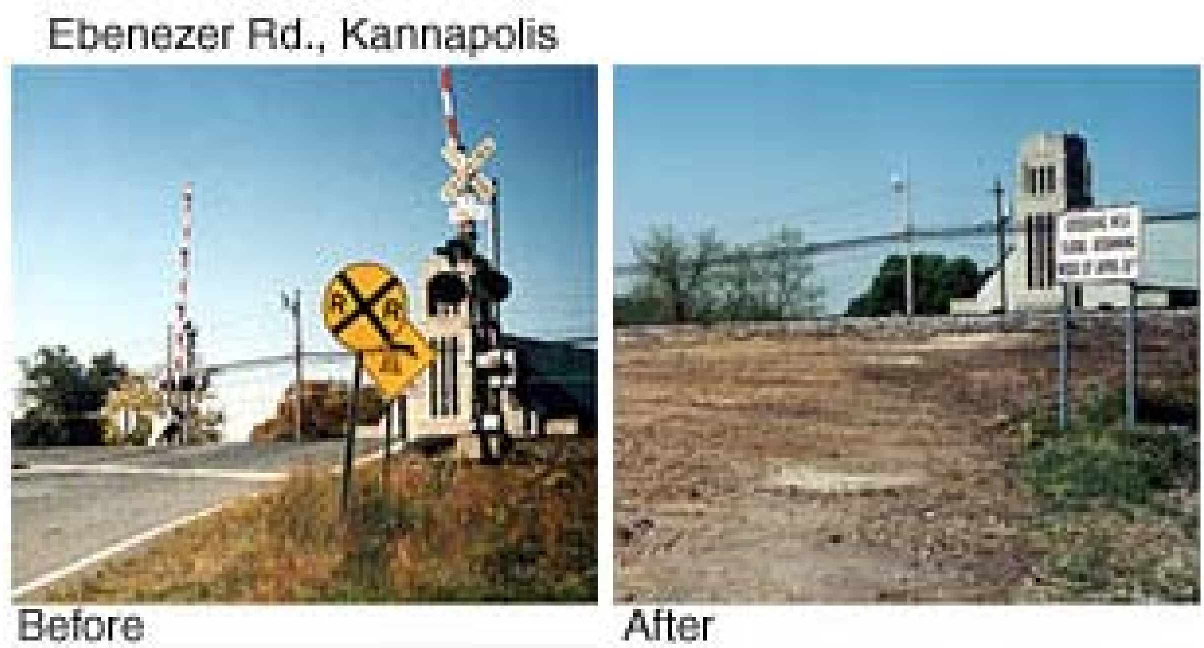


**Figure 4. "Before and After" Views of Ebenezer Road**

### 1.5.2 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. Since 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

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.

### 1.5.3 Video Enforcement

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 (NC HSRC) 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, there were 64 documented instances where drivers were observed to illegally proceed around the lowered crossing gates as a train was approaching. Evidence of violations was obtained from a photo-based system implemented in conjunction with instrumentation installed at the site by NC DOT and the Norfolk Southern Corporation. With the cooperation of local law enforcement, violators were ticketed and fined. This demonstration resulted in a reduction in violations by 72 percent, showing that photo-based video enforcement methods combined with a fine/penalty structure are an effective alternative to traditional enforcement.

The NC HSRC conducted a study of grade crossing violators. The report "Prior Driver Performance and Expressed Attitudes Toward Risk Factors Associated with Railroad Grade Crossing Violations" was prepared for the NC DOT Rail Division in June 1999. The NC HSRC concluded that all of the factors, which give rise to the driver's behavior of proceeding around a physical barrier, are not fully understood. The study suggested that the variables that contribute to driver behaviors that result in traffic violations, especially speeding, might also contribute to the likelihood of illegal and dangerous behavior at railroad grade crossings. The NC HSRC also noted that there are no known methods to ensure the level of learning and behavioral/social control necessary to stop inappropriate driver behaviors. The behaviors can be either intentional, or as the result of misperception or poor judgment. The only way to guarantee the presence of a "Sealed Corridor" is to physically prohibit the opportunity for vehicles to be present on the tracks when a train is approaching.

### 1.5.4 Four-Quadrant Gate Systems

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. During initial tests at Sugar Creek Road in Charlotte (selected because it has the highest Average Annual Daily Traffic (AADT) in the Corridor at more than 21,000 vehicles per day) violations were reduced by 86 percent. 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.

**Figure 5. 4-Quad Gates at West Craighead Road, Charlotte, NC**

### 1.5.5 Longer Gate Arm Systems

NC DOT tests at the Orr Road crossing in Charlotte, NC were conducted to evaluate the effectiveness of longer gate arms (see Figure 6) to reduce the drivers' ability to run around the gates. These longer gate arms cover at least 3/4 of the roadway. NC DOT conducted three tests at the Orr Road crossing. The first test gathered driver violation data "before" treatment was installed. The second test gathered post-treatment 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 have improved over the second test to show an 84 percent reduction in crossing violations compared with pre-treatment "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.

**Figure 6. Long Arm Gate at Orr Road, Phase I**

### 1.5.6 Traffic Channelization Devices

NC DOT believes that traffic channelization devices have proven to be a low-cost investment with a high rate of return in safety at crossings (see Figure 7). Also known as median barriers, these devices cost on average $10,000 per location. Considering their low maintenance cost and high effectiveness, traffic channelization devices are NC DOT's preferred devices to deter violators at crossings. When first used at Sugar Creek Road, the traffic channelization devices reduced violations by 77 percent.

Traffic channelization devices consist of a prefabricated mountable island made of a composite material painted yellow. Reflectorized paddle delineators or tubes, 24-inces 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 when impacted by vehicles. Concrete island median barriers also are used with the yellow striped delineators mounted to them.

**Figure 7. Traffic Channelization Device at Hickory Ridge Road, Harrisburg, NC**

### 1.5.7 Signs, Pavement Markings and Health Monitoring

Sign and pavement marking upgrades will be 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, will be placed on all crossings receiving treatment. Another sign will be used to provide a 1-800 emergency phone number that motorists can use to call the railroad to report any malfunctions of the crossing signals. The 1-800 sign will be placed at all crossings that receive treatment on the "Sealed Corridor" program.

An Intelligent Signal Monitoring System is proposed for each public crossing to notify railroad personnel about malfunctions, and to improve the reliability of warning devices. Since a roadway equipped with four-quadrant gates will essentially be impassible when the gates are activated, it will be important that the devices have a very high level of reliability and performance.


**Figure 8. Grade Crossing 1-800 Sign on the Phase I Corridor**

# 2.0 FATAL CRASH AND RISK ANALYSIS

Two different methods were used to estimate the number of lives saved and the potential for sustainability of a reduction in collisions through the year 2010.

The first, known as the "fatal crash analysis method" calculates, based on actual experience at the improved crossings, the differences between the annual (or monthly) fatality rates before and after the improvements are made at each crossing. To calculate "Lives Saved" those differences were multiplied by the number of years (or months) through December 2000 that each separate crossing had been improved. The sum of these results was then calculated over all of the crossings that were improved.

The second method, known as the "modified U.S. DOT accident prediction formula" 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 can be used to estimate the annual fatality rates at each crossing before and after each improvement. Both methods are described and illustrated in this chapter. Trend results are shown between the two methodologies employed and findings are discussed. In showing trend results using these two approaches it is important to understand the differences in the methodologies, summarized in Table 3.

**Table 3. Comparison of Analysis Approaches**

| Criteria | Modified U.S. DOT Formula | Fatal Crash Analysis |
|---|---|---|
| **Crossing Environment** | Considers adjustments to train speed, AADT, train movements, warning device changes | Not considered |
| **Timeframe** | Comparison of two 5-year periods - 1991-1995 and 1996-2000 | Sliding 5-year period around implementation date |
| **Crashes** | All Crashes | Fatal Crashes only |
| | After period – Last 5 years | After period - extended out to 5 years based on last known risk |

## 2.1 Fatal Crash Analysis

A review was conducted of 52 crossings along the Phase I portion of the "Sealed Corridor" improved through September 2000. The total Phase I project corridor has 100 crossings, but at the time of this writing only 52 had been treated and/or closed. The remaining 48 are in the design stage or are awaiting construction. The baseline information for the study was obtained from the FRA Railroad Accident Incident Reporting System database from 1987 through December 2000, NC DOT collision reports, police reports, and newspaper articles. There were 154 crashes for all of the Phase I crossings from 1987 through December 2000.

Phase I improvements were initiated in March of 1995. This assessment report documents the findings related to the crossings treated through September 2000. In-depth analysis was conducted on the 10 treated crossings that had a history of fatal crashes after 1987 and 2 are presented here. The 8 other treated crossings are covered in general details in this section of the report for crashes in the pre- and post-treatment condition through December 2000.

Table 4 shows the number of fatal crashes since 1987 as well as the characteristics of these fatal crashes. Ten percent of the Phase I crossings had fatal crashes. A total of 19 fatalities resulted from 14 separate crashes. In summary, the general characteristics of the fatal crashes indicate the following. The highway vehicle speed of most of the crashes ranged between 0 and 40 mph. Trucks were involved in four of the crashes and the rest of the crashes involved automobiles. Twelve out of 14 of the fatal crashes occurred during daylight hours. The train speeds were between 40 and 50 mph at the time of the crash. Ninety three percent of the crashes resulted from the driver of the vehicle driving around or through the gates. Crossings with fatal crashes will be analyzed in the next section of this report in more detail.

**Table 4. Characteristics of Pre-Treatment Fatal Crashes at Treated Crossings in Phase I**

| Crossing / Date of Crash | Deaths | Vehicle Speed / Type | Time of Day | Train Speed / Type | Vehicle Position | Driver Action | Type of Treatment / Date | AADT Change | Train Speed Change | New Crossing Warning |
|---|---|---|---|---|---|---|---|---|---|---|
| Sugar Creek Rd. 8/26/94 Mile post 374.02 | 1 | 40 mph Auto | Dark | 55 mph Yard | Moving over | Drove around gate | 4 quad gates 8/31/95, Traffic Channelization Devices, 1 bell 6/1/98 Health monitoring 7/28/00 | 18,450 to 20,700 10/2/95 | 79 mph No Change | 4 quad gates, traffic channelization devices, flashing lights, bells, crossbucks |
| Henderson St. 7/1/94 Mile post 329.6 | 2 | 35 mph Auto | Day | 42 mph Freight | Moving over | Drove around gate | Gates, lights 12/4/90 Video Monitoring 9/1/98 | 1,500 No Change | 45 mph No Change | Gates, flashing lights, bells, crossbucks |
| Henderson St. 2/23/95 Mile post 329.6 | 1 | 5 mph Auto | Day | 48 mph Freight | Moving over | Drove around gate | Gates, lights 12/4/90 Video Monitoring 9/1/98 | 1,500 No Change | 45 mph No Change | Gates, flashing lights, bells, crossbucks |
| Hickory Ridge Rd. 3/7/92 Mile post 363.95 | 1 | 0 mph Truck | Day | 44 mph Freight | Stopped | Drove around gate | Traffic channelization devices, health monitoring 5/17/00 | 500 to 1,079 5/16/00 | 79 mph No Change | Traffic channelization Devices, gates, flashing lights, bells |
| W. Craighead Rd. 1/20/89 Mile post 374.39 | 2 | 15 mph Auto | Dark | 58 mph Freight | Moving over | Drove around gate | 4 quad gates 3/17/95 | 6,210 to 6,507 10/28/97 | 79 mph No Change | 4 quad gates, flashing lights, bells, crossbucks |
| W. Craighead Rd. 9/1/87 Mile post 374.39 | 1 | 10 mph Auto | Dark | 42 mph Freight | Moving over | Drove around gate | 4 quad gates 3/17/95 | 6,210 to 6,507 10/28/97 | 79 mph No Change | 4 quad gates, flashing lights, bells, crossbucks |
| Ebenezer Rd. 11/18/89 Mile Post 348.06 | 1 | 0 mph Auto | Day | 58 mph Freight | Stopped | Drove around gate | Closed crossing 3/13/00 | 2,150 to 3,248 3/12/00 | 55 to 79 mph 3/12/00 | Closed |

**Table 4. Characteristics of Pre-Treatment Fatal Crashes at Treated Crossings in Phase I (continued)**

| Crossing / Date of Crash | Deaths | Vehicle Speed / Type | Time of Day | Train Speed / Type | Vehicle Position | Driver Action | Type of Treatment / Date | AADT Change | Train Speed Change | New Crossing Warning |
|---|---|---|---|---|---|---|---|---|---|---|
| Corban Avenue 1/11/88 Mile post 356.3 | 1 | 20 mph Truck | Day | 52 mph Freight | Moving over | Drove around gate | Traffic channelization devices, Health monitoring 6/1/98 | 2,500 to 3,500 10/28/97 | 60 to 79 mph 10/28/97 | Traffic channelization devices, gates, flashing lights, bells, crossbucks |
| Lower Lake Road 4/13/87 Mile post 311.99 | 1 | 33 mph Truck Trailer | Day | 45 mph Freight | Moving over | Did not stop | Long arm gates 4/1/00, Health monitoring 10/12/00 | 150 No change | 70 to 79 mph 1/1/94 | Long arm gates, flashing lights, bells, crossbucks |
| Lower Lake Road 10/28/87 Mile post 311.99 | 1 | 0 mph Auto | Day | 44 mph Freight | Stalled | Other not specified | Long arm gates 4/1/00, Health monitoring 10/12/00 | 150 No change | 70 to 79 mph 1/1/94 | Long arm gates, flashing lights, bells, crossbucks |
| C Ave. 12/27/94 Mile post 335.40 | 1 | 10 mph Truck | Day | 56 mph Freight | Moving over | Did not stop | Closed 4/15/97 | 350 to 0 8/13/97 | 50 mph No change | Closed |
| Knox Street 4/8/90 Mile post 334.45 | 3 | 8 mph Auto | Day | 50 mph Freight | Moving over | Did not stop | Closed 8/13/97 | 500 No change | 35 mph No change | Closed |
| Lumber Street 5/10/90 Mile post 335.85 | 1 | Auto 6 mph | Day | 44 mph Freight | Moving over | Did not stop | Closed 1/13/98 | 600 to 181 5/16/99 | 50 to 79 mph | Closed |
| Lumber Street 9/2/98 Mile post 335.85 | 2 | Auto 10 mph | Day | 45 mph Freight | Moving over | Did not stop | Closed 1/13/98 | 600 to 181 5/16/99 | 50 to 79 mph | Closed |
| Total Deaths / Average Characteristic | 19 | Low Speed Auto | Day | 50 mph Freight | Moving over | Drove around gate | N/A | N/A | N/A | N/A |

### 2.1.1 Sugar Creek Road

The Sugar Creek Road crossing is a public crossing located in Charlotte, NC. The crossing spans two mainline tracks and a siding track separated by approximately 100 feet. The AADT at this crossing is 22,100 vehicles per day, with 22 train movements per day (12 day, 8 night, 2 switching). The maximum train speed at the crossing is 79 mph. According to NC DOT records, trucks account for four percent of the vehicles moving through this crossing. Between 1987 and 2000 there were three crashes at the Sugar Creek Road crossing, resulting in a total of one injury and one fatality. There have been no crashes at Sugar Creek Road since the installation of four-quadrant gates and traffic channelization devices.

At the time of the crashes the crossing was equipped with standard gates and flashing lights. The crossing warning devices were then enhanced with four-quadrant gates (August 31, 1995) and traffic channelization devices (June 15, 1998). Figure 9 shows the crossing after the installation of four-quadrant gates and traffic channelization devices. The fatal collision at Sugar Creek Road occurred at night on August 26, 1994. The driver of the vehicle, who was killed, drove around several vehicles and around the standard gates to try to beat the oncoming train. According to police reports from witnesses, the driver tried to back up out of the train's path, but did not make it in time. The freight train hit the front end of the vehicle and dragged it several hundred feet down the track. Alcohol was not a factor in the collision.

**Figure 9. Sugar Creek Crossing with 4 Quad Gates and Traffic Channelization Devices at Night**

### 2.1.2 Lumber Street

The Lumber Street crossing was a double track public crossing located in Salisbury, NC. The AADT at this crossing was 600 vehicles per day, with 8 train movements per day (4 day, 2 night, 2 switching). The maximum train speed at the crossing was 79 mph. According to NC DOT records, trucks accounted for three percent of the vehicles moving through this crossing.

Between 1987 and 2000 there were seven crashes at the Lumber Street crossing, resulting in three injuries and three fatalities from two crashes. At the time of the crashes the crossing had only crossbucks as the primary warning device. Lumber Street had two pre-treatment fatal crashes. The first occurred in May 1990 resulting in one fatality. The May 1990 crash involved a car that did not stop and drove over the crossing with a freight train approaching. The locomotive struck the car and killed the driver. On September 2, 1998 a crash occurred resulting in two fatalities. The crash occurred when a car did not stop at the crossing as a freight train was approaching. The collision occurred during the day with no obstructions at the crossing. The train struck the car and fatally injured the driver and one passenger. The crossing has been closed since November 1998.

### 2.1.3 Post-Improvement Crashes

Post-improvement crashes have occurred on crossings treated in Phase I of the "Sealed Corridor" program. There was only one fatality out of the three post-treatment grade crossing crashes. Corban Avenue had one post-treatment fatal crash that occurred during the day on August 8, 2000. The vehicle was stopped on the tracks. The Charlotte Observer newspaper reported that a man drove around the railroad crossing gate arm and parked his car on the tracks. As the train approached, the driver pulled off the tracks, made a U-turn and parked again across the tracks with the driver's side toward the train. The crash fatally injured the driver. Based on witness reports of the driver's behavior, the police reported the crash as a suicide.

### 2.1.4 Summary of Fatal Crash Analysis Results

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. These 10 grade crossings have been analyzed to assess the number of fatalities that have occurred in the pre-treatment conditions and "Lives Saved" under the post-treatment condition through December 2000 along the Phase I portion of the "Sealed Corridor" in North Carolina. In the base year 1987, eight of the ten crossings analyzed had already been up-graded to the most effective standard treatment, i.e. two-quadrant gates with flashing lights. Table 5 shows the historical fatalities for five years prior to treatment and illustrates an average of one fatality per year in the pre-treatment condition.

**Table 5. Five-Year Fatal Crash Analysis Pre-Treatment Fatalities**

| Improvement | Crossing Name | Mile Post | Historical Fatalities (Five years prior to Treatment) |
|---|---|---|---|
| 4-Quad Gates | W. Craighead Road | 374.39 | 0 |
| Video Enforcement | Henderson Street | 336.24 | 3 |
| 4-Quad Gates & TCD | Sugar Creek Road | 374.02 | 1 |
| Closure | C Ave. | 335.40 | 1 |
| Long Gate Arm | Lower Lake Road | 311.99 | 0 |
| Closure | Ebenezer Road | 348.06 | 0 |
| TCD | Hickory Ridge Road | 370.71 | 0 |
| TCD | Corban Street | 356.30 | 0 |
| Closure | Lumber Street | 334.85 | 2 |
| Closure | Knox Street | 334.45 | 0 |
| | **Average Fatalities per Year** | | **1.4** |

Table 6 and Figure 10 illustrate the development of a fatal crash rate for each case study crossing. The table shows the distribution of that rate over the post-treatment time period to obtain the number of "Lives Saved" as a result of the treatment. The fatality rate is calculated by dividing the pre-treatment fatalities for each crossing from 1987 through when it was treated by the pre-treatment time period in months. The fatal crash rate for each crossing is then multiplied by the post-treatment time period in months. Any post-treatment fatalities would be subtracted from the estimated lives saved. The final calculation determines the "Lives Saved" through December 2000 for each crossing.

**Table 6. Fatal Crash Analysis Results – "Lives Saved" Post-treatment through 12/00**

| Improvement | Crossing Name | Pre-Treatment Fatalities | Pre-Treatment Time Frame (Months) | Post-Treatment Fatalities | Post-Treatment Time Frame (Months) | Analysis of "Lives Saved" |
|---|---|---|---|---|---|---|
| 4-Quad Gates | W. Craighead Road | 3 | 99 | 0 | 69 | 2.091 |
| Video Enforcement | Henderson Street | 3 | 93 | 0 | 27 | 0.871 |
| 4-Quad Gates & TCD | Sugar Creek Road | 1 | 104 | 0 | 64 | 0.615 |
| Closure | C Avenue | 1 | 116 | 0 | 40 | 0.345 |
| Long Gate Arm | Lower Lake Road | 2 | 160 | 0 | 8 | 0.100 |
| Closure | Ebenezer Road | 1 | 159 | 0 | 9 | 0.057 |
| TCD | Hickory Ridge Road | 1 | 161 | 0 | 7 | 0.043 |
| TCD | Corban Street* | 1 | 150 | 0 | 18 | 0.120 |
| Closure | Lumber Street | 3 | 145 | 0 | 23 | 0.476 |
| Closure | Knox Street | 3 | 124 | 0 | 44 | 1.065 |
| | **Total** | **19** | | **0** | | **5.783** |

* One post-treatment fatality at Corban Avenue on August 8, 2000, was ruled a suicide by police and is discounted and not shown.

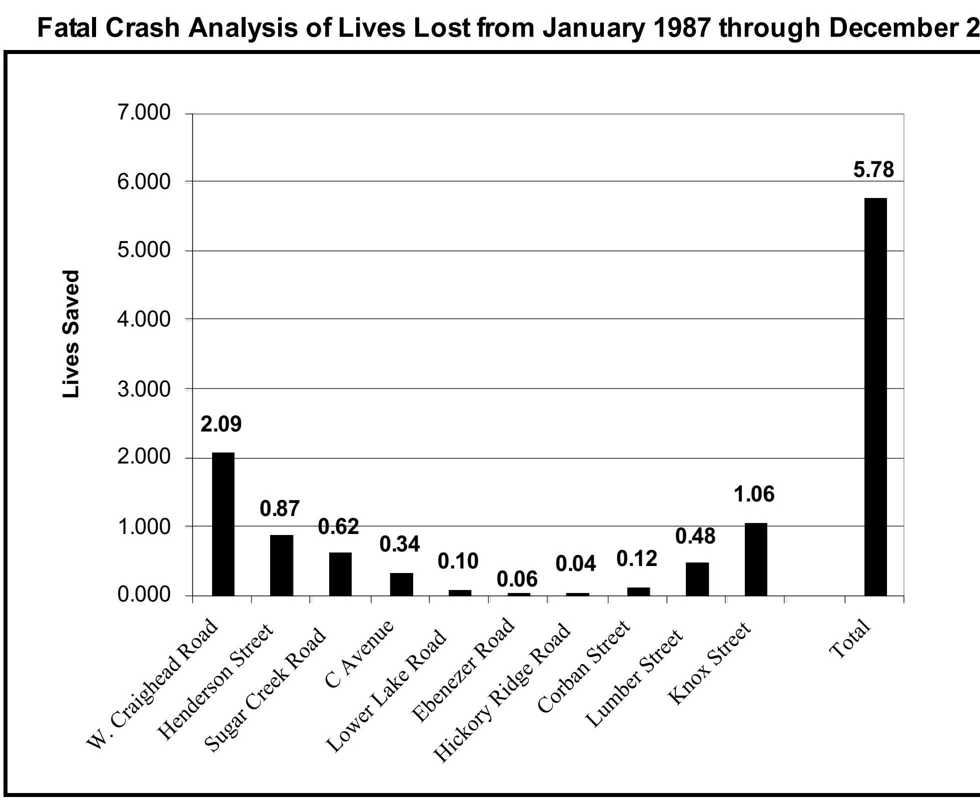


**Figure 10. Fatal Crash Analysis of "Lives Saved" per Crossing through December 2000**

The determined benefits of the treatment can then be translated into monetary worth. Table 7 shows the achieved benefits in "Lives Saved" as it would translate into a dollar value based on the U. S. DOT guidance for the value of life memorandum dated April 29, 1996 with a life benefit cost of $2.7 million per life saved.

**Table 7. Benefits for Analyzed Crossings**

| Location | Crossing Improvement | Cost of Improvement | Post-Improvement Lives Saved | $ Savings from Lives Saved |
|---|---|---|---|---|
| Sugar Creek Road | 4-Quad Gates/MB | $135,000 | 0.615 | $1,660,500 |
| Henderson Street | Video Enforcement | $55,000 | 0.871 | $2,351,700 |
| Hickory Ridge Road | Median Barrier | $10,000 | 0.043 | $116,100 |
| Ebenezer Road | Closed | $15,000 | 0.057 | $153,900 |
| West Craighead Road | 4-Quad Gates | $125,000 | 2.091 | $5,645,700 |
| Lower Lake Road | Long Arm Gates | $5,000 | 0.1 | $270,000 |
| Corban Avenue | Median Barrier | $10,000 | 0.12 | $324,000 |
| C Avenue | Closed | $15,000 | 0.345 | $931,500 |
| Knox Street | Closed | $15,000 | 1.065 | $2,875,500 |
| Lumber Street | Closed | $15,000 | 0.476 | $1,285,200 |
| **TOTAL** | | **$400,000** | **5.783** | **$15,614,100** |

Therefore, the benefit to cost ratio for improving the highway-rail grade crossings that have had fatal crashes is 40:1. It should be noted that the most risky crossings have been treated by the NC DOT first to maximize benefits quickly. The success of the treatments within the program's short history should be commended.

## 2.2 Risk Formula Analysis and Results

The U.S. DOT Fatal Accident Prediction Formula was used as the baseline to calculate risk in the corridor. The DOT standard formula has many variables to predict the severity of a crash at a grade crossing. The Volpe National Transportation System Center developed the formula used to analyze data for this assessment study. This formula handles high-speed rail and additional enhancements and was based on the U.S. DOT Fatal Accident Prediction Formula with updates to the collision severity portion.[3, 4, and 5] To determine accident probability, this study used the standard U. S. DOT Accident Prediction Formula (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 footnoted below, was used. This severity model includes as one of its attributes the use of vehicle mix in the determination of severity in passenger train operations.

A few variables use 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 use the FRA Highway-Rail Grade Crossing Accident/Incident Reports for crossing crash history. Individual crossing information is used to help determine the final risk at each crossing.

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[3] "Rail-Highway Crossing Resource Allocation procedure," FRA Office of Safety Analysis. August 1987. DOT-TSC-FRA-87-1.

[4] "Sealed Corridor," Worley, P., and Mastrangelo, A., Draft Study Results, North Carolina Department of Transportation and Norfolk Southern Corporation Report. 1997.

[5] "Assessment of Risks for High-Speed Rail Grade Crossings on the Empire Corridor – Next Generation High-Speed Rail Program." Mironer, M.; Coltman, M.; McCown, R.; FRA. Final Report August 2000. DOT-VNTSC-FRA-00-03, DOT/FRA/RDV-00/05.

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 crash history of the crossing over the previous five-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 five-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 five 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 five 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.

### 2.2.1 Framework of the Risk Analysis Formula

The original DOT formula was developed based on national collision statistics from 1975 to 1980.  Once the methodology was developed, current collision statistics were periodically utilized to upgrade various constants used in the formula.  This formula was developed to provide a relative risk ranking for a set of crossings and was not intended to directly compare to actual historical crash or fatality experiences especially under conditions of small data sets.  There are many factors that contribute to crashes, which are not expressly addressed by the formula.  The trend analysis shown in Chapter 3 is used only to illustrate that both methodologies used have results indicating a risk reduction.  All data used for this study were obtained from the FRA and NC DOT inventory databases.  Train operations, traffic growth and timetable speeds were obtained from the FRA or NC DOT.  The normalizing constants were developed from the latest collision statistics for the three types of warning devices.  Collision data through 1992 were used to determine the normalizing constants as shown in Table 8.

**Table 8.  Risk Analysis Normalizing Constants**

| Warning Device Groups | Normalizing Constants |
|---|---|
| Passive | 0.8239 |
| Flashing Lights | 0.6935 |
| Gates | 0.6714 |

Vehicle type mix at the crossings was another factor in determining the probability of a fatal crash.  The vehicle mix is used in the modified U. S. DOT formula in the severity calculations.  The AADT was available from NC DOT records.  Once the risk is calculated using the formula, a reduction factor is applied to the final results depending on the type of treatments (improvements) applied above the standard gates and flashing lights.  Table 9 gives the effectiveness rate based on the treatment type used above the standard two-quad gate system.

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 five-year intervals for both pre- and post-treatment time periods.  A year-by-year input of the variables from the FRA/NCDOT inventory was used.  The analysis included the effect of the past five years of actual collision history as used in the standard APF.  The analysis of the data and the proposed schedule of grade crossing improvements were geared to calculate the change in risk due to the changes in the Phase I portion of the NC DOT "Sealed Corridor."  The analysis evaluates the existing risk with the projected risk after all the grade crossing improvements are completed. Two of the Phase I crossings are discussed in detail below.

**Table 9. Effectiveness Crossing Improvements**

| | Closure | Long Gate Arm | Traffic Channelization Devices | Video Enforce ment | 4-Quad Gates | 4-Quad Gates w/ Channel-ization | Grade Separation |
|---|---|---|---|---|---|---|---|
| **Effectiveness*** | 100% | 75%** | 80% | 72% | 82% | 92% | 100% |

*** Effectiveness over Gates taken from the FRA NPRM on Railroad Horn Systems**
**** Volpe estimate based on FRA NPRM effectiveness of other supplemental safety devices**

### 2.2.2 Sugar Creek Road

The Sugar Creek Road example estimates a risk of 0.07 fatalities per year in 1991 for the pre-treatment condition (see Figure 11). The risk changes over the years depending on the collision statistics or crossing improvements applied. The risk increases because of crashes in 1992 and 1994, and decreases when four-quadrant gates are installed in 1995.

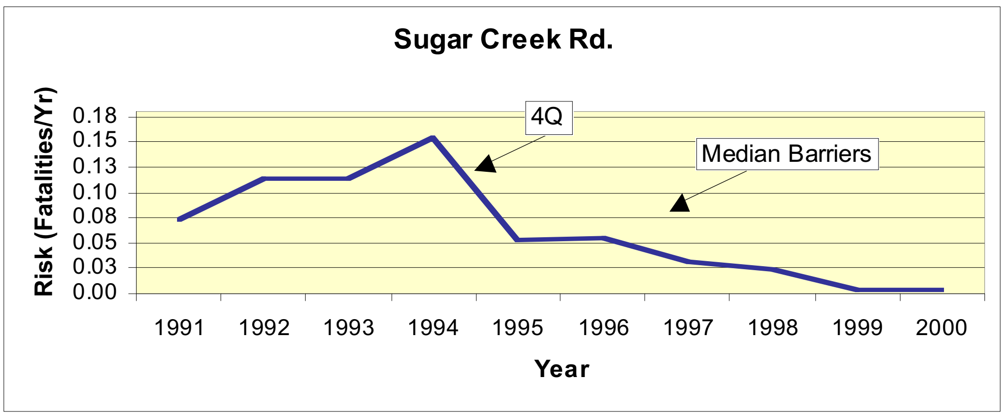


**Figure 11. Risk at Sugar Creek Road**

In 1995, the risk was reduced by approximately 0.10 fatalities per year until 1996 when an increase in AADT from 18,450 to 22,100 vehicles caused a slight increase in risk despite improvements during the previous year. After 1997, the risk continues to decrease because there were no post-treatment crashes. By 2000, the risk attains 0.004 fatalities per year.

### 2.2.3 Lumber Street

Figure 12 shows the risk in 1991 at Lumber Street as 0.09 fatalities per year. In 1995 the risk dropped to a low of 0.06 fatalities per year. There were two crashes in 1996, February 19 and August 21, which increased the risk at the crossing to 0.09 fatalities per year. On September 2, 1998 a catastrophic crash occurred at the Lumber Street crossing resulting in two fatalities.

The risk reached its highest value in 1998 at 0.15 fatalities per year. In late 1998 the NC DOT finally was able to close Lumber Street. Since the crossing was closed the risk has been eliminated.

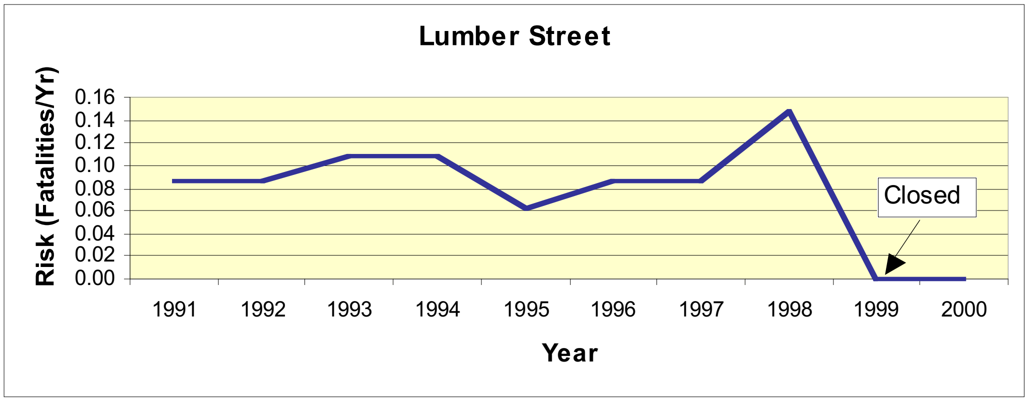


**Figure 12. Risk of Fatalities per Year at Lumber Street Crossing**

### 2.2.4 Risk Formula Results

The risk-based fatalities for the pre-treatment condition were calculated for the 10 grade crossings analyzed with fatal crash histories and are shown in Table 10. The pre-treatment risk in fatalities was determined by summing the annual risk for the five years before the date of the grade crossing treatment. The table illustrates that the risk-based methodology calculates the total number of fatalities in the five-year pre-treatment condition to be 2.65 fatalities or a rate of 0.53 fatalities per year.

**Table 10. Risk-Based – Predicted "Lives Lost" Under Pre-treatment Conditions**

| Improvement | Crossing Name | Mile Post | Pre-treatment Risk (Fatalities / 5 yrs) |
|---|---|---|---|
| 4-Quad Gates | W. Craighead Road | 374.39 | 0.55 |
| Video Enforcement | Henderson Street | 336.24 | 0.33 |
| 4-Quad Gates & Traffic Channelization | Sugar Creek Road | 374.02 | 0.53 |
| Closure | C Avenue | 335.40 | 0.24 |
| Long Gate Arm | Lower Lake Road | 311.99 | 0.14 |
| Closure | Ebenezer Road | 348.06 | 0.05 |
| Traffic Channelization | Hickory Ridge Road | 370.71 | 0.10 |
| Traffic Channelization | Corban Street | 356.30 | 0.15 |
| Closure | Lumber Street | 334.85 | 0.49 |
| Closure | Knox Street | 334.45 | 0.06 |
| **Total 5 yr Pre-treatment Fatalities** | | | **2.65** |
| **Total Pre-treatment Fatalities / Yr** | | | **0.53** |

The "Lives Saved" for the same set of crossings was determined from formula predictions. The post-treatment risk was calculated using the five future years from the date of the grade crossing improvement. The risk-based "Lives Saved" for the post-treatment condition for the 10 crossings is shown in Table 11. The post-treatment risk in fatalities was determined by summing the annual risk for the five years after the date of the grade crossing treatment. The table illustrates that the risk-based methodology calculates total fatalities in the five-year post-treatment condition of 0.72 or a rate of 0.144 fatalities per year. The difference between the pre- and post-treatment risk also provided in Table 11 and illustrates the yearly "Lives Saved" at each crossing.

**Table 11. Predicted "Lives Saved" for Treated Crossings over the Post-Treatment 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 |
|---|---|---|---|---|
| 4-Quad Gates | W. Craighead Road | 0.55 | 0.18 | 0.36 |
| Video Enforcement | Henderson Street | 0.33 | 0.22 | 0.11 |
| 4-Quad Gates & TCD | Sugar Creek Road | 0.53 | 0.17 | 0.36 |
| Closure | C Avenue | 0.24 | 0.00 | 0.24 |
| Long Gate Arm | Lower Lake Road | 0.14 | 0.01 | 0.13 |
| Closure | Ebenezer Road | 0.05 | 0.00 | 0.05 |
| TCD | Hickory Ridge Road | 0.10 | 0.02 | 0.09 |
| TCD | Corban Street | 0.15 | 0.12 | 0.03 |
| Closure | Lumber Street | 0.49 | 0.00 | 0.49 |
| Closure | Knox Street | 0.06 | 0.00 | 0.06 |
| | | **2.65** | **0.72** | |
| | | **Predicted Average 5** | **Yr "Lives Saved"** | **1.95** |
| | | **Predicted Average** | **"Lives Saved" / Yr** | **0.39** |

The calculated "Lives Saved" using the risk-based five year "before and after" conditions indicates approximately 1.95 lives have been saved. Therefore, the rate of "Lives Saved" is equivalent to 0.39 lives per year. Therefore the results for both methods, the fatal crash analysis and the modified U.S. DOT formula have trend results indicating a reduction of risk.

## 2.3 Total Phase I Risk Formula Results

Figure 13 compares the risk for 1991 and 2000 for the 52 treated crossings and for the entire Phase I corridor (100 crossings). The results show that between 1991 and 2000 the risk for the treated crossings was reduced by 84 percent or 1.317 "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 shows that there is still a significant potential to reduce risk in the corridor even though the crossings with the highest risk have been addressed first.

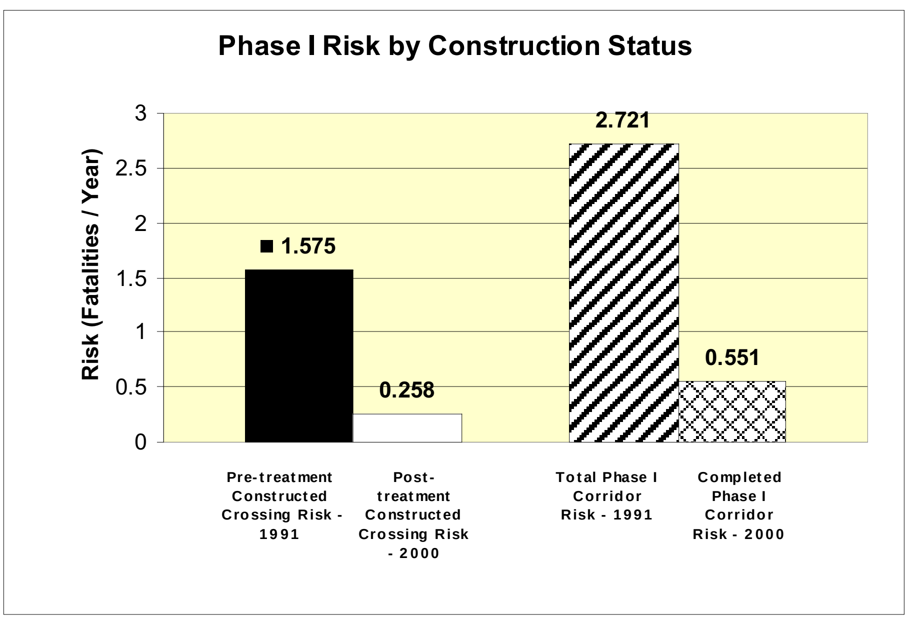


**Figure 13. Corridor Risk for the Phase I Project**

## 2.4 2010 Risk Projections

The formula was used to project the Phase I corridor risk in 2010, as shown in Figure 14. The projected 2010 risk for Phase I is 1.8 fatalities per year. The figure also indicates that the greatest proportion of this risk is to highway vehicle occupants. Comparing the change of risk to highway occupants from 1991 to 2000, the risk of fatality is decreased by a substantial 43 percent even with increases in vehicle and train traffic.

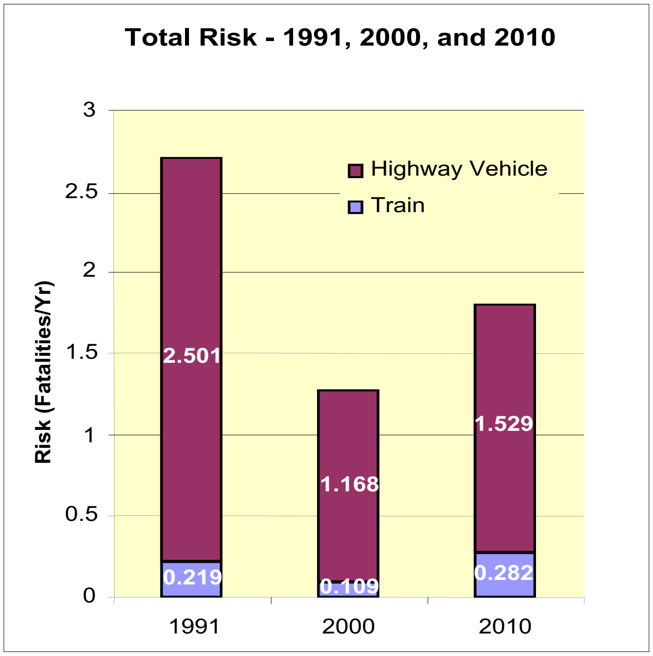


**Figure 14. 1991, 2000 and 2010 Total Risk – All Phase I Crossings**

### 2.4.1 Year 2010 Build, Partial Build and No-Build Scenarios

The 2010 Build scenario assumed that all of the crossing treatments and enhancements were implemented as planned. For the 2010 risk factor, the condition of the corridor in 2000 was projected for 2010 after application of modest growth factors. Since information about future trends and collision statistics were not available, certain assumptions were made. Year 2000 train volumes in the corridor are assumed to grow by two percent per year through 2010 resulting in 23 passenger train movements in the corridor per day in 2010 as NC DOT plans indicate. The train operating speed was assumed to increase to 110 mph, the target speed for this corridor set by the NC DOT for 2010. Year 2000 AADT was assumed to grow by a factor of two percent per year through 2010. Closed and grade separated crossings had no AADT growth applied. For collisions, the 2000 collision data were applied as a constant to the 2010 scenario. In 2010, two main tracks were used for all Phase I crossings in the corridor as projected by the NC DOT.

For the 2010 Partial Build scenario, 52 of the 100 crossing implementation crossing warning devices were assumed to remain in place through 2010 - no treatments or enhancements were applied to the other 48 remaining crossings. The 2010 Partial Build scenario used AADT with a two-percent growth factor applied through 2010. The train speed was assumed to be 110 mph for the High-Speed Rail corridor beginning in 2010, this accounts for the steep increase in Figure 15 between 2009 and 2010. The number of train movements was increased by two percent annually resulting in 23 movements by 2010. For collision data, the last pre-implementation collision rate was used. This tends to be an underestimation due to increased train speed and more train movement exposure.

For the 2010 No-build scenario, pre-implementation crossing warning devices were assumed to remain in place through 2010 - no treatments or enhancements were applied to the crossings. The 2010 No-build scenario used pre-implementation AADT with a two-percent growth factor applied through 2010. The train speed was assumed to be 110 mph for the High-Speed Rail corridor beginning in 2010, this accounts for the steep increase in Figure 15 between 2009 and 2010. The number of train movements was increased by two percent annually resulting in 23 movements by 2010. For collision data, the last pre-implementation collision rate was used. This tends to be an underestimation due to increased train speed and more train movement exposure.

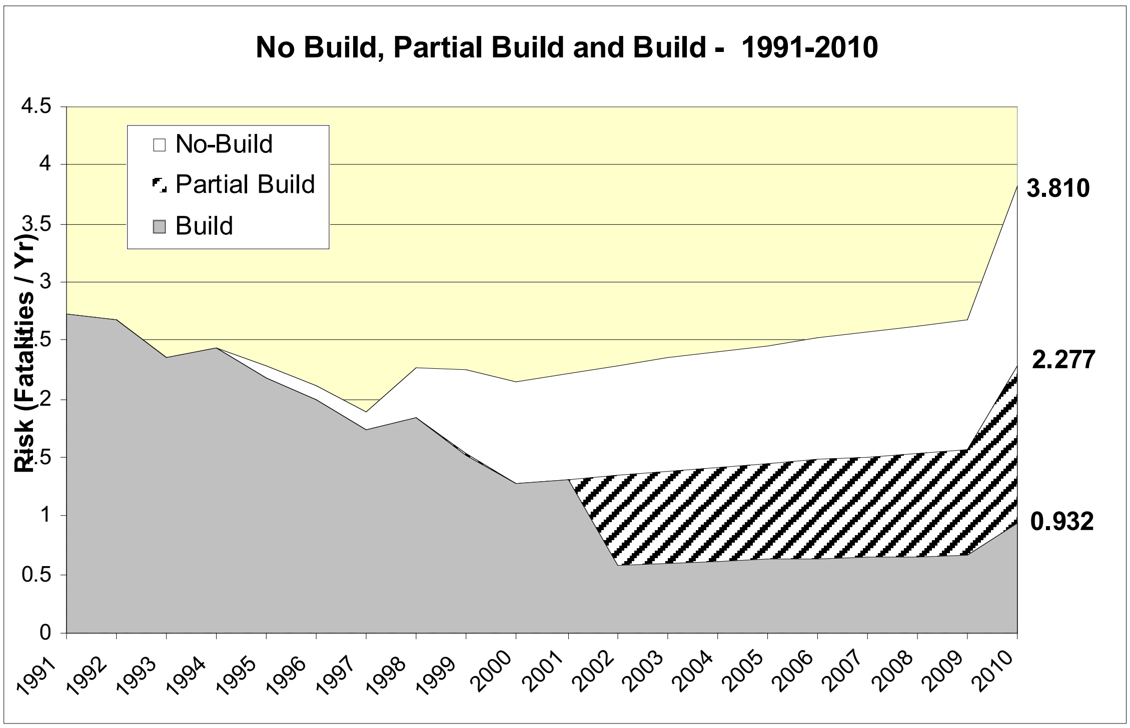


**Figure 15. 2010 Build, Partial Build, No-Build Total Risk – All Phase I Crossings**

The 2010 No-build scenario (see Figure 15) shows a significant increase in risk without the application of enhanced grade crossing devices. This scenario results in 2.9 fatalities per year more than the 2010 Build scenario, a 308 percent increased fatality risk. The 2010 Build scenario does result in an increase over the completed Phase I 2002 risk, but this is due primarily to increased train speeds anticipated by 2010, and to increased exposure. In the 2010 Build scenario maximum exposure to risk was assumed to err on the conservative side of predicted risk. Regardless, the No-build scenario would increase risk and fatalities per year by an alarming 240 percent compared to 2000. The Build Scenario assumes a 2002 implementation date for all the grade crossing safety improvements. 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 December 2000, and will save even more lives in the next 10 years.

# 3.0 FINDINGS AND CONCLUSIONS

## 3.1 Costs and Effectiveness of Crossing Warning Applications

Phase I of the "Sealed Corridor" project employed several grade crossing warning devices. These treatments (described in Chapter 1) were four-quadrant gates, long-arm gates, traffic channelization devices, video enforcement, crossing closures and grade separations. These treatments, each with varying degrees of effectiveness, were used individually and in combination to reduce risk of human injury and fatality resulting from grade crossing crashes. These applications also have a cost associated with their implementation that can be used to measure whether the reduction in risk of a fatality has a benefit/cost ratio greater than one for the specific grade crossing application.

Of the 100 crossings in Phase I of the Sealed Corridor, 52 have been upgraded and 48 are in the process of being upgraded. Before the project was started there were 85-gated crossings, 4 crossings with flashing lights and 11 crossings with passive warning devices. The most employed method of treatment for Phase I was crossing closures, which occurred at 19 crossings. The next most frequent grade crossing treatment was four-quadrant gates, which were installed at 12 crossings. Long-arm gates were installed at nine crossings, traffic channelization devices were installed at seven crossings, long-arm gates with channelization were installed at two crossings, and four-quadrant gates with channelization, video monitoring, and grade separation occurred at one crossing each in Phase I. Although the Sealed Corridor project began in 1995, as Figure 16 shows, most of the upgrades were installed between 1998 and 2000. Upon completion of Phase I of the project the most numerous treatments deployed will be crossing closures (32) and crossings with longer arm gates (31).

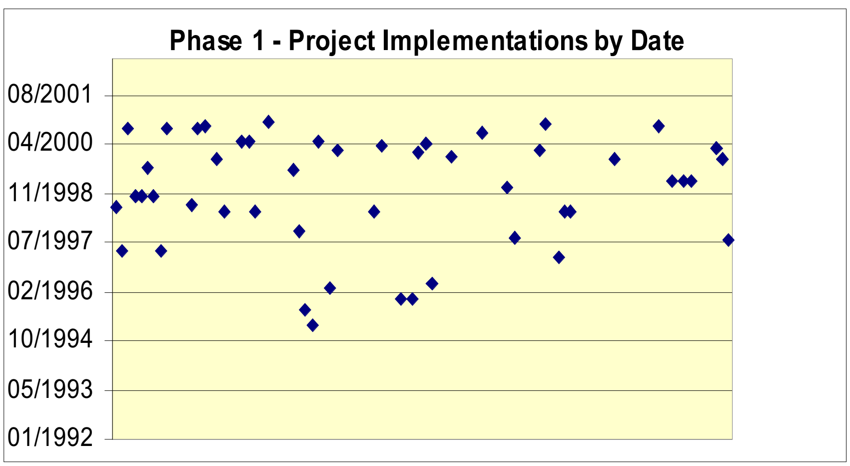


**Figure 16. Project Implementation by Date**

In the future, activities include the installation of 18 crossings with four-quadrant gates, 8 with traffic channelization devices, 4 with both longer arm gates and channelization, 2 crossings with four- quadrant gates and channelization, 1 crossing with video monitoring, and 3 grade separated crossings. Completion of all crossing treatments will further reduce risk of human injury and fatality in Phase I of the "Sealed Corridor". Completion of Phase I is scheduled for late 2002.

### 3.1.1 Effectiveness and Cost

The "Sealed Corridor" assessment study utilized information from the U. S. DOT FRA Notice of Proposed Rulemaking on Use of Locomotive Horns at Highway-Rail Grade Crossings to determine the effectiveness of the devices employed, these values are shown in Table 9 and described and referenced in Chapter 2. While the results are preliminary, they provide a reasonable approximation of the effectiveness of such systems. Note that the cost estimates assume 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. NC DOT anticipates no extensive increase in maintenance costs for the treatments used.

It should also be noted that the numbers shown in Table 12 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 12. Effectiveness and Cost of Crossing Improvements**

| | Closure | Long Gate Arm | Traffic Channelization Devices | Video Enforcement | 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 12 demonstrates grade separation and closure are the most effective applications at grade crossings, each with 100 percent effectiveness over and above gates. Obviously 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 closure is one of the least expensive measures to implement once local and community agreement has been reached. There was one Phase I project that involved a grade separation.

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 achieves 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 up-grade to two-quadrant gates has 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 up-grade 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 mid-range 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 Phase I of the Sealed Corridor Project. The cost for the 20 Phase I crossings that are slated for four-quadrant gates are more expensive than all of the other 79 crossing treatments planned for deployment by NC DOT in Phase I.

## 3.2 Lives Saved and Risk Reduction Analysis

Two methods were utilized in estimating the reduction in risk and the resulting "Lives Saved" for the Sealed Corridor project. The fatal crash analysis and the modified U.S. DOT formula approach discussed in Chapter 2 summarize the trends in "Lives Saved" using these two approaches for the treated crossings. The US DOT formula was developed to provide a relative risk ranking for a set of crossings and cannot be directly compared to actual historical crash or fatality experiences especially under conditions of small data sets. There are many factors that contribute to crashes that are not expressly addressed by the formula. The pre-treatment fatalities from these two approaches are similar in nature; both approaches together average approximately one fatality per year as shown in Figure 17. The modified U.S. DOT methodology was used to predict 2010 projected numbers.

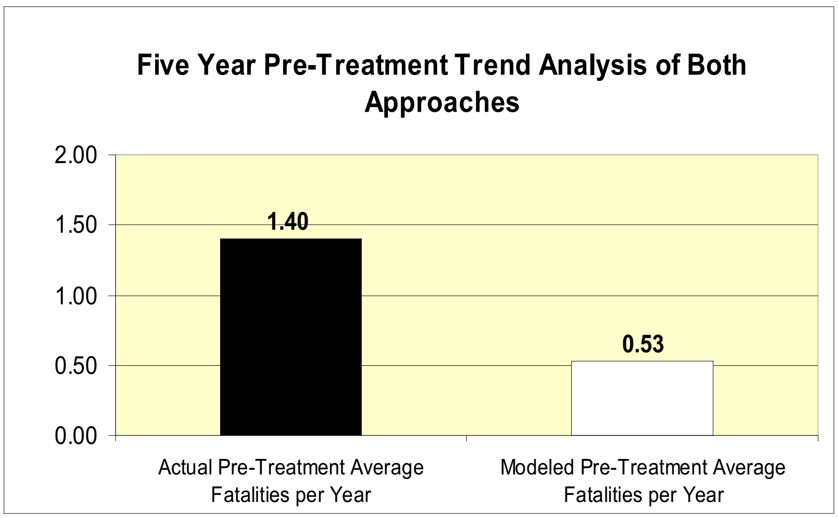


**Figure 17. Five Year Pre-Treatment Trend Analysis of Both Approaches**

### 3.2.1 Sugar Creek Road

It will not be possible to obtain a full risk picture of the Phase I treated crossings and the resulting estimated "Lives Saved" until the crossings pass their five-year post-treatment period. However, since Sugar Creek Road is one of two crossings with a full five-year pre- and post-treatment history available, it can be used as a point of discussion for benefits estimation. Sugar Creek Road was treated with four-quadrant gates in 1995 and traffic channelization was added in 1998. Using the fatal crash analysis approach this crossing experienced a five-year "Lives Saved" of 0.615. At a treatment cost of $135,000 this yields a benefit/cost ratio of 22:1.

### 3.2.2 Risk Reduction Results for Phase I Crossings

Although between 1991 and 2000 the annual risk has been reduced by 1.3 fatalities per year, with 52 of 100 of the Phase I crossings constructed, the 48 unconstructed crossings account for 77 percent of the remaining risk in the Phase I portion of the corridor. This indicates that there is considerable room for even more improvement as the Phase I crossings are completed. This is especially important given the economic growth occurring in the region, increased freight and passenger movement, and increased average daily trips. Figure 18 shows the total risk by year from 1991 through 2000, comparing the treated and untreated grade crossings. Significant reductions in the risk of human fatality (67 percent) occurred between 1998 and 2000 when the bulk of the treatments were deployed. During the same time frame the overall risk of fatalities at crossings not yet treated remained constant between 0.9 and 1.1 fatalities per year.

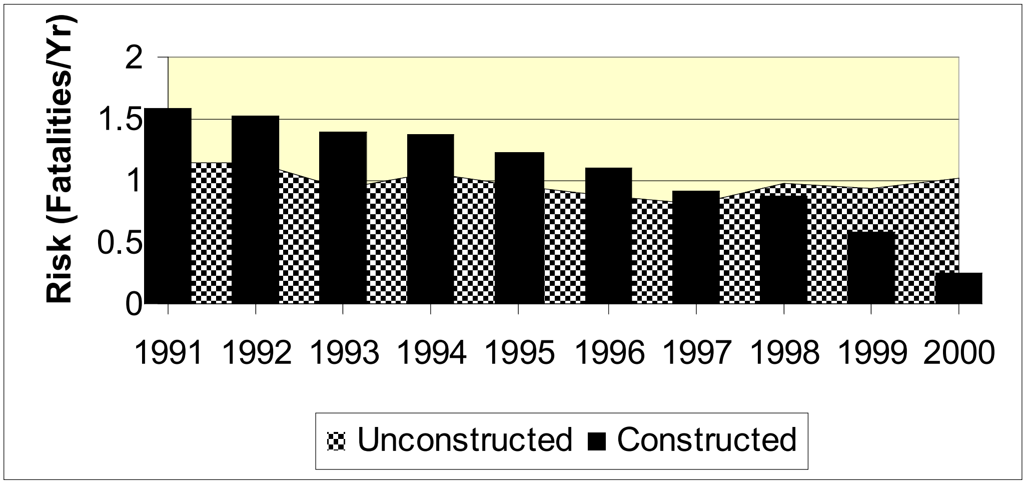


**Figure 18. Total Risk by Year Constructed vs. Unconstructed, 1991-2000**

### 3.2.3 Trend Analysis Findings

Both benefit estimation approaches, the Fatal Crash Analysis and the modified U.S. DOT formula, support the conclusion that lives have been saved based on 52 crossings being improved through September 2000. Furthermore, both approaches predict that future savings in lives will occur through 2010.

While a detailed analysis was not performed on the additional 116 crossings on the “Sealed Corridor” that are planned to be improved in Phases II, III, and IV, a simple extrapolation of the results of Phase I can be estimated. If the rate of reduction in fatalities found in the treated crossings in the Phase I analysis (.0253 fatalities per year per crossing) is multiplied by the total number of crossings in the “Sealed Corridor” (216), the result suggests that approximately 5.5 lives per year would be saved by implementing all phases of the Sealed Corridor program.

Furthermore, the highway-rail grade crossings along the Phase I portion of the NC DOT “Sealed Corridor” are not atypical of the other 10 designated HSR corridors. Crossing consolidation activities are very beneficial to other HSR corridors and the applications of non-standard warning devices have interested most of the other corridors. Some of the other HSR corridors, e.g., Florida, are experimenting with innovative devices also. We believe the results of the assessment study of the NC DOT “Sealed Corridor” Phase I program are transferable to most, if not all, designated HSR corridors nationwide. The experiences found along the “Sealed Corridor” in North Carolina are similar to freight corridors across the country and these techniques and innovations can be applied to these types of corridors as well.

## 3.3 Conclusions

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 public crossings and 44 private crossings. Since 1992, 33 public crossings have been closed. This report specifically assesses Phase I 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 and traffic channelization devices, 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 with sidings with approximately one crossing per mile. The route carries 35 freight trains per day with approximately 6 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 52 treated crossings along the Phase I portion of the "Sealed Corridor." Phase I consists of 100 crossings, but 48 crossings have not been treated at the time of the study. The crash history for Phase I indicates 154 crashes occurred between 1987 and September 2000. Twenty-seven fatalities were reported for those 154 highway vehicle-train crashes. Examination of the accident reports of the 10 treated crossings with fatal accident histories was conducted. A total of 19 fatalities resulting from 14 crashes occurred among the treated crossings. Ninety-three percent of the crashes resulted from the driver of the vehicle driving around or through the grade crossing gates.

It will not be possible to obtain a full risk picture of the Phase I treated crossings and the resulting estimated "Lives Saved" until the crossings pass their 5-year post-treatment period. However, since Sugar Creek Road is one of two crossings with a full five-year post treatment history available it has been used as a point of discussion for benefits estimation. Sugar Creek Road was treated with four-quadrant gates in 1995 and channelization was added in 1998. Using the fatal crash analysis approach this crossing experienced 0.615 "Lives Saved" from the time of implementation through December 2000. At a treatment cost of $135,000 this yields a benefit/cost ratio of 22:1.

A fatal crash rate was determined for each of the 10 crossings that had a fatal crash history from 1987 through December 2000. The crash rate was distributed over the post-treatment period to obtain a value for "Lives Saved" in the post-treatment period through December 2000. It was determined that the treatments to improve grade crossing safety at the treated crossings had resulted in 5.8 "Lives Saved" through December 2000. The economic value of the "Lives Saved" due to the improvements is $15,614,100. The cost of improvements was $400,000 resulting in a benefit to cost ratio of 40:1 for the treated crossings.

Of the 100 crossings in Phase I of the "Sealed Corridor" program, 52 have been upgraded and 48 remain untreated. An effectiveness and cost of crossing improvements was developed for Phase I. Grade separation is the most expensive improvement with four-quadrant gates second. Traffic channelization devices and long arm gates were the least expensive of the improvements made. Although between 1991 and 2000 the annual risk has been reduced by 1.317 fatalities per year, with 52 of the 100 Phase I crossings constructed, the 48 untreated crossings account for 77 percent of the remaining risk in the Phase I portion of the corridor. This indicates that there is considerable room for even more improvements as Phase I crossings are completed. Highway vehicle occupants account for a large majority of the total risk. Comparing the change of risk to highway vehicle occupants from 1991 to 2000, the risk of fatality is decreased by a substantial 43 percent.

### At least five lives have been saved.

The "fatal crash analysis method" resulted in an estimate of 5.8, or, conservatively, 5 lives saved as a result of the 52 improvements implemented through December 2000. The "modified USDOT accident prediction formula" estimated that the improvements implemented through 2000 are reducing fatalities by approximately 1.3 each year, or over 1 life saved each year. This correlates well with the results derived from the "fatal crash analysis method", thus providing FRA confidence in the benefits of the improvements to date.

### The accident reduction result is sustainable.

In order to estimate future accident reduction rates, the second of the above methods was used to ensure increases in train and vehicle exposure over time are considered in the analysis since the vehicle traffic volume will increase and the frequency and speed of trains will increase. The second method is capable of taking these factors into account.

Figure 19 shows the estimated annual fatalities under three conditions: (1) all 100 Phase I crossings have been treated (build), (2) no additional crossings are treated (i.e. only 52 of the 100 crossings have been treated, partial build) and (3) the baseline that would have existed if none of the 100 Phase I crossings had been treated (no build). The graph shows the influence of the improvements, which were initiated in March 1995, on reducing the annual fatalities through the year 2000. In the build case, the improvements at the remaining 48 crossings in Phase I were assumed to be implemented in 2002, resulting in a further reduction in annual fatalities. The gradual increase in traffic volume and train frequency from 2002 through 2010 is expected to gradually increase annual fatalities under all three conditions. Finally, the increase in train speed to 110 mph assumed to occur in 2010 would further increase all fatality rates.

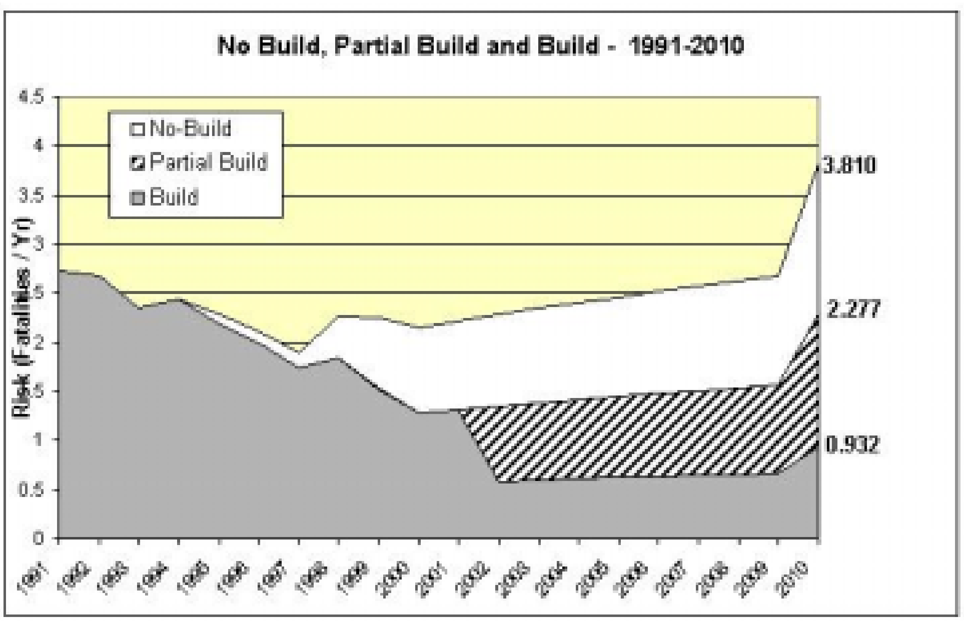


**Figure 19. Build, Partial Build, No Build Risk Calculations from 1991 through 2010 Using the Modified U.S. DOT Formula**

As can be seen in Figure 19, the difference in annual fatalities (the number of lives saved per year) under all three conditions of improvement (build, partial build and no build) would continue to increase throughout the period to 2010. By 2010 the fatality rate resulting from the full implementation of Phase I would be 75 percent lower than the no build condition. Furthermore, if there were no more improvements implemented beyond 2000, the annual fatalities in 2010 would still be 40 percent lower than the no build condition.

Further conclusions include:

- The benefit/cost ratio of the improvements at crossings with fatal crash histories can be especially high. For example, the fatal crash analysis showed that this ratio would be 40:1 for the 10 crossings in Phase I with a history of fatal crashes, and 22:1 for the Sugar Creek Road crossing, where 5 years of post-improvement history is available.
- A detailed analysis was not performed on the additional 116 crossings on the "Sealed Corridor" that are planned to be improved in Phases II, III, and IV. A simple extrapolation of the results from Phase I, however, suggests that approximately 5.5 lives per year would be saved by implementing the remaining phases of the Sealed Corridor program.
- The crossings along the Phase I portion of the Sealed Corridor are also typical of conditions on the 10 other high-speed rail corridors designated under Section 104 (d) (2) of Title 23, US Code. This suggests that similar plans for corridor grade crossing improvements be given serious consideration in connection with high-speed rail upgrades in these corridors.
- The implementation of the North Carolina "Sealed Corridor" initiative is a demonstration of non-standard corridor highway-railroad grade crossing improvements. As the rest of this demonstration is implemented it should be monitored to serve as a basis for assessing the potential impact of similar programs in other corridors.