FINAL REPORT

For

RESEARCH PROJECT 2001-16
(FHWA/NC/2002-017)

A Sign Inventory Study to Assess and Control Liability and Cost

By

Stephanie C. Vereen
Graduate Research Assistant

Joseph E. Hummer, Ph.D., P.E.
Associate Professor

William J. Rasdorf, Ph.D., P.E.
Professor

Department of Civil Engineering
North Carolina State University
Raleigh, NC

August 2002

Technical Report Documentation Page

1. Report No. FHWA/NC/2002-017	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A Sign Inventory Study to Assess and Control Liability and Cost		5. Report Date August 2002
		6. Performing Organization Code
7. Author(s) Stephanie Vereen, Dr. Joseph E. Hummer, and Dr. William Rasdorf		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Civil Engineering North Carolina State University Campus Box 7908 Raleigh, NC 27695-7908		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Analysis Group 1 South Wilmington Street Raleigh, NC 27601		13. Type of Report and Period Covered Final Report January 1, 2001 - June 30, 2002
		14. Sponsoring Agency Code 2001-16
15. Supplementary Notes		

16. Abstract

The goal of this work was to determine, quantify, and present to the North Carolina Department of Transportation (NCDOT) alternative approaches for meeting the Federal Highway Administration's (FHWA) proposed minimum levels of retroreflectivity for signs. This study used knowledge of the current NCDOT sign maintenance practices to synthesize a list of components and alternatives to comply with the standard. The fundamental contribution of the work lies in creating alternative methods to evaluating sign retroreflectivity to ensure compliance with a standard while minimizing the cost and labor required to do so. The four alternatives formulated were:

1) Continue with current inspection method,
2) Make improvements to current inspection method,
3) Implement a Sign Inventory Management System in addition to the current inspection method, and
4) A combination of alternative 2 and alternative 3.

It was the recommendation of this report that, although the most costly, alternative 4, the combination of alternative 2 and 3, be adopted by NCDOT. It was also recommended that an evaluation be made periodically to determine what benefits and improvement in sign condition, if any, have resulted from the alternative's implementation.

17. Key Words signs, retroreflectivity, standards, inventory, inspection		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 218	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

DISCLAIMER

ACKNOWLEDGEMENTS

Significant assistance was provided for this project by several organizational units of the NCDOT. Of particular note are Ray Goff from Division 6, Tom Thrower from Division 10, and J. Dean Ledbetter from Division 11, who were of great assistance. Ron King and Susan Kunz of the Signing Unit provided unlimited information. In addition, Brad Hibbs and Frank Julian of the Federal Highway Administration, Chuck Congelton and Danny Stanley of Correction Enterprise and the Bunn Sign Shop, and Tim Foster and Lorraine Jennings of Highway Division 11 provided assistance. The entire NCDOT Research Unit, the Project 2001-16 Committee, and the late Mohammed Mustafa provided help and valuable feedback. This assistance is gratefully acknowledged.

EXECUTIVE SUMMARY

The State of North Carolina currently maintains approximately 78,000 miles of road and approximately 1 million signs. In the near future, the Federal Highway Administration (FHWA) is expected to release minimum levels for sign retroreflectivity. The pending guidelines will present several new issues to state transportation agencies responsible for sign placement and maintenance, including liability, safety issues, organizational concerns, and resource concerns such as labor and cost. “The implementation of retroreflectivity standards would create a need for accurate, reliable, and cost-effective method to review traffic signs in the field[1]”. To date, no one has developed a system or methodology to meet the standards on a scale as vast as that faced by NCDOT.

The main objective of this project is to determine, quantify, and present to NCDOT alternative approaches for meeting the standard. This project will identify a number of approaches, work with the NCDOT to select a subset of the most promising approaches, gather data and information to quantify the alternatives against various criteria, and present them to NCDOT. The result will be to lay out and quantify choices that would enable NCDOT to minimize costs, reduce liability, improve safety, and comply with the proposed standards.

A literature survey revealed two reports formulated by FHWA in 1998. The first report used input from several state and local agencies to “evaluate the applicability and practicality of: the minimum-maintained levels of sign retroreflectivity proposed by FHWA and the hand-held retroreflectometer that measures signs retroreflectivity[2].” The second report presented explanations and procedures to assist agencies in developing their own sign management systems to meet the minimum retroreflectivity requirements[3]” which was used as a guide in the sign management system section of this project.

Other literature addressed issues such as how many signs may not be in compliance when the proposed standards are implemented, the cost to replace these signs, feedback from agencies on the standards and hand-held retroreflectometer evaluations.

The current sign maintenance and inspection methods of NCDOT were observed and evaluated. A life cycle of a sign in North Carolina was created based on visits to the sign manufacturing plant in Bunn, NC, discussion with State Signing Engineers, and visits to State highway Divisions to see storage methods and accompany an actual nighttime sign inspection.

---

[1] Black, K.L., McGee, H.W., and Hussain, S.F., *Implementation Strategies for Sign Retroreflectivity Standards*. NCHRP Report 346, Transportation Research Board, Washington, D.C. (April 1992).

[2] McGee, Hugh W., and Taori, Sunil, “Impacts on State and Local Agencies for Maintaining Traffic Signs Within Minimum Retroreflectivity Guidelines” BMI, Vienna, VA (1998)

[3] McGee, Hugh W. and Paniati, Jeffrey A., *An Implementation Guide for Minimum Retroreflectivity*

Two studies were performed in conjunction with this report to estimate the number of signs on North Carolina roads because an accurate approximation was unknown. These reports resulted in an estimate of approximately 11,300 signs on Interstate roads, 369,700 signs on primary routes and 605,000 signs on secondary routes.

A main impetus for this report and concern of NCDOT with the proposed standards is driver safety. Another concern is liability issues and the state's exposure to increased liability. The maximum amount that can be awarded to a defendant in a tort claim against the State was raised from $150,000 to $500,000 on June 30, 2000. The threat of another increase to $1,000,000 and the forthcoming implementation of the proposed minimum values as a standard expose DOT to a high potential for liability claims as a result of non-compliant signs. Although, history reveals that few claims are actually awarded any money (of the claims filed during 2001 that cited some type of signing concern as the cause -not necessarily retroreflectivity- no awards were made or the cases were still pending), the opportunity for high cost claims to occur will be increased.

Research included exploring retroreflectivity and it's principles, sign types and their classifications, sign sheeting types, and software and technologies available for measurement.

Using the existing literature and information collected from NCDOT meetings and observations, a preliminary list of about 30 alternatives was generated. These alternatives were presented to the NCDOT research team to retrieve comments and feedback as to which alternatives they would like to see evaluated. The meeting resulted in four alternatives, which are:

1) Maintain nighttime visual inspection method (current method),
2) Maintain nighttime inspection method with improvements,
3) Implement a sign inventory management system, and
4) Combination of Alternatives 2 and 3.

The four alternatives were outlined and costs were generated for each one.

A spreadsheet to determine the accuracy of nighttime sign inspection method was created. It was also used to calculate how many signs would potentially not be in compliance after visual inspection. It was determined that the visual inspection method produces a fairly low percentage of signs that are potentially not in compliance after the inspection. It is anticipated that the percentage of signs potentially not in compliance for NCDOT are lower because of sign personnel experience and that accuracy would increase if improvements were made to inspector training.

Requirements for Traffic Signs, USDOT, FHWA Research and Development. McLean, VA (1998).

The conclusions resulted in a recommendation of alternative 4, the combination of alternatives 2 and 3, improving on the current method and implementing a sign inventory management system. Although the most costly, this alternative met the most goals and objectives outlined in this report and by the NCDOT research committee. Alternative 4 continues the current nighttime visual inspection, keeps record of sign inspections and the condition of signs, samples a population of signs with a retroreflectometer, and improves training, along with achieving many other objectives.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The state of North Carolina currently maintains approximately 1 million signs. In the near future, the Federal Highway Administration (FHWA) is expected to release minimum levels for sign retroreflectivity. Compliance with the standard will be costly and noncompliance will have potential liability implications. "The implementation of retroreflectivity standards would create a need for an accurate, reliable, and cost-effective method to review traffic signs in the field"(1). To date, no one has developed a system or methodology to meet the standard on a scale as vast as that faced by NCDOT.

The purpose of this project is to determine, quantify, and present to NCDOT alternative approaches for meeting the standard. "If the performance standard is to be a minimum retroreflectivity value, an easy method for measuring this property of in-service signs is required"(1).

There are several possible alternatives for implementing the new standards other than immediately measuring the retroreflectivity of each sign on every road. It is possible that the NCDOT could use sign age as a surrogate for retroreflectivity; could establish a sign labeling system to easily and quickly determine sign age; could establish a sampling system for retroreflectivity measurement; could establish a priority system by sign type; could implement some combination of these; or could pursue additional alternatives.

A policy resolution formulated by the American Association of State Highway and Transportation Officials (AASHTO) recommended that agencies have the option to select from four alternative approaches to ensure adequate night visibility (2). The suggested approaches are to: conduct nighttime sign inspections and compare sign legibility distances to distances in a table; conduct nighttime sign inspection by trained observers who would know how to subjectively evaluate signs; knowing how long certain retroreflective materials last in a certain geographic area, establish a schedule to ensure sign replacement prior to it's reaching the end of it's service life; or measure sign retroreflectivity with an instrument and compare this measurement to numeric values in a table.

This project will identify a number of different approaches, work with the NCDOT to select a subset of the most promising approaches, gather data and information to quantify the alternatives against various criteria, and present them to NCDOT. The result will be to lay out and quantify choices that will enable NCDOT to minimize costs, reduce liability, improve safety, and comply with the proposed standards.

2.0 BACKGROUND

The effectiveness of retroreflective sign sheeting has, in the past, not been quantified. Beginning in 1984, the Center for Auto Safety petitioned FHWA to establish standards for retroreflectivity. Then in 1993, the Department of Transportation Appropriations Act stated that the US Secretary of Transportation should revise the Manual for Uniform Traffic Control Devices (MUTCD) to include "a standard for a minimum level of retroreflectivity that must be maintained for pavement markings and signs, which shall apply to all roads open to public travel" (2). Currently, the MUTCD states only that "regulatory, warning, and guide signs shall be retroreflective or illuminated to show the same shape and similar color by both day and night." This is the same requirement that has been present for 45 years (2).

Two reports were formulated by FHWA in 1998. The first report, *Impacts on State and Local Agencies for Maintaining Traffic Signs Within Minimum Retroreflectivity Guidelines*, used input from several state and local agencies to "evaluate the applicability and practicality of: the minimum-maintained levels of sign retroreflectivity proposed by FHWA and the hand-held retroreflectometer that measures sign retroreflectivity" (3). The second report, *An Implementation Guide for Minimum Retroreflectivity for Traffic Signs* presented explanations and procedures to assist agencies in developing their own sign management systems to meet the minimum retroreflectivity requirements (4).

Also in 1998, AASHTO requested that FHWA rulemaking on the proposed minimum in-service guidelines for retroreflectivity be delayed until they can submit formal recommendations. "AASHTO's Standing Committee on Highways (SCOH) created a Retroreflectivity Task Force to look at the research and development recommendations for FHWA" (2). The Task Force formulated the previously mentioned policy resolution that outlined recommendations to FHWA about the guidelines and suggested four methods for evaluating retroreflectivity. A copy of the policy resolution is location in Appendix G. The AASHTO SCOH and Board of Directors approved the resolution in 2000. Although the 2000 Millennium edition of the MUTCD did not include retroreflectivity guidelines, Section 2A.09 of the MUTCD is reserved for their addition.

The pending guidelines will present several new issues to state transportation agencies responsible for sign placement and maintenance. "The principle behind such a standard is that signs and other devices that rely on internal retroreflectance to be visible should maintain a level of performance that relates to minimum driver visibility requirements. This objective is not without technical, logistical, and practical obstacles" (1). These obstacles include liability and safety issues, organizational concerns, and resource concerns such as labor and cost.

The State of North Carolina owns and maintains approximately 78,000 miles of roadway. Interstate and primary roads contain approximately 388,000 (5) signs and secondary roads contain approximately 605,000 (6). Clearly this new standard poses serious challenges to the North Carolina DOT. When standards are finally implemented, it will be necessary to comply with it and to prove that compliance.

2.1 Scope

The objective of this research is to provide alternatives to the North Carolina Department of Transportation for ensuring compliance with the proposed minimum in-service retroreflectivity levels and to evaluate these alternatives. The focus of the study is on signs;

pavement markings are not being considered. In addition, this report pertains to static signs only. Changeable, temporary, and contracted signs are not considered. Finally, it is not the intention of this report to create a sign inventory, but to evaluate multiple alternatives to assist the state of North Carolina with addressing the forthcoming retroreflectivity guidelines.

This report it is not inclusive of municipalities and counties; however, signs on non-state maintained roads are just as much of a concern and the standard is applicable to all signs, not only state maintained signs.

2.2 Proposed Standards

In the 1980's the Federal Highway Administration (FHWA) designated in-service retroreflectivity as the subject of a High-Priority National Program Area. The program was to define the minimum nighttime visibility requirements for traffic control devices and develop the measurement devices and computer management tools necessary to effectively implement the requirements (7).

FHWA designed a Computerized Analysis of Retroreflective Traffic Signs (CARTS) model that assesses critical determining factors such as sign attributes, roadway, vehicle, and driver, when analyzing retroreflectivity. Previous studies and literature addressing the problem were inconsistent and unreliable. Output from the CARTS model was used to "identify the critical variables affecting sign retroreflectivity and to provide insight into the levels of retroreflectivity that are required for meeting drivers needs" (7).

The proposed minimum in-service sign retroreflectivity guidelines formulated as a result of the FHWA research are listed in Appendix A. "These minimum levels would be considered thresholds below which the sign would be considered inadequate and should be replaced" (4). The guidelines consist of five tables, four of which contain actual guideline values, and a fifth, which clarifies signs recognized by the first table. Table 1 includes guidelines for warning signs with yellow or orange backgrounds and black legends (turn or curve). Table 2 specifies levels for regulatory and guide signs with white backgrounds and black or black and red legends (Keep Right). Table 3 specifies levels for regulatory signs with red backgrounds and white legends (Stop). Table 4 specifies levels for guide signs with green backgrounds and white legends (an Interstate exit sign). Table 5 lists the MUTCD code and sign types for warning signs with bold symbols, which are distinguished differently from fine symbol and word signs in Table 1. The guidelines outlined in these tables do not apply to street name signs, overhead guide signs, parking signs, brown signs, or blue signs.

Originally the standards were to cover only regulatory and warning signs, however, the requirements have been extended. FHWA "believes this will improve safety and visibility during adverse ambient conditions" (8).

The forthcoming standards will be distinguished by one of the following categories set forth by the MUTCD: standard, guidance, option, or support. A standard will indicate a regulation, use the verb "shall", and require transportation engineers to follow the instructions provided. Guidance is described as text that is "highly recommended and uses the verb "should." The third category of option is "provided for consideration" and will use the verb "may". And finally, "support text is added as discussion to provide useful details or descriptions" for traffic engineers (8). Which category the standards are defined as in the MUTCD will affect the extent to which the state is liable.

2.3 Retroreflectivity

Retroreflectivity is the process of light being placed on the surface of a retroreflective material and that light being sent back along a path at an angle, α, away from the path it came from as shown in Figure 2.1.

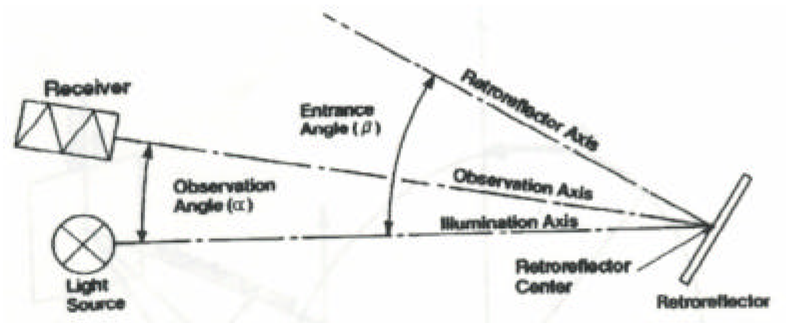


Figure 2.1: Basic Principles of Retroreflectivity

The light sources of interest here are the headlights of a vehicle. The light travels along the illumination axis, which is a half-line from the center of the source aperture to the center of the retroreflective device. It is then reflected back to a receiver, the human eye, along the observation axis, which is a half-line from the center of the retroreflector to the observation point or receiver. The observation angle, α, is the angle between the illumination axis and the observation axis. The entrance angle, β, is the angle between the illumination axis and the retroreflector axis. The retroreflector axis is a designated half-line from the retroreflector center (9).

At night, it is important that signs not illuminated by streetlights or their own lights maintain an adequate level of retroreflectivity. When light hits a sign at night, internal sign sheeting technologies cause the sign to appear as if it is glowing. Higher retroreflectivity means drivers are able to see signs from greater distances at night, thus improving their safety (15). "Retroreflective elements can serve to provide positive visual guidance that helps to keep cars in their lanes or on the road and … offers other information to drivers. Retroreflectivity is a critical ingredient in creating a much safer road environment." (10).

Retroreflectivity is a finite measure that assigns numerical values to roadway sign sheeting. These values can then be compared to the proposed minimum in-service retroreflectivity guidelines. The standard used to measure retroreflectivity of roadway signs is the coefficient of retroreflection, R_A, which is also described as specific intensity per unit area, or SIA. The unit of measurement for R_A is candelas per foot-candle per square foot ($cd/fc/ft^2$) in English units or candelas per lux per meter squared ($cd/lx/m^2$) in metric. A basic explanation of R_A is "the amount of light (i.e. luminance measured as candelas per square foot or square meters) that comes out from the retroreflective material per amount of light coming in from the light source, i.e. the vehicle headlights (i.e., illuminance measured as foot-candels or lux)" (4).

2.3.1 Retroreflective Sign Sheeting

Retroreflective sign sheeting is the material that returns light from vehicles headlights back to the driver. This makes roadway signs visible at night. Retroreflective sign sheeting has a thin continuous layer of small retroreflective elements on or very near its exposed surface as described by ASTM E808, Standard Practice for Describing Retroreflection (9).

There are two technologies that are currently used to create retroreflective sign sheeting. The first involves manufacturing very small glass spheres, or beads, into sheeting. Roundness and transparency are the properties that allow the glass beads to be retroreflective. The transparency allows light to pass through them and roundness causes the incident light beam to be refracted, sending the reflected light beam back at a slightly different angle than it entered the bead as shown in Figure 2.2.

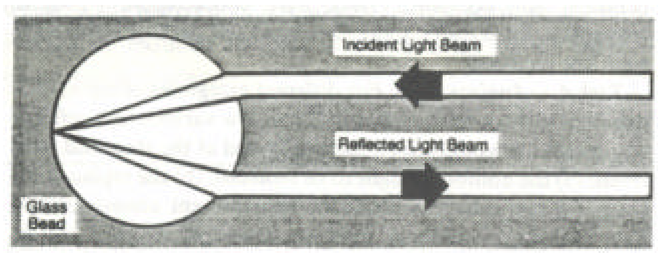


Figure 2.2: Glass Bead Retroreflection (11)

The second technology uses prismatic cube corner reflectors as shown in Figure 2.3. The incident light beam (a car's headlights) enters the reflector and bounces off the sides of the cube, sending the reflected light back to the driver.

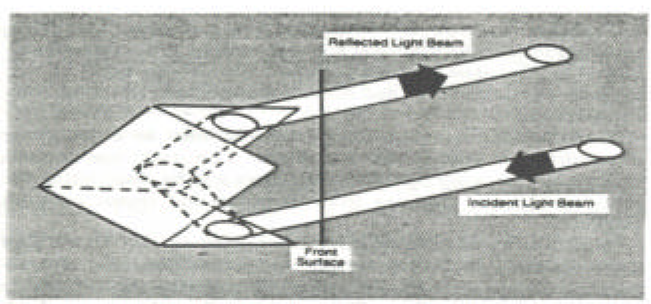


Figure 2.3: Prismatic Cube-corner Retroreflection (11)

Many of these tiny reflectors are embedded in sheets of retroreflective material.

2.3.1.1 Types

There are many types of reflective sheeting and different intensities and methods of reflection used for each one. The types vary among manufacturers; Avery Dennison, 3M Company, and Nikka Polymer Company are some commonly used brands. A state contract determines which manufacturer's product will be used by the Highway Divisions and the Department of Corrections. Avery Dennison holds the current state contract.

Table 1 lists the types of retroreflective sheeting, principles, and characteristics of each one. Sheeting types I – III increase in intensity and quality level; however, the remaining sheeting types do not necessarily increase in intensity or quality as their type number increases.

Table 1: Retroreflective Sheeting Types

TYPE	CHARACTERISITCS
I	Lowest type. Medium-intensity. Enclosed glass bead. Engineering Grade
IIIA III B	High Intensity/High Performance Grade. A – Encapsulated glass beads, B and C – Honeycomb type prismatic reflectors
VI	High Performance Vinyl Sheeting. Low durability, used on cones and temporary fold up signs.
VII	Long Distance Performance (LDP). Stronger further away, strength diminishes as one approaches the sign.
VIII	Equivalent to Type III. Prismatic technology used instead of honeycomb.
IX	Visual Impact Performance (VIP). Becomes much stronger the closer you get. Used on the new fluorescent yellow-green non-motorized warning signs.

Source: ITE Traffic Sign Handbook, NCDOT Chief Signing Engineer

The physical composition and construction of each sheeting type varies. Enclosed lens sheeting, which is found in sheeting Types I and II, is illustrated in Figure 2.4. It consists of glass beads imbedded inside durable transparent plastic over a base of metallic reflector coating, a pre-coated adhesive, and a protective liner.

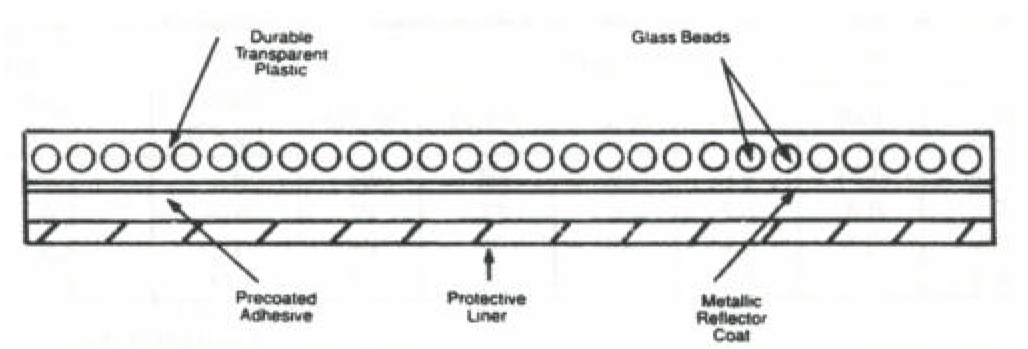


Figure 2.4: Enclosed Lens Sheeting (4)

Figure 2.5 illustrates encapsulated lens sheeting, which is used in Type IIIA. It is similar to the enclosed; however, a transparent plastic film is placed over the top glass beads.

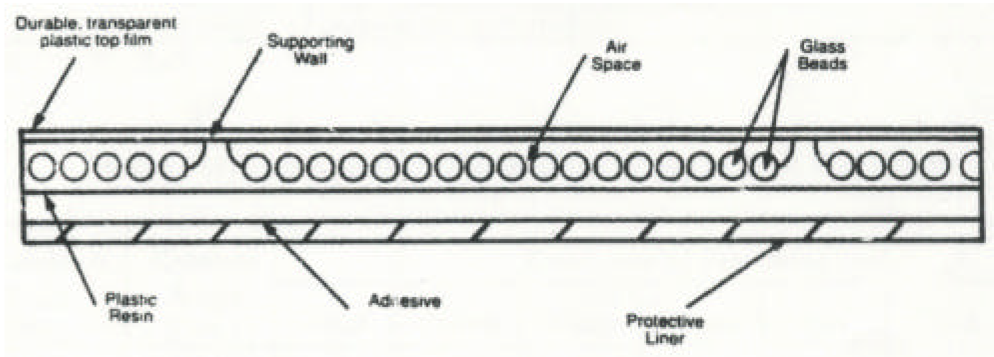


Figure 2.5: Encapsulated Lens Sheeting (4)

Figure 2.6 shows cube corner sheeting, also known as prismatic consists of many of the tiny cube corner reflectors.

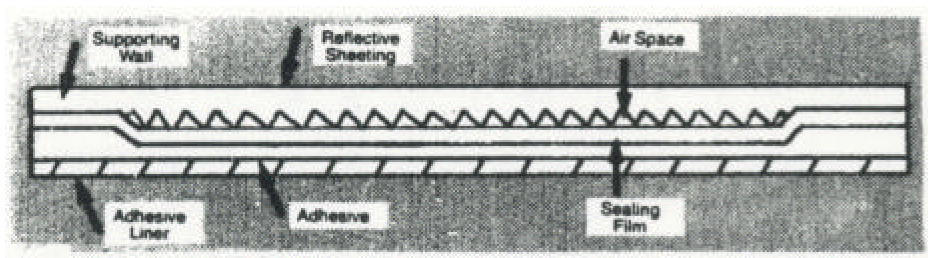


Figure 2.6: Prismatic Cube-corner Sheeting (4)

The main performance difference between the types of sheeting is captured in the R_A, or coefficient of reflection value (4). Table A compares the coefficient of retroreflection values between different sheeting types of the same color. The values in parenthesis are the proposed minimum in-service value for the same sheeting type and color expressed in cd/lux-m^2. The value for the largest sign and highest speed value was chosen if more than one option was available for a color.

Table 2: Coefficient of Retroreflection of Various Sheeting Types and Colors

	R_A Values (cd/lux-m^2)*			
TYPE / COLOR	**TYPE I**	**TYPE II**	**TYPE III**	**TYPE IV and VII**
RED	14 (8)	30 (8)	54 (8)	56 (8)
YELLOW	50 (20)	100 (25)	200 (30)	270 (40)
ORANGE	25 (20)	60 (25)	120 (30)	160 (40)
WHITE	70 (25)	140 (30)	300 (40)	400 (50)
GREEN	9 (7)	30 (7)	54 (7)	56 (7)

Source: Reference (4) , Appendix A

*Observation angle = 0.2 °, Entrance angle = -4°

The intensity of light reflected back by each sheeting type varies greatly. A driver viewing light that enters and reflects back from signs that are the same color but different sheeting types, is likely seeing a wide range of intensities. At the same degradation rate, a higher quality sign sheeting should meet the proposed standard for a longer period of time, which leads to a lower replacement rate.

2.3.1.2 Protective Film

3M currently manufactures a clear plastic protective film that can be placed over the original sign sheeting. The film is a graffiti resistant polymer type film that allows the paint to be easily removed from the sign without damaging the sheeting. The ink on the sign is also protected and the sign does not fade as fast due to protection from weathering.

It is currently too expensive to use on every sign manufactured. The cost is about $1.00 to $2.00 per square foot plus labor and processing cost, but as the volume of usage increases the cost will decrease. No additional equipment is needed to apply the sheeting. It can be applied with pressure during the sign making process. The procedure adds about one day to the sign manufacturing process.

According to the Department of Corrections Sign Shop, there has been periodic use of the sheeting by some divisions. There has been discussion by the DOT to use the sheeting on 'stop' signs, school zone signs (because of high vandalism), and 'do not enter' signs. The protective film is not completely infallible; it can still be cut by glass (bottles being thrown at the sign.)

2.4 Literature Review/Related Studies

In 1992, Black, McGee, and Hussain (1) evaluated how many signs would have to be replaced, what would be the costs to replace them, and what the cost will be to various state, county, city, and town agencies to maintain the proposed FHWA standard. In addition, the authors assessed the impacts of alternative standards and provided alternatives and guidelines for implementing the standard.

Preliminary information addressed included the status of the Nation's signs regarding their retroreflectivity levels, how many signs exist on the Nation's roadways, and the cost to replace the signs by type, material, and jurisdictional level.

Their report did not, however, cover alternatives that could be implemented by states; they addressed the issue on a national level. They did conclude that the initial cost to comply with the standard would be very high and "beyond the resources of many jurisdictions" and suggest that alternatives for meeting the standards would need to be formulated. Their suggestions were limited to staggered implementation periods for different sign sheeting types and colors, but not specific steps that states could take to address liability and complete compliance.

In 1996, Gene Hawkins, et al. performed research to determine the most effective method to allow the Texas Department of Transportation to comply with the minimum proposed retroreflectivity values and "to identify the key issues that affect implementation of alternative sign replacement methods" (3). Issues such as relative cost of the various methods, required increases in personnel, sign service life, and features of sign management systems were addressed. The research evaluated three alternatives: total replacement of all signs, sign inspection and replacement, and sign replacement based on a sign management system. These alternatives or variations of them have been considered in this report.

In 1998, McGee published a comprehensive report that provides state and local governments information ranging from types of reflective sheeting to data collection techniques and inspection and maintenance methods (4). The guide's purpose is to help agencies be cost-effective in meeting the proposed minimum maintained retroreflectivity guidelines while still maintaining safe and adequate signage.

This report did break down and explain in detail components of a sign management system, inventory, inspection, maintenance; but it did not outline complete alternatives that agencies could follow to meet the proposed requirements.

In 1998, McGee and Taori collected data from sixteen state agencies (not including North Carolina) and nine local agencies to evaluate the proposed minimum-maintained retroreflectivity levels and to evaluate a hand-held retroreflectometer (3). The data collected from the agencies included retroreflectivity measurements from a sample of signs, results of analysis the agencies performed on their data, sign replacement cost information, assessments of the use of the hand-held retroreflectometer, and assessments on impacts of the guidelines on their agencies (cost, labor, practices, etc.).

The same study estimated the percentage of signs that would not meet the proposed minimum levels of retroreflectivity. Based on data collected from state and local agencies, they concluded that if their sample represented the condition of signs nationwide, then about 5.5% of the total signs in the nation would need to be replaced (based on background sheeting color).

Each of these documents outlines individual steps that can be taken to ensure signs maintain adequate retroreflectivity. However, none include a detailed alternative; a complete plan or program. And they are all addressed to responsible agencies in general, not to NCDOT as an individual entity. Specific NCDOT procedures for evaluating signs and organizational structure are not addressed. This report intends to integrate current NCDOT inspection procedures and organizational practices into the formulated alternatives.

3.0 NCDOT ORGANIZATION

Although equipment and methodologies for gathering and analyzing retroreflectivity are important, data is the foundation of the NCDOT organization. "The institutional barriers to efficient data collection and presentation are often more imposing than the technical barriers"(18). Understanding the current operations and procedures of NCDOT is essential to formulating alternatives that are synonymous with current practices. Many departments within NCDOT play a vital role in the task of ensuring adequate and safe signing on North Carolina roads all of which play a role in meeting the forthcoming standards. Manufacturing, design, installation, and maintenance, all play a part in ensuring adequate signs on North Carolina roads.

3.1 Life Cycle of a Sign in North Carolina

All signs in North Carolina follow the same general life cycle process. Figure 3.1 outlines the cycle each sign follows, beginning with manufacturing and ending with replacement or destruction. In addition to the signs manufactured by the Bunn Sign Shop or a private manufacturer, most of the Highway Divisions have basic sign shops in which they are able to create small signs.

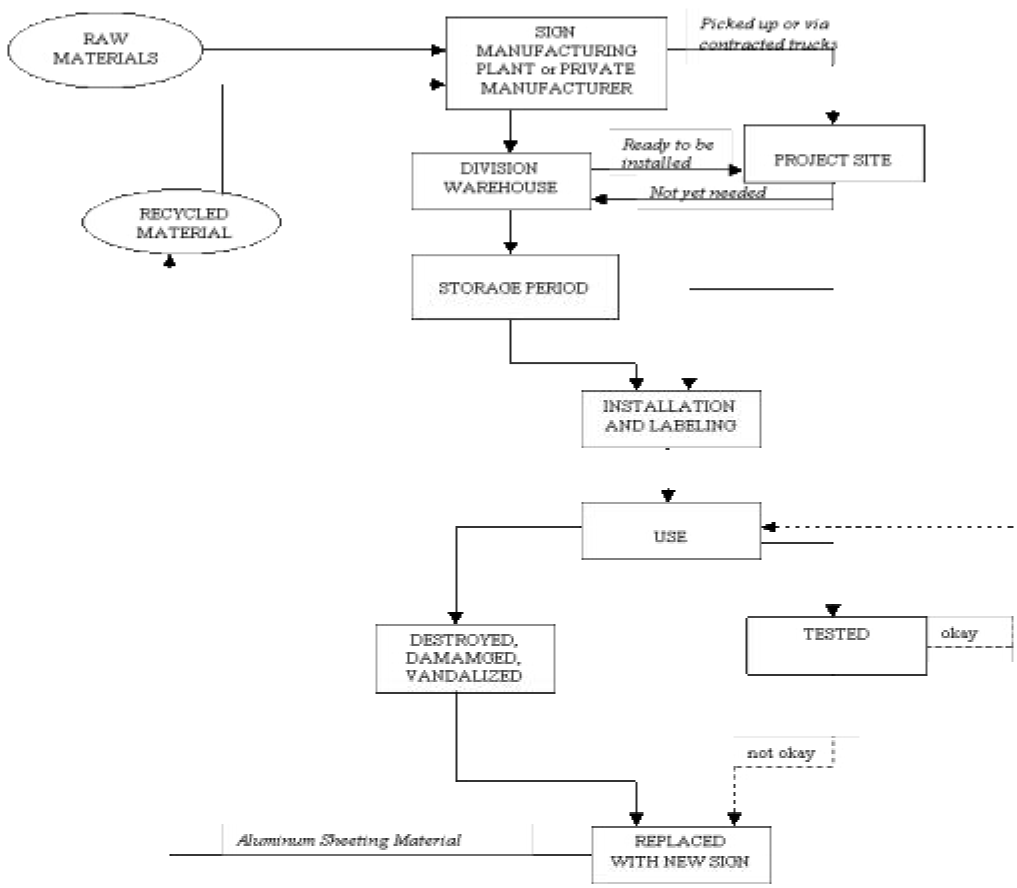


Figure 3.1: Life Cycle of a Sign in North Carolina Flow Chart

The Correction Enterprises sign shop in Bunn, NC manufactures 90% of signs for the NCDOT. The remaining 10% come from private manufacturers. Frequently used signs are created in bulk at the sign plant and kept readily available for shipment to divisions or whoever purchases them. These signs are usually sent to divisions and municipalities in bulk for their inventory, where they remain until they are used. New signs (directional, green/white) or road improvement signs are requisitioned through NCDOT Signing according to contractor's schedules. NCDOT signing engineers use the Guide Sign software to create sign layout sheets, which are then submitted to the sign manufacturer for production. These signs are usually transported directly to project sites for immediate installation or stored at a Highway Division yard.

When signs are created, the date of manufacturing is etched into the back of the aluminum substrate. When signs are installed, a sticker is placed on the lower corner of the sign closest to the road on the back of the sign indicating the month and year in which the sign is placed. On project sites, contractors are responsible for placing the sticker.

Once a sign is installed, it remains in place until damaged, destroyed, or, vandalized, or until nighttime visual inspections deem the sign inadequate. Each of these cases results in the sign being replaced with a new sign. It is important to note that a sign deemed inadequate might not be replaced immediately if division sign funds do not allow it if it is not of a critical nature.

The signs taken down are collected in bins (Figure 3.2). The reflective sheeting is removed from aluminum substrate that is not damaged and these pieces are returned to the sign plant for new signs to be created (Figure 3.3). Aluminum pieces not able to be reused are recycled.

Figure 3.2: Damaged and Replaced Signs in Bins


Figure 3.3: Used Aluminum Substrate Back at the Sign Plant to be Used Again

3.2 Current Maintenance Procedures

The NC Division of Highways is divided into 14 divisions. . Each division is responsible for evaluating the retroreflectivity of the Interstate, primary, and secondary roads in their division. Nighttime visual inspection is the method used by divisions to determine if the retroreflectivity of state maintained signs is sufficient.

Two-person crews drive by signs at night to identify deficiencies in the sheeting. Based on their observation, the crew determines whether the sign needs replacing. A sign earns either a “yes” rating, meaning it needs to be replaced, or a “no” rating, indicating the sign does not need to be replaced. Critical regulatory signs, like Stop signs, are replaced immediately or the next day. Signs deemed less critical to driver safety may be replaced in the days and weeks following the ride, as time and money allow. Currently, no division owns a retroreflectometer or has any other equipment to measure retroreflectivity.

3.2.1 Sign Condition Survey Guidelines

The procedure for nighttime visual inspection is outlined in the Sign Condition Survey Guidelines. Kent Langdon of the North Carolina DOT wrote the guidelines in 1992 as a result of a Traffic Services Supervisors Meeting. A copy of the Guidelines is in Appendix C. The objective of the guidelines is to ‘systematically review all highway systems to identify those signs which should be replaced because of inadequate legibility, reflectivity, or installation.’ This is to be accomplished by visual inspection without the aid of electronic measuring devices. The report is divided into several sections, each providing instruction on a certain aspect of assessing the conditions of signs on division/state maintained roads.

The guidelines include suggested frequencies for testing signs is every 3 years for secondary roads, 2 years for primary roads, and every year for interstates (12). The actual breakdown of how this is accomplished is shown in the following table.

Table 3: Night Ride Frequencies

SYSTEM	PERCENT REVIEWED ANNUALLY	INDIVIDUAL ROAD REVIEW FREQUENCY EVERY
Interstate	100%	Year
Primary	50%	2 years
Secondary (paved and unpaved)	33 1/3%	3 years
Urban	50%	2 years

Source: NCDOT Sign Condition Survey Guidelines (12)

According to the procedure section of the report, each state-maintained route is to be ridden in each direction during nighttime hours to identify signs that are not performing and should be replaced. Inadequate signs are to be marked in a manner chosen by the division, such as spot painting the sign or marking the road nearest the sign. In addition, each marked sign is to be recorded in a sign condition survey report form that resembles Table 4.

Table 4: Sign Condition Survey Report Form

ROUTE	SIGN SIZE	MESSAGE	COMMENTS	ACTION CODE	DATE CORRECTED

"Route" is the US Route, State Route, or Interstate number on which the sign is located. "Sign size" corresponds to standard sign dimensions; unique signs are estimated to the nearest inch possible. The sign text is entered in the message box and additional information can be entered in the comments box. The action code is rated as a 1, 2, or 3, depending on the importance of the sign type. Code 1 signifies 'immediate action'; this applies to red signs such as stop or yield. Code 2 is for yellow yield and warning signs and indicates replacement 'as soon as possible'. Code 3 is for all other signs such as informational and signs that are less critical to the driver's safety; these replacements are "scheduled as needed" or as budget and time allow. The final column is left empty during the initial ride. It is completed later when the sign is actually replaced. This means the report should be kept on file and accessible until all signs, regardless of code, have been replaced.

It is stated in the schedule section that work will be conducted during the months of November, December, January, and February because of the length of the nights. The guidelines also state that the work should be performed during the hours of 2:00 pm and 10:30 pm, however most divisions work from about 5:30 to 9:30 when it is dark.

The training portion of the guidelines suggests that sign erectors and their helpers or other competent staff perform the surveys. A four-hour training course and video were developed in conjunction with guidelines. All Division Traffic Engineers and their assistants are supposed to receive the training and pass the information on to sign erectors and other personnel involved in the procedure. According to Kent Langdon, each division administers the four-hour training course as they see fit. It should review the rating system used to evaluate signs, show physical examples of good and bad signs, and include a viewing of the training video. The training video reviews how to assess signs, characteristics of inadequate signs, and the procedure for marking the sign and filling out the previously described form to note which signs need replacing.

The training should be performed every year prior to the night ride season. According to a questionnaire submitted to the fourteen NCDOT highway divisions, six divisions reported using the video for training, two reported using demonstrations, one reported following the Sign Condition Survey Guidelines, and one reported pairing new workers with experienced ones (three divisions did not respond). No division mentioned administering a four-hour training course.

Finally, a section on Data Management is included in the guidelines. The section indicates that as the data are collected on the forms, it is then to be keyed into a computer program designed specifically for this activity. Once the electronic forms are complete, they are to be forwarded to the NCDOT Road Maintenance Unit through Corporate Tie, an internal data transfer program used before the internet. According to Tom Gobel of the NCDOT Road Maintenance Unit, the department to which the data collected as a result of the survey were to be submitted, the program no longer exists. Data came in from every division for one or two years when the program was initiated; only three or four divisions consistently continued data submissions until it died out. Several divisions still submit data to the Maintenance Unit. One division reported submitting their data to the Chief Engineer's Office.

When the program was operating, data were submitted electronically to the Road Maintenance Unit. A computer program called Paradox and another internal program written specifically for the project were used to process the data. Nothing was ever done with the information and no one was actively monitoring the program so it stopped. The only record of the information ever being accessed was use in a presentation prepared by Mr. Gobel. There were plans for a web-based submittal format, but they were never employed. Divisions still perform nighttime rides to assess whether signs should be replaced but data are no longer formally collected and forwarded to a central location to ensure it is being done.

3.2.2 Division Surveys

A questionnaire was formulated to assess the familiarity and fulfillment of the Sign Condition Survey Guidelines and the nighttime ride sign evaluation procedure throughout the fourteen North Carolina Highway Divisions. Questions about sign evaluation procedures, manpower commitments, sign inventory and other aspects were included. The questionnaire was distributed via e-mail on Monday, July 30, 2001 to the Division Traffic Engineer of each division. 70% of divisions responded. The complete survey and responses are in Appendix E. Of the fourteen divisions surveyed, ten responded; visits had been made to two of the responding division previous to the survey distribution.

3.2.2.1 Survey Analysis

The results indicated that of the ten responding divisions, eight were familiar with the Sign Condition Survey Guidelines. However, the two who were not ‘familiar’ with them, still performed nighttime rides to evaluate sign performance in a manner similar to the division who were ‘familiar’ with the Guidelines. So all the responding divisions were familiar with the procedures as described by the guidelines, but not with the guidelines. All of the divisions reported using the sign condition survey form included with the guidelines. And all, except one, marked signs needing to be replaced with spray paint mark, colored sticker, or orange ribbon; the other relies solely on what is recorded on the form. None of the divisions owns a handheld retroreflectometer, but at least one suggested they be used and would like to use them.

All of the divisions performed nighttime rides to assess the condition of signs in their division. Training methods varied from division to division. Some divisions only performed a simple demonstration. Others had workers attend an annual meeting at which training is done, showed the training video each year, paired older workers with new ones to teach and share skills, or a combination of these. The time of year, number of labor hours devoted to the task, and training methods varied, as indicated by questions 5, 6 and 7. All performed their nighttime rides from November through March. The amount of manpower devoted to nighttime rides varied. Table 5 lists the amount of labor used and the time of year the divisions responding to the survey perform nighttime rides.

Table 5: Manpower and Time Frame Committed to Night Rides by NCDOT Divisions

MANPOWER USED	HOURS ANNUALLY	TIME OF YEAR PERFORMED	DIVISON
7 sign trucks, 2 employees/truck, 6 hrs/wk for 20 weeks	1680 hours annually	November to March	4
40-60 hours per 2-person crew	640-960 hours annually	Late Fall into Winter	8
11 workers from December to February**	1056 hours annually	December to February	9
Six 2-person crews for 2-3 weeks*	480 – 720 hours annually	October or November	14
Not provided	1400 hours annually	November to February	3
Six 2- person crews for one week*	240 hours annually	January and February	13
12 people, 6 vehicles, 3-4 weeks*	720 - 960 hours annually	Fall	2
48 – 60 hours per county per year. 7 counties	336-420 hours annually	Fall	5
4 crews, 2 people each (plus 3 additional out of town crews) 60-80 hrs per person each season	840 – 1120 hours annually	November - February	11
Not provided	600 – 700 hours annually	January – March	6

*Assumed 4 hours per week/ 5 days week
*Assumed 4 hours per week/ 2 days week

The questionnaire did not assess how many divisions still attempt to submit data collected during the nighttime rides to the NCDOT Road Maintenance Unit as is specified by the Guidelines. However, one respondent noted that they were contacted in 1999 because they did not submit data; the respondent proceeded to inform the caller that previously submitted data had never been accessed nor had a formal report acknowledging receipt of the data been formulated.

Another concern was regarding drowsy driving because the nighttime rides were being done in addition to a regular eight-hour workday. Other divisions have employees perform night-rides in addition to their regular eight-hour workday, a situation that could definitely lead to reduced accuracy and safety, although some shift the workers days so eight-hours begins later in the day to accommodate the night-ride hours.

Overall, the survey indicates that the responding divisions all perform sign evaluation, but to varying degrees. There are many specifics that should be clarified and distributed to all divisions. Any new or updated programs initiated as a result of this or future studies needs to include a comprehensive education program across all divisions to ensure everyone is on one accord and the program is meeting it's goals of ensuring safe signs with proper retroreflectivity.

3.2.3 Nighttime Visual Inspection Procedure

Nighttime observation of signs is the procedure outlined in the Sign Condition Survey Guidelines (Appendix C) to determine whether signs are visually adequate. A visit was made to North Carolina DOT Highway Division 11, located in North Wilkesboro, NC, to accompany two of their sign personnel on a night ride of secondary roads in Wattauga County, NC.

Each crew takes a car or a small truck; they try to avoid using the signing trucks because they are large and cumbersome and difficult to maneuver, especially on dirt roads. Each night ride consists of a 2-person crew, a driver and a recorder; both persons work together to evaluate signs. No samples are evaluated before the ride begins to 'calibrate' the observers' eyes. (The NCDOT Sign Condition Survey Training Video is viewed in November prior to the night ride season.) Most inspectors are experienced; new or temporary employees are always paired with an experienced observer. The recorder is also responsible for navigating the map. A map highlighted with the section to be ridden is used to navigate; as each road is ridden, it is highlighted in a separate color.

The procedure is simply to follow the map and evaluate all signs. Roads are ridden in both directions. However, on many through secondary roads, where signs are sparse and would not require the crew to come back on the same road, the crew will slow the car and shine a light back on signs in the opposite direction and evaluate them this way. Signs are evaluated at posted speed limits, using the headlights of the car as the light source. A flashlight is shone on signs that the cars headlights do not hit. If a sign is questionable, the crew will get out of the car to take a closer look at the sign sheeting; some signs that appear to have poor sheeting are just dirty. The sticker indicating the installation date of the sign is checked. (The manufacturing date that is etched on the aluminum during fabrication is not checked.) If the sticker indicates the sign is older than 7 years, it is noted for that sign to be replaced.

An example illustrating the process was a bridge end sign that was questionable so the team got out the car and examined it closely. The sign was just covered with dust. The installation sticker was also checked and it indicated the sign was installed on December 11, 1997, so it was still in the allowable 7 year time period. If a sign is questionable, the sign inspectors must also take into consideration whether the sign will last for three years, until the next inspection, because secondary roads are only ridden once every three years.

The recorder uses the Sign Condition Survey Report table (Table 4) to record signs needing to be replaced. However, some signs do not need replacement but require some other action. These signs are recorded on a separate sheet of paper and will be labeled with other actions codes. For example, signs with light vandalism can be cleaned, so they are given a 513 code. This is also done for missing signs. The sign cannot be given a 1,2, or 3 rating as described in the Sign Condition Survey Guidelines, so they must be included on another sheet.

Employee quality is an important factor in the condition of signs. The same employee may work the same county for many years and be very familiar with the roads and take great pride and enjoyment in ensuring the signs in the area he or she is responsible for are excellent. But some employees are not as meticulous in their work. Also new and temporary employees do not feel as great a sense of pride and responsibility for maintaining the signs that results in a lower work standard and poor sign replacement practices.

Physical sign characteristics, other than retroreflectivity are evaluated during night rides. Some signs were the wrong height or position or may have been bent or obstructed by bushes. For example, during the night ride a black on white weight limit sign still had a little retroreflectivity left, but the weight numbers were not the correct font or cut neatly so this sign was written down to be replaced. Sign placement is also noted. During the ride, several stop signs and bridge ends were not installed at a proper location or height. These are situations that cannot be predicted by a computer system. However, the sign personnel felt that having a laptop that contained the location and information of each sign would help to identify signs that were missing and also decrease the time spent entering the night ride data into a computer since the information would be entered directly into the system.

3.3 Manpower

Most divisions have a complete staff of sign erectors that are employed year round. Some divisions employ temporary workers when needed. Quality control, self-pride, and motivation are important aspects to the positions that are not congruent with employment conditions. Sign erectors are the lowest paid entry-level position in the DOT. In addition, they are expected to have map-making skills and are on call 24 hours a day. They do not receive overtime until their weekly hours exceed fifty; forty-one to forty-nine hours per week are dispersed as compensatory time. They sometimes accrue so much compensatory time, they end up being out for several weeks.

A sign crew consists of anywhere from two to six people. A sign erector, a helper and two temporary employees are an example of a four-person work crew. Work is often slowed because training is ongoing for the temporary employees. Each crew is responsible for replacing signs and performing night rides, in addition to other division duties.

3.4 Equipment

Each division is equipped with signing trucks. Each truck cost approximately $40,000. This cost includes the truck itself, a front-end post pull, an auger, a crane, and other miscellaneous hand tools. The trucks are used to transport and install signs (larger signs require alternate transportation methods). Figures 3.4 and 3.5 show a typical sign truck.

Figures 3.4 and 3.5: Front and Rear Views of a Typical Signing Truck

Signs are sometimes damaged on trucks before they are even installed. It is difficult for workers to maneuver signs in and out of the storage racks on the trucks and they often get scratched. Figure 3.6 shows a close up view of the racks on the back of a signs truck.

Figure 3.6: Sign Storage Racks on a Signing Truck

Scratches cause signs to deteriorate more quickly. A protective paper is placed on signs during manufacturing and stays on signs while in inventory. But the paper must be removed before being placed in a truck because moisture caused by humidity and rain causes the paper to stick to signs creating a watermark on the sheeting, which ruins it. Protective spacers are available to keep signs in place on the truck and reduce scratching. However, the spacers are cumbersome and trucks not able to return to the warehouse everyday need to carry numerous signs so there is no room available for them.

3.5 Sign Storage

Each division keeps frequently used signs in stock. Proper storage conditions can ensure that signs last for their warranty life and far beyond. In Division 6, a representative from the 3M Company assisted with design of their sign storage area. The shelf system designed involves keeping the signs elevated using metal pipes as shown in Figure 3.7. Signs also remain wrapped in the packaging in which they were received from the Department of Correction Sign Shop. This protects the signs from scraping against each other while in storage as shown in Figure 3.8.

Figure 3.7: A Pipe Keeps Signs Elevated

Figure 3.8: Stored Signs Kept Wrapped

Signs may be unbundled (not unwrapped) during yearly inventory checks or to verify that a sign is in the correct place but they remain wrapped to help protect the sheeting.

3.6 Information Transfer Among Units

All North Carolina DOT divisions are connected through a mainframe computer system, known as the IRMA mainframe. Inventories of signs that are kept the division warehouses are tracked using this system. A record of how many of each type of sign used each year is stored for 5 years. This helps each division prepare a budget based on how many signs they think they will need for the coming year. This also allows neighboring divisions to check each other's warehouse inventory in case they need to borrow a sign. Divisions can also check the order status or history of signs, but once signs leave the warehouse to be installed, they are no longer kept in the inventory system.

Corporate Tie is a program used by NCDOT to transfer information among computers in the mainframe. It allows PC users to access data from the mainframe, send data to the mainframe and share data with other microcomputer users in a network (13). It was implemented in the pre-internet era, however it is still used. Corporate tie also has the capability to develop custom programming applications and set up comprehensive security, administration and management systems. File transfers to unattended PCs can be conducted at any time through an optional feature.

Beginning on July 1, 2002, NCDOT will be switching to a windows based mainframe program. The effect of this change on current sign maintenance and inventory procedures is not known.

4.0 RETROREFLECTIVE MEASUREMENT

There are currently two methods to assess the retroreflectivity of a sign. The first is to rate a sign based on visual assessment, which is the current method used by North Carolina. This can be done at night using a bright light and the human eye or during the day using a Q-beam light source. The second method is to utilize retroreflectometers, either handheld or mobile. Handheld units use an internal beam of light to measure retroreflectivity and mobile units utilize lasers. Neither of the two methods is completely accurate. Different individuals may have varying visual observations of the same sign and hand-held retroreflectometers can be time-consuming, often requiring up to four readings per color. Mobile retroreflectometers are still being developed and improved. “There are currently no traceable methods in the United States to determine the accuracy of retroreflectivity measurements because national calibration standards for retroreflectivity do not exist” (2).

4.1 Validity of Visual Measurement

The effectiveness of roadway signs can be evaluated using the human eye. The evaluator rides a stretch of road in a car and assesses each sign that is passed. Although no qualitative data is collected using this method does not mean the method is inadequate. However, the proposed minimum in-service values are quantitative standards so how can NCDOT ensure that trained state workers performing observations are maintaining signs to meet the standard?

The Washington State Department of Transportation completed a study entitle *Traffic Sign Retroreflectivity Measurements Using Human Observers.* The objectives of the project were “to review all available literature on maintaining retroreflective traffic signs and survey all state transportation agencies to learn about the methodologies employed in making retroreflective judgments on highways” and to assess the accuracy of trained observers in evaluating traffic sign retroreflectivity. They performed a series of experiments that included a training period and an evaluation exercise that involved rating a series of signs and providing them with a rating of 0 to 4, 4 being best. The results of the observers’ ratings of signs during the exercise were compared with ratings of the signs calculated using a retroreflectometer. The results showed that 74 percent of warning signs and 75 percent of stop signs were evaluated correctly. This means the observer made an accurate and reliable decision to replace a sign when compared with the numerical measurement of a retroreflectometer.

The study concluded that because of “the sensitivity of the eye, the observer cannot be totally accurate,” however, “the trained observer can make accurate and reliable decisions to replace signs.” Several factors that could improve the accuracy of sign evaluators, such as driving in pairs, incorporating a sign management system, and cleaning signs, were also included (14).

4.2 Mobile Measurement

The Federal Highway Administration has a prototype van able to measure retroreflectivity while moving at highway speeds. It is known as SMARTS, or Sign Management and Retroreflectivity Tracking System. Handheld devices require the user to physically stand next to the sign and the hold the instrument directly against the sign; the SMARTS allows signs to be measured from the van while it is moving at normal highway speeds. The van uses a calibrated strobe lamp, mounted on top to bounce light off highway signs. The returned light is processed by computer to account for observation, angle, and distance, and is then measured and compared to guidelines (15). The van evaluates up to 153,000 pixels; with a handheld, 1 shot is equivalent to 1 pixel.

The van is a standard club wagon that has been modified to fit the equipment. The equipment includes a turret mounted on top of the van, which houses a xenon flash tube (a basic airport runway light), a laser range finder, and 3 cameras (2 black and white - a 75 mm for smaller signs and a 50 mm for larger signs - and 1 color camera). The van also includes a pan tilt mount to rotate the flash unit, a computer system, a monitor, image processing and image capture cards, and a GPS unit. The entrance angle of the light from the flash tube cannot be controlled but the observation angle is maintained at 0.2 degrees. The picture taken by the black and white cameras is equivalent to what the driver's eye would actually see at night. Handheld retroreflectometers that are placed directly next to a sign do not reflect what driver sees (the driver's entrance angle).

Two people are required for operation of the van, a driver and an operator. The operator views the road on a computer screen and uses a mouse to locate a roadway sign with a pointer. The system will track the designated sign and at 200 feet, flash a light and perform retroreflectivity calculations. The data the van collects are input into a database that includes a digital color picture of the signs, average retroreflection values for the background and legend colors, location (GPS coordinates), speed of the van, date, and time. The average, high, and low retroreflectivity values for the sign are also given.

There are two software programs used in conjunction with the van. One is recognition software designed to look for retroreflective objects with sharp edges (sometimes backs of trucks and license plates can interfere). The other program, Sign Evaluator Software, is for analyzing the data. Data can be exported to Lotus or Excel.

The van can operate in daytime hours only (but it measures what the driver would see at night). It cannot be operated in inclement weather and rough road conditions make aiming difficult. Measuring multiple signs in a row is difficult because a successive sign closer than 200 feet falls beneath the tracking range distance. Also, the software is set to look for the brightest signs, which is not ideal because out of a group of signs, the one needing replacement is the one missed. When left, right, and overhead signs are located at the same distance, multiple passes would be required to get all of them, which could prove to be very costly. The current software is only designed to run on a 200 Mhz processor.

The actual cost per mile to run the van is unknown. The cost of the current van and all of the equipment and software was about $210,000. This does not include continuous maintenance and upgrades. This van is several years old and to reproduce the same van today would cost a considerable amount more. Finite data validating the accuracy and repeatability of the van are not yet available; it is being sent for a review by HITEC in August of 2001 for a complete evaluation.

3M is also developing a mobile retroreflectivity measurement van that utilizes a laser retroreflectometer. It is based on a handheld model they have developed that uses a blue laser, but it can only read beaded sheeting; the laser cannot pick up prismatic sheeting or blue colored sheeting. They are currently upgrading their technology to enable it to read all colors.

In addition to the van development and sheeting technologies, 3M also provides a sign management service. It is a turnkey management service where they contract a local private company to measure a state's signs. The sign information gathered is then input into an inventory system. Predicted modeling is used to determine when a sign's retroreflectivity will expire and the sign should be replaced. The computer system then notifies the state when certain signs should be replaced. Limited information is available regarding the 3M van and sign management service because they are still in development.

4.3 Hand-Held Retroreflectometers

Hand-held retroreflectometers are instruments capable of measuring the retroreflectivity of signs. They are relatively small, ranging in size from about 40 to 90 square inches and weighing around five pounds. They can be transported easily in the field; most available units are equipped with rechargeable batteries, some which are able to be charged in as little as 15 minutes. Currently, there are several different models available with varying capabilities. The underlying function and principles behind each instrument are the same. When placed directly against the sign, the instrument emits a beam of light and measures the amount of reflected light returned from the signs sheeting. The unit can be operated by one person but may sometimes require an extension pole to reach tall signs. The operator must be positioned in front of a sign and be able to place the unit directly against the sign sheeting surface.

It is necessary for retroreflectometers to be calibrated for each sheeting color and type before use in order to maintain accuracy. Most models come with a calibration standard with known retroreflectivity levels, which are used to test the instrument at a time interval determined by the manufacturer. The reference standard is supplied by the manufacturer in a storage case that is never to be carried to the field where it may be altered by uncontrolled conditions. Some models have calibration services available upon request.

Some models require a separate calibration standard for each sign color. "Although the retroreflectometer is an objective method, it can be expensive and time-consuming. As many as 60 measurements may be needed to evaluate the retroreflectivity of a large sign; frequently a lane of traffic must be closed to do so" (16).

Some units are capable of data collection, storage, and download; the storage capacity varies from unit to unit. Stored measurements can later be downloaded to a computer. However the number of measurements held by the instruments is sometimes limited to a little more than 1000 for some models. If at least four measurements are taken per sign, then only about 250 signs can be measured before the data will need to be downloaded into a computer. Retroreflectometers cost about $9,000, although this varies among manufacturers.

An evaluation of the cost, accuracy, and performance of six retroreflectometers is currently underway by the HITEC division of the Civil Engineering Research Foundation (CERF). A report with their evaluation findings is expected for release in the fall of 2002.

5.0 INFORMATION MANAGEMENT

The State of North Carolina has approximately 384,000 signs on Interstate and primary roads and approximately 616,000 signs on secondary roads. Collecting data about each sign - location, retroreflectivity, and installation date, for example - could prove to be a very arduous task. There seems to be a need for information about signs to be gathered and recorded, but the question of how to manage all of the desired information needs to be answered.

The amount of data that can possibly be generated from almost 1 million signs is quite extensive. There are several different information management tools that could assist with the task of managing those data. Geographic Information Systems (GIS) and sign inventories are two management tools that could possibly be useful to the State of North Carolina.

5.1 Geographic Information Systems and Global Positioning System

Geographic Information Systems, or GIS, are "computer tools for analyzing spatial data". GIS link database information with spatial or map information. They can act as a tool for analyzing spatial data, as an information system, or many other things (17). GIS are "rapidly becoming the technology of choice for managing and presenting roadway inventory data" (18).

GIS could be very beneficial to retroreflectivity measurement and sign management. A database containing spatial data and other information about signs, such as retroreflective values or sheeting color, could be used to generate maps showing deficient sign areas. Several sign management software programs have GIS components integrated in the system to more effectively manage data.

The North Carolina Department of Transportation has a Geographic Information Systems Unit. Their goals include providing and maintaining a comprehensive road configuration and attributed digital database and providing GIS, Mapping, and Road Inventory services to the North Carolina Department of Transportation.

The Boulder County Road Maintenance Department in Colorado used ArcPad GIS software loaded onto pocket-sized computers to collect sign data to populate an inventory. Their efforts resulted in reduced paperwork, data entry errors, and employee mileage for sign replacement. It is estimated that each of the three sign technicians employed by their Road Maintenance Sign Shop save one to two hours a day which can be spent performing other maintenance tasks. The time savings due to the elimination of data entry from paperwork is approximately two hours per week. They spent only $3,500 to implement the procedure and received a savings of over $20,000 a year (19).

A study is being conducted by North Carolina State University to investigate the possibility of integrating sign attributes with the existing linear reference data using GPS co-ordinates (20). Linking sign data, such as retroreflectivity data (quantitative or qualitative), to GPS co-ordinates and using the data in conjunction with a GIS could significantly reduce the labor and cost of maintaining signs. A sample inventory will be created as part of the project to evaluate the labor, time, and cost involved and will be discussed and evaluated in later Section 9.2.3.1.2 (20).

A GIS could be very beneficial to NCDOT in maintaining and tracking in-place signs. A GIS would allow many different types of attribute data to be linked to any one sign, including data such as location (which could take many different forms, including GPS co-ordinates or mileposts). The feasibility of using GIS and the potential costs and benefits to NCDOT will be discussed later.

5.2 Sign Inventories

A sign inventory is one part in the overall sign management process. A sign inventory can serve many purposes other than keeping a record of what signs are located where. Additional benefits provided by a sign inventory include targeting signs for replacement, identification of problems, minimizing tort liability, planning and budgeting for sign replacement, and maximizing productivity (4). Sign inventories also help agencies identify if a sign is missing during a visual inspection of a road section.

As part of a study, the Texas Transportation Institute (TTI) conducted a survey of state transportation agencies to evaluate their individual sign management methods. Of the 30 states surveyed, 13 used a computerized sign management inventory system (21). Benefits and obstacles associated with implementation and maintenance of a sign inventory system were not included in this or any other current studies.

A sign inventory can be comprised of an unlimited amount of data, depending on the users needs. Signs have many attributes and characteristics that could be captured by a sign inventory. Unlimited amounts of data can be attributed to a single sign. When creating a sign inventory, the first decision to be made is what data elements should be included about the inventory population.
Hawkins et al. (21) asked surveyed state agencies to determine "what type of data is (SIC) recorded in [their] sign inventories" if they have one. The following list is a portion of the results of this survey question.

- Location
- Orientation
- MUTCD sign number
- Installation date
- Maintenance times
- Unique sign number
- Type of sheeting
- Predicted retroreflectivity
- Type of maintenance
- Substrate material
- Date of last inspection
- Post condition
- Mounting height
- Date of manufacture
- Measured retroreflectivity
- Digitized image of sign
- Sign condition

Sign attributes range from describing the location and condition of the sign to inspection dates and mounting heights. However, the more attributes, the more time and labor (and therefore cost) associated with collecting all of the information.

5.2.1 Sign Management Systems (SMS) and Sign Inventory Management Systems (SIMS)

A sign management system, often referred to SMS, provides a complete sign management program encompassing the life cycle of a sign. "A management system can be defined as an integrated and coordinated set of policies, procedures, methods, and tools that assist decision makers in providing a product in a serviceable condition in the most cost-effective manner" (4). A well-implemented sign management system will identify worn-out signs, minimize requirements for field inspection and inspection costs, plan and budget resources properly, be usable as a liability defense, track problem areas, and anticipate future need (3).

"A sign management system should, therefore, be able to predict, or estimate, the remaining service life for every sign, based on the particular factors and data related to each individual sign" (14). However, in addition to being able to identify signs that are no longer reflective, NCDOT notes that a sign inventory is also helpful in identifying signs that are missing, which are just as critical as signs with poor retroreflectivity. Some benefits of developing and maintaining a sign management system as stated by previous research by TTI (21) are:

- Allows an agency to predict service life of individual groups of signs along a stretch of roadway.
- Reduces the likelihood of tort liability claims by increasing the likelihood that signs meet the values, by providing documentation of conditions existing at the time of the accident, and also by illustrating an agency's efforts to improve a given situation. An added benefit (at least for agencies that are not self-insured) is that some insurers recognize the value of an agency having a sign inventory system. For example, the Utah Risk Association reduces premiums by 3 percent for agencies that maintain a sign inventory.
- Allows an agency to identify problem locations. It can help to identify repeat vandalism locations. This information can help in knowing when to use vandalism-resistant hardware or other counter-measures.
- Allows an agency to mange traffic control devices in a more efficient manner because of better planning.
- Permits an agency to respond to citizen complaints or questions more effectively.
- Allows an agency to utilize personnel more effectively.
- Allows an agency to better evaluate risks.
- Saves management time.
- Saves field personnel time.
- Allows an agency to develop contract quantities and provide description and location (including map) for contractor.
- Allows an agency to better organize and distribute project assignment to work crews.
- Allows an agency to be able to determine the correct quantity needed when purchasing materials, and possibly allows an agency to buy greater quantities at one time, thus allowing for additional savings.
- Allows an agency to estimate the amount of material that will be available for recycling.
- Reduces paperwork, especially if used as part of a closed-loop system.

"When fully developed, a comprehensive Sign Management System can effectively manage various activities that take place during the life cycle of highway signs from purchasing of materials or fabricated signs through the sign's service life and eventual replacement and recycling" as illustrated in Figure 5.1.

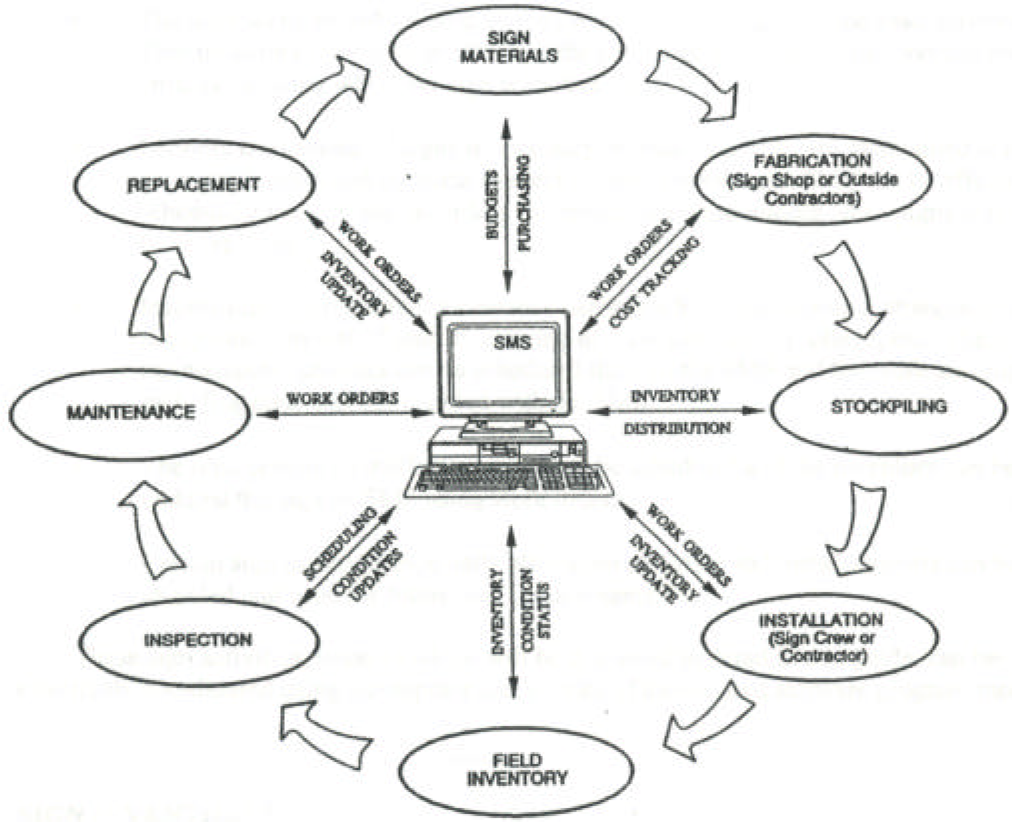


Figure 5.1: Integration of Signing Activities Through a Sign Management System (4)

The outer arrows of the figure follow the actual movement of a sign through an agency. Each oval represents a phase in the life cycle of a sign. The two-sided arrows within the circle show what information is transferred to and from the Sign Management System during each phase of the life cycle. For example, during installation, work orders are issued to notify a sign crew or a contractor that a sign needs to be installed. In turn, the sign is removed from the warehouse inventory, and entered into the field inventory presumably with characteristics such as location and installation date. Different information is entered and retrieved from the Sign Management System during every step in the life cycle of a sign.

When fully integrated, all aspects of sign management, beginning with raw materials and fabrication in the Sign Shop, continuing through installation and the complete life cycle of a sign, ending with replacement are encompassed by a Sign Management System. Figure 5.1 is very similar to Figure 3.1, which outlines the life cycle of a sign in North Carolina. Components from Figure 3.1, such as storage, installation and labeling, and 'replaced with new sign' correspond with stockpiling, installation, and replacement, respectively, in Figure 5.1. A computer system could link the entire life cycle of a sign in North Carolina.

In addition to Sign Management Systems, there are also a wide variety of Sign Inventory Management System (SIMS) programs available. A SIMS, as opposed to a SMS, encompasses only the inventory management aspect of signing. A SMS, as shown in Figure 5.1, includes all aspects of signs, beginning with fabrication and continuing through destruction or replacement. According to the ITE Traffic Signing Handbook, " a sign inventory will form the core of such a [sign management] system" (22).

Some SIMS are well developed, web-based programs that integrate GPS technologies; others are simple, user specific programs custom tailored to a particular region's needs. Although the primary function of these programs is to provide an accurate account of quantity and locations of signs, the assembly of information presents opportunities for more detailed information on each sign, such as whether or not it meets forthcoming requirements.

Whether the NCDOT is interested in implementing either a complete SMS or only a SIMS depends on the amount of time and money available to devote to either program. The extent to which the system can benefit NCDOT is also a strong factor in their decision to adopt such available technologies.

5.2.1.1 SIMS Software Assessment

There are many off-the-shelf software inventory management systems available. It is very possible that some of this software might be appropriate for NCDOT to adopt for their sign inventory management purposes. In order to assess whether any of the current software available might meet NCDOT needs, a thorough knowledge of the existing programs is needed. A software assessment of most existing sign inventory management software was performed by North Carolina State University (37). A complete copy of the assessment is located in Appendix I. This section summarizes the findings of the assessment.

All of the programs can be categorized as a SIMS even though some are advertised as an SMS. No software was found to be capable of managing every element of the complete sign life cycle as depicted in Figure 5.1. All software identified concentrate on in-place sign inventories only. Originally, fifteen programs were identified; however, eight of those were eliminated from the evaluation for reasons such as products no longer being available or designed to run on outdated operating systems and equipment. Table 6 contains the seven software programs evaluated in the assessment. In the table, each software is given an identification number, lists the name of the software, the company that manufactures the software, and the location from which information about the software was retrieved.

Table 6: SIMS Software

No.	Software Name	Company	Information Source
1	SIGN*view*	CarteGraph Systems, Inc.	http://www.cartegraph.com
3	VIMMS	Vulcan, Inc.	http://www.vulcaninc.com
4	Sign Inventory and Replacement	3M	http://www.3m.com/us/safety/tcm/solutions/prg_sms.jhtml
5	SIMS99	UNH T2 Center	http://www.t2.unh.edu/pwms/
6	SIGNMASTER™	MasterMind Systems, Inc.	http://www.mastermindsystems.com
9	TOSSSI		MCTRANS, 99-00 Catalog, p 23
15 *	FHWA Sign Management System	FHWA	[McGee and Paniati 1998]

*Evaluated based on summary information in the Appendix of Reference (4)

Six sets of quality parameters were used to evaluate the requirements and features of each software and assess how ready each SIMS was for use. The quality parameter sets were:

- Data Matrix – determines what data attributes of a signs the software can store
- Data Acquisition, Input, and Exchange – provides information about how field data is collected, input to the system, analyzed to answer questions, and communicated among users
- System Functionality – evaluates capabilities of software (i.e. replacement forecasting, data analysis, priority replacement analysis, customization)
- System Requirements – determines the hardware, software, and supporting accessory requirements for installation and operation of the software
- Costs and Technical Support – determines costs to run, maintain, and update the software and the availability of technical support and training
- Ease of Use – evaluates user-friendliness of the system based on interface design

A table for each quality parameter was created to evaluate each parameter for each software. The assessment concluded the following facts from each data parameter table.

- Data Matrix

All software packages are able to store location, installation date, sign type, size, facing direction, substrate material, sheeting information, survey date, sign condition, and work history. Sign Inventory and Replacement enables the use of video to record sign information, extract that information automatically, and inputs that information into system automatically. All packages except SIMS99 and FHWA SMS incorporate the use of picture. All packages store sign condition; however, only four out of seven packages are designed to store retroreflectivity readings. All packages allow for customized data attributes. The assessment concluded that there was no significant difference between software packages from the data item point of view. However, it is important to note that only four of the seven packages store retroreflectivity readings if NCDOT plans to generate numerical retroreflectivity data for input.

- Data Acquisition

Location information can be either acquired using GPS or manually. Sign Inventory and Replacement uses videotape to record and extract sign information; all other packages require users to get sign information manually (i.e. facing direction, dimension, type, etc.). All software packages enable the generation of customized reports.

- System Functionality

All software packages support replacement forecasting analysis. Only VIMMS and FHWA SMS have developed built-in default forecasting models, while still allowing for customization. Others support replacement forecasting in the way of letting users specify replacement conditions in the format of customized queries. All software packages support scheduling replacement and maintenance and focus on in-place sign inventory only. Additionally, *SIGNview* includes warehouse inventory. TOSSSI does not have a built-in sign library. It is also not able to perform real-time checking because it does not store retroreflectivity readings, only sign condition. Other packages have built-in sign libraries to allow users to click and select instead of typing everything into the system. All packages allow for limited customization and support recording work histories. It was concluded that except TOSSSI, all software packages demonstrate system functionality.

- System Requirements

All software packages are developed for Windows operating system. SIMS99 had the lowest requirement in processor (486 is good enough) and VIMMS had the highest CPU requirements (Pentium III 433 MHz or higher). All the others fall between these requirements. A CD-ROM would be a necessity to install all the software. Free space requirements are demanding because of the amount of sign information needed to be stored. SIGN*view* and VIMMS require supporting software. SIGN*view* requires supporting database management system. VIMMS requires a system module that is developed by the same vendor as VIMMS. No conclusions were drawn based on system requirements; all software with outdated system requirements were not included in the evaluation.

- Costs and Technical Support

The price for licensing ranges from free to $4000.00 (one time cost). SIGN*view* has the most expensive licensing cost ($4000.00) while SIMS99 is free. Only SIGN*view* and VIMMS have specified costs for updating. Sign Inventory and Replacement has update available, but no cost information is available yet. However, it is offering a one-pass program to take care of sign inventory and maintenance at the price of $11-12 per sign. SIMS99 has free updates. All others do not have updates. Only SIGN*view* provides training with a cost. For technical support, situations vary widely. It is obvious though, expensive commercial software packages have higher level of technical support.

- Ease of Use

All software packages have graphical user interface. SIGNview has a relatively complicated one while all others have relatively basic design. However, from the evaluator's point of view, all packages have easy to use interfaces. These interfaces are user friendly. There is no functional difference in user graphical interface design.

The software assessment did not identify one particular software that emerged as a champion above any other, it only evaluated the features and capabilities of several programs currently available, one or more of which NCDOT may find appropriate for their needs.

6.0 SIGNS AND SIGN PRIORITY

According to the ITE Traffic Signing Handbook, "for signing to be effective, it should follow a five-step process" (22): need and selection, design and fabrication, placement, maintenance, and management. This report focuses on maintenance and management aspects; however, it is necessary to have an understanding of basic sign categories and classifications.

There are three basic types of signs: regulatory, warning, and guide (22). "Regulatory signs inform the road user of a law, regulation or legal requirement." Some examples are stop, yield, speed limit, do not enter, and one-way signs.

There are three basic types of signs: regulatory, warning, and guide (22). "Regulatory signs inform the road user of a law, regulation or legal requirement." Some examples are stop, yield, speed limit, do not enter, and one-way signs.

Figure 6.1: Examples of Regulatory Signs

"Warning signs alert the user of a condition that may be hazardous on or adjacent to the facility"; this includes stop sign ahead, lane ends, merge left, pedestrian crossing, and intersection approaching.

Figure 6.2: Examples of Warning Signs

Finally, guide signs "provide directional or navigational information." They are mainly motorist's information signs including white-on-green directional signs and also blue information signs with information about services available at an exit, also brown and blue tourist and cultural signs.

Figure 6.3: Examples of Guide Signs

Signs are categorized into types, ranging from A through F (omitting C, what used to be Type C has now been integrated into Type B). Each of the sign types is shown in Table 7. The types are used by NCDOT to categorize signs according to size, which determines the mounting requirements. The types classify signs based strictly on size, which then determines mounting requirements and application. Type A and B are the largest, and type A is the most expensive per square foot.

There is no official or absolute listing of “critical” or “priority” signs, however, certain signs, such as stop and yield, are emphasized when educating division personnel. Application of a sign is more important than the category.

Table 7: Sign Types and Characteristics

SIGN TYPE	CHARACTERISTICS
A	Guide signs designed specifically for a need. Size greater than 144” x 48”. Z-bars on back for ground mounted supports or overhead mounting. Multiple aluminum sheets pieced together. Ex: Large green overhead signs.
B	These are the same as type A signs, however they only require one piece of aluminum substrate and less expensive. Size is less than or equal to 144” x 48”. Ex: Blue Logo signs
D	Mostly green, brown, and blue signs. Typically a small directional sign indicating a city name and a directional arrow on an exit ramp. Usually special designs created from dye cuts. Can be mounted on U-channel posts for cross - bracing on back. Ex: Green directional sign indicating a city name and a directional arrow
E	48” x 48” and smaller warning and regulatory signs. Usually screened and created in bulk for lower costs. These signs are most critical as far as placement. Ex: stop, one-way, and yield signs
F	Usually referred to as “F assemblies”. Ground mounted assemblies consisting of cardinal directions, shields and arrow panels. Stacked groupings of small signs mounted on U channel posts. These signs are usually screened. Ex. US highway route signs.

Source: NCDOT Signing Engineers

6.1 Placement

Sign placement is defined as the “longitudinal placement of a sign relative to its subject, and the lateral and vertical placement of the sign relative to the roadway”(22). The angle and height at which signs are placed affect how a sign is seen. The entrance angle of light into signs (the angle between the illumination action and the retroreflector axis) and the height at which a sign is placed, or the observation angle (the angle between the illumination axis and the observation axis) both affect how a driver perceives a sign. Trucks and cars do not see the same thing because of height difference; a truck may see a brighter or dimmer sign based on the fact that his headlights are at a higher level and creating different entrance angle of illumination than that of a car’s headlights at a lower height.

This should be taken into consideration by sign installers when placing signs. Simply, tilting a sign towards or away from a road can affect the level of intensity reflected back by a sign. However, a field study conducted by the Louisiana Department of Transportation and Development showed “no clear links between factors such as proximity to the road, or sign orientation to a premature deterioration of sign sheeting material” (23).

6.2 Cost of Signs

The cost of signs varies depending on factors such as size and sheeting grade. A national survey reported that the average cost of sign fabrication in cities is $54 per sign and in counties $68 per sign (1); these figures include material, labor, and equipment costs. The model considered signs costs based on engineering or high performance grade sheeting material, transportation costs, the amount of labor, and the hourly cost of labor.

Signs in North Carolina are less expensive to manufacture because of the cheap prison labor used to create them. A stop sign manufactured by the Department of Corrections costs the NCDOT $17.82. Sign costs vary by size, manufacturing method, and sign sheeting grade. Larger signs obviously require more material. Common signs, such as stop and yield, are produced in mass by a screen painting, but specific signs, such as a unique exit sign, is made by hand-pressing letters from die cuts, which is a slower, more labor intensive (and therefore more expensive) process. And different grades of sheeting cost different amounts. Engineer grade sign sheeting, which is most used by NCDOT, costs around $0.70 per square foot. High intensity and diamond grade sheeting are more expensive at $2.00 and $4.00 per square foot, respectively.

Causes of sign replacement include poor retroreflectivity, knockdown, and vandalism (1). As previously mentioned, replacing vandalized signs accounts for over half of sign expenditures in some North Carolina divisions.

6.3 Number of Signs In North Carolina

At the start of this project, an unknown factor was how many signs there are in the State of North Carolina. One casual estimate estimated over 3 million, but an actual count and breakdowns by background color and road type were not known. Without an inventory or previous attempt at counting the signs, there is no definite way to estimate or calculate the number of signs in North Carolina.

Identifying how many signs the state has, along with what type, color, and where they are, can be beneficial when formulating sign maintenance alternatives. A technique that may be feasible and cost efficient for 1,000 signs may not be for 1,000,000 signs.

6.3.1 NCDOT GIS Mileage Data

Each year, the NCDOT Division of Highways Geographic Information Systems Unit publishes a Highway and Road Mileage report of the state. It contains roadway mileage data broken down by various categories, such as by county, roadway type, paved or unpaved, and others. The following mileage data was extracted from the January 2000 report (23).

Mileages for the three road types, interstate, primary, and secondary, are in Table 8. The glossary in the Highway and Roadway mileage report includes interstate within some of its primary road counts; however, that is not reflected in the following table. Rural is defined as areas beyond the corporate limits of municipalities and municipal is defined as within the city limits of an incorporated city or town (and is used interchangeably with the term urban in some tables). The Interstate category includes Interstate Business Loops, which are not official Interstate Highways but are designated as such for directional purposes.

Table 8: NC State Road Mileages (NCDOT GIS Systems Unit)

	RURAL	MUNICIPAL	TOTAL
INTERSTATE	821.10	262.09	1,083.19
PRIMARY	11,117.28	2,415.85	13,533.13
SECONDARY	59,168.18	4,298.88	63,467.06
TOTAL	71,106.56	6,976.82	**78,083.38**

6.3.2 Sign Count Data and Estimates

Several different sources were used to calculate a better estimate of signs in North Carolina, including a sign count study done specifically on North Carolina signs. An existing report and data from a NC highway division were also used.

6.3.2.1 North Carolina Highway Division 6

Highway Division 6 provided estimates of the number of signs on two-mile stretches of primary and secondary roads in the each of the five counties in their division. Two separate data sets were collected from each type of roadway: interstate, primary, and secondary. The sign erectors in each of the counties listed randomly selected the routes. The data from each of the two samplings are in the Tables 9, 10, and 11.

Table 9: Highway Division 6 Primary and Secondary Route Sign Count Data Set #1

	PRIMARY		SECONDARY	
COUNTY	**ROUTE**	**# of SIGNS**	**ROUTE**	**# of SIGNS**
BLADEN	US 701	70	SR 1150	34
COLUMBUS	US 701	248	SR 1005	41
CUMBERLAND	NC 53	57	SR 1006	41
HARNETT	US 421/NC 27	116	SR 1532	110
ROBESON	US 74	126	SR 1003	27
TOTAL		**617**		**253**
AVG.PER MILE		**61.70**		**25.30**

Source: (20)

Table 10: Highway Division 6 Primary and Secondary Route Sign Count Data Set #2

	PRIMARY		SECONDARY	
COUNTY	**ROUTE**	**# of SIGNS**	**ROUTE**	**# of SIGNS**
BLADEN	NC 37 BUS	132	SR 1150	62
COLUMBUS	US 701 BUS	91	SR 1916	56
CUMBERLAND	NC 24	274	SR 1006	41
HARNETT	US 421	163	SR 1793	53
ROBESON	NC 41/211	168	SR 2104	52
TOTAL		**828**		**264**
AVG.PER MILE		**82.8**		**26.4**

Source: (20)

Table 11: Highway Division 6 Interstate Count Data

	INTERSTATE	
COUNTY	**ROUTE**	**# of SIGNS**
ROBESON	I-95 NB	79
ROBESON	I-95 SB	74
TOTAL		**153**
AVG. PER MILE		**38.25**

Source: (20)

Once the data was collected, the average number of signs per mile by roadway type was then established by dividing the number of signs counted by 10 miles (5 counties, 2 miles each). Comparing this data with the GIS Highway and Road mileages yields the sign quantity estimates in Table 12.

Table 12: Sign Count Estimate Based on Data from Division 6

	TOTAL MILES	AVERAGE SIGNS PER MILE	TOTAL SIGNS
INTERSTATE	1083	38	41,154
PRIMARY	13,533	72*	977,759
SECONDARY	63,467	26*	1,650,142
TOTAL	78,083	-	**2,669,055**

* Average of the two data sets provided.

A rough estimate of 2,669,055 was generated based on sample sign counts and state GIS mileage data. This estimate does not provide any information on sign color, type, or condition (retroreflectivity).

6.3.2.2 NCHRP Report 346

National Cooperative Highway Research Program (NCHRP) Report 346 “Implementation Alternatives for Sign Retroreflectivity Standards” (1) provided estimates for sign population per roadway mile. These estimates are contained in Table 13. Their estimations are based on a survey distributed to 790 counties, 85 cities, and 50 states. Data from these sources was also collected regarding sign population per capita, however, this information was not considered in this report.

Table 13: Sign Population Per Roadway Mile

	CITY	COUNTY
Regulatory Signs per mile	18	4
Warning Signs per mile	10	4
Guide Signs per mile	1	3
TOTAL	**29**	**11**

Note: Street name and parking series signs not included.

Comparing this data with NCDOT GIS Highway mileage estimates yields the sign estimates in Table 14. Although North Carolina does not maintain municipal signs unless the service has been contracted to the state, the total county and city signs per mile is considered state-maintained for the purpose of this estimate; using only the county figures does not produce a reasonable estimate.

Table 14: Sign Count Estimate Based on Data from Additional Source

SIGN TYPE	TOTAL MILES	SIGNS PER MILE	TOTAL SIGNS
Regulatory Signs	78,083	22	1,717,826
Warning Signs		14	1,093,062
Guide Signs		4	312,332
TOTAL			**3,123,220**

Using a combination of municipal and county data yielded an estimate of 3,123,200.

6.3.2.3 North Carolina Sign Count Studies

Two independent studies to determine the number of signs on North Carolina's Interstate and Primary routes were performed by North Carolina State University. The goal of the studies was to formulate an accurate estimate of the number of state maintained signs in North Carolina categorized by background color and roadway type.

The first study collected sign count data on continuous interstates routes, US Routes and North Carolina Routes. This included interstate interchanges (exit and entrance ramps) and mile markers. The second study collected sign count data from rest areas, welcome centers, visitors centers, and weigh stations on Interstates, US Routes and NC Routes. It also included all signs on the state secondary road system.

As signs were counted, they were categorized by background sheeting color. Stop signs were considered separately from all other red signs because they are considered very critical. Signs were also divided according to road type, either urban or rural. Urban roads are defined as "areas that have populations of 5,000 and up" and rural roads are defined as "all areas beyond the corporate limits of municipalities" and "all municipalities of under 5,000 population" (24). The second sign count, which encompassed secondary roads, broke down rural roads in Type I Rural and Type II. Type I Rural secondary roads are located in counties with population densities less than 525 persons per square mile. Type II Rural secondary roads are located in counties with population densities greater than 525 persons per square mile.

The sign counts were done on randomly selected stretches of road across the state. A sign density for each road type and background sheeting color was calculated by dividing the number of signs counted by the number of miles driven. The sign densities were then multiplied by NCDOT GIS roadway mileage counts. Table 15 contains a total sign count for Interstate, primary, and secondary roads in North Carolina. Rest areas, welcome centers, and visitor's centers are abbreviated RA, WC, and VS respectively. The calculations may differ by one in some columns and rows due to rounding.

Table 15: Sign Count Totals for Interstate, Primary and Secondary Roads in NC

	Road Location	Background Sign Sheeting Colors								Totals
		Blue	**Yellow**	**Green**	**White**	**Orange**	**Brown**	**Red**	**Stop**	
Interstates	Rural	1928	1421	4844	2104	900	53	0	0	11,250
	Urban	1345	821	3240	1085	232	61	0	0	6784
	RA&WC	230	50	0	770	0	0	290	0	1340
	Interchanges	1997	694	897	3385	542	51	2370	694	10,630
	Weigh Stations	32	76	96	288	0	0	56	40	588
Interstate Total	**-**	**5533**	**3063**	**9077**	**7632**	**1674**	**165**	**2716**	**734**	**30,592**
US Routes	Rural	4995	22,296	9522	49,855	1915	639	10,979	0	100,200
	Urban	6165	8956	8311	51,261	1716	849	3159	31	80,448
	RA&VC	63	0	21	189	0	0	84	21	378
	Weigh Stations	0	0	0	4	0	0	2	0	6
	US TOTAL	*11,223*	*31,252*	*17,854*	*101,309*	*3631*	*1488*	*14,224*	*52*	*181,033*
NC Routes	Rural	2417	40,054	9108	60,787	3031	1304	1235	823	118,758
	Urban	7854	13,991	3324	40,020	2160	567	2003	0	69,919
	RA	1	0	0	11	0	0	4	2	18
	NC TOTAL	*10,272*	*54,045*	*12,432*	*100,818*	*5191*	*1871*	*3242*	*825*	*188,696*
Primary Total	**-**	**21,495**	**85,297**	**30,286**	**202,127**	**8802**	**3359**	**17,466**	**877**	**369,709**
Secondary	Type I Rural	3238	213,190	20,509	107,405	4318	1619	1619	43,717	395,615
	Type II Rural	1403	33,722	1143	30,709	935	104	883	5716	74,615
	Urban	7695	38,647	6233	82,410	4772	1204	3611	1634	146,206
Secondary Total		**12,336**	**285,559**	**27,885**	**220,524**	**10,025**	**2927**	**6113**	**51,067**	**616,436**
TOTAL		**39,364**	**373,919**	**67,248**	**430,283**	**20,501**	**6451**	**26,295**	**52,678**	**1,016,739**

Table 15 is divided into sign totals by each interstate, primary, and secondary road type based on each background sheeting color. The primary division includes both US routes and NC routes. Each individual section and the total section at the bottom of the table, gives a total for rural and urban roads separately, then an overall total for all signs.

According to these sign count studies, there are just over 1 million signs on North Carolina roads. The greatest number of any color of sign is white, which include regulatory signs such as Keep Right, and No Left Turn; they account for approximately 40% of the total, with yellow being number two with 38%.

There were approximately 52,000 stop signs, the most critical of all signs. This is only about 5% of all signs. Although this seems low, the fact that interstates do not have stop signs (with the exception of rest areas and access ramps) and most primary routes are controlled by traffic lights must be taken into consideration. Red (including stop), yellow, and orange signs, which are considered critical to driver safety, represent 8, 38 and 2% of the total sign population, respectively.

6.3.2.4 Comparison of Sign Estimate Studies

Table 16 contains the totals from the various sources of sign estimate data. There is a considerable difference between each estimate.

Table 16: Comparison of Sign Estimate Studies

SOURCE	INTERSTATE	PRIMARY	SECONDARY	TOTAL
NC Highway Division 6	41,154	977,759	1,650,142	2,669,055
NCHRP Report 326	-	-	-	3,123,220
NC Sign Count Studies	30,592	353,469	616,436	969,905

In the beginning of this report, it was estimated that there were over three million signs in place on North Carolina roads. However, this was a rough estimate and not based on any study or methodical method. The calculations formulated using the sign density estimates provided by Highway Division 6 and extracted from NCHRP Report 346 calculate numbers close to three million. The estimate formulated by independent study generated an estimate of less than one million. However, because the independent sign count studies were the most detailed and specific to North Carolina roads, it is used for all further sign count estimate assumptions for the remainder of this report.

6.3.3 Percent of NC Signs Potentially Not in Compliance Upon Implementation of Standards

As stated earlier in the literature review, it was reported by McGee that 5.5% of existing signs would not be in compliance when the standard is implemented (3). That figure was based on the information in Table 17.

Table 17: Percent of Signs Not Meeting Retroreflectivity Standards Upon Initial implementation of Standards

		Jurisdiction		
Sign Group	**Sheeting Color**	**State**	**Local**	**Combined**
Group 1	Yellow (background)	3.01	9.51	8.77
Group 2	White (background)	3.68	6.86	4.40
Group 3	White (legend)	1.67	3.44	2.11
	Red (background)	4.31	7.81	5.15
Group 4	White (legend)	3.77	5.81	4.13
	Green (background)	9.61	2.90	8.46
All Signs	Legend	2.31	3.98	2.69
	Background	4.48	8.00	5.48

Source: (3)

Table 18 estimates how many of signs in North Carolina will potentially not be in compliance. The data is based on sign count estimates from the North Carolina Sign Count Studies and the data in Table 17.

Table 18: Number of NC Signs Potentially Not Meeting Retroreflectivity Standards Upon Initial Implementation Standards

	Background Sign Sheeting Color				TOTAL
	Yellow (8.77%)	**White (4.40%)**	**Red (5.15%)**	**Green (8.46%)**	
Interstate	269 (3062)	336 (7632)	140 (2716)	768 (9078)	1,513
Primary	7,749 (88,359)	7,171 (162,997)	1,039 (20,182)	3,330 (39,634)	19,289
Secondary	25,043 (285,559)	9,703 (220,524)	315 (6,113)	2,359 (27,885)	37,420
TOTAL	33,061	17,210	1494	6457	58,222

KEY: 54 (4582) = Percent of signs not in compliance (Total number of signs)

According to Table 18, approximately 58,000 signs in North Carolina will not be in compliance with the standards when they are implemented. This estimate is 6.0% of the total estimated sign population in the state. The report did not indicate whether these percentages were for roads on which any type of inspection had been performed. If not, it can be assumed that the percentages on North Carolina roads would be considerable lower because of visual inspection procedures.

7.0 LIABILITY

One of the main concerns of state DOT's is that the implementation of standards for minimum levels of retroreflectivity in the MUTCD could place the states in positions where they are held liable for accidents. Statistics from the National Highway Traffic Safety Administration reveal that in 1999, there were 286,000 crashes due to stop sign issues alone nationwide (25). The ITE Traffic Sign Handbook states, "if signing is done improperly, longer response times, inappropriate responses or errors will result, all of which adversely affect safety" (22). A report by the FHWA reveals that the risk of dying in a crash at night is nearly three times that of dying in the daytime (10). It is imperative that a finite sign testing and replacement program be outlined and implemented by the NCDOT to significantly reduce the risk of liability.

Before the possibility of minimum retroreflectivity standards, basic sight assessments to determine whether a sign still had adequate reflectivity were sufficient (14). Now that numerical standards are going to be implemented, the steps or measures now acceptable to reduce the liability to the state in case of an accident are a concern. A special provision in the state budget that went into effect on June 30, 2000 raised the tort claim liability limits from $150,000 to $500,000 (26). The possibility of an increase of the maximum claim amount from $500,000 to $1 million has increased the concern even more. Conducting and maintaining an inventory of devices, replacing devices at the end of their effective lives, knowing the laws relating to traffic control devices, and applying state traffic control device specifications and standards are four basic principles suggested by the ITE Traffic Signing Handbook to "significantly reduce tort liability lawsuits involving traffic control devices" (22).

7.1 Liability Literature

The ITE Traffic Sign Handbook states that results from a highway tort liability study in Pennsylvania "showed that signing deficiencies were cited as the principal factor in 2% of the sampled tort actions, second only to pavement deformities." When looking at accidents in which "a fatality or serious injury occurred, signing deficiencies ranked as the factor most often cited as the cause (41 %)" (22).

According to a report entitled, "Practical Guidelines for Minimizing Tort Liability", there are several elements that "must exist for valid tort action," one of which is the breach of a legal duty or negligence (27). This is defined as "the failure to exercise such care as a reasonably prudent and careful person would use under similar circumstances." The author also states that the "essence of negligence is the adequacy of performance." There are two ways in which negligence can be judged and that is either "wrongful performance (misfeasance) or the omission of performance when some act ought to have been performed and was not (nonfeasance)" (27).

Impact of Minimum Retroreflectivity Values on Sign Replacement Practices (Hawkins et al. 1996) performed a national survey and asked agencies if they expected "an increase in tort claim lawsuits as a result of the minimum retroreflectivity values." 65.5 % of the respondents replied yes, their agency expected an increase in tort claim lawsuits if the proposed values are implemented. The survey respondents claimed that "whether the retroreflectivity contributed to the accident or not, the lawyers will be aware of the minimum values and use them against the state." The same report also noted that although the fatality rate on Texas roads at night is approximately three times greater than that of day, sign retroreflectivity is "not the only safety issue related to nighttime driving" and in fact "no single causal factor can be attributed to nighttime accidents"(21).

7.2 NCDOT Liability Information

In North Carolina, cities and counties are covered by sovereign immunity, which means they are immune from liability for injuries arising out of governmental activities. But the state does not have sovereign immunity in accident cases because of the Tort Claims Act. According to Article 31, Chapter 143 of the North Carolina General Statutes, the state may be held liable in an accident case if there is proven negligence by a state employee (28). A driver cannot recover damages from an accident if they contribute to the collision (contributory negligence), which is failure to exercise reasonable care for their own safety. But, a passenger in the car or any individual involved in the accident not found negligent can still sue the state for damages.

According to the North Carolina General Statutes, Section 143-299.2, "the maximum amount that the State may pay cumulatively to all claimants on account of injury and damage to any one person arising out of any one occurrence…shall be five hundred thousand dollars ($500,000)" (28).

7.2.1 Tort Claims Records and Cost to State Estimates

There are thousands of tort claim cases filed against the State of North Carolina every year. The majority of cases are settled before they ever reach a trial; they are dropped, settled with the state, or settled with another party (29). Regardless of outcome, money and time is spent on every claim filed. The NCDOT has a team of six representatives who address all general liability claims (falls, signs, etc.) made against the state; their job is to intervene in accident cases. They investigate and identify possibilities of tort claims and resolve situations through mediation, paying for damages or whatever means necessary to prevent a lawsuit from being filed.

The docket section of the North Carolina Industrial Commission is responsible for placing assigned numbers on all claims against state agencies in which negligence is claimed against any named state employee, including the Department of Transportation. According to their records, between November 22, 2000 and October 30, 2001, 45 claims in which negligence was claimed against a DOT employee were filed. Cited reasons for claims ranged from car damage due to potholes to wrongful death claims; claim amounts ranged from $229 to the maximum allowable, $500,000 with an average claim amount of $193,764. A complete listing of the claims is in Appendix H.

Of the 45 claims, five directly cited sign maintenance related issues as the cause, and three more cases indirectly cited sign maintenance issues. Of these eight claims, six were dismissed and the outcome of the other two is not known. The claims were dismissed for reasons such as not naming a specific employee or failure to prove negligence. In one case, the plaintiff failed to prove that the act or failure to act by NCDOT was "an oppressive and manifest abuse," which is required in order to recover damages under the states Tort Claims Act.

According to the 1996 North Carolina Traffic Crash Facts, of 208,017 traffic crashes reported statewide, 30,430 involved signs (the exact manner in which the sign was involved was not specified). This includes 22,694 accidents occurring at stop signs, 997 at yield signs, and 996 at flashing signals with stop signs. According to the NCDOT Traffic Safety

Management Unit, of 220,502 crashes reported statewide in 2000, the “roadway contributing circumstances” for 381 of them was coded as “traffic control device inoperative, not visible, or missing (which could include signal or pavement markings as well)”(30). It is not know how many of these crashes involved serious injuries or fatality, which led, or could have led, to wrongful death claims.

Using the previously stated accident and claim facts, approximately 18% (8 out of 45) of accidents involving ‘not visible or missing’ signs will result in a claim against NCDOT. And there are always overhead and administrative costs associated with all claims regardless of outcome. Some amount of time and labor is devoted to every claim filed regardless of outcome however; this figure cannot be quantified. Although, all of the claims citing signs as the cause that were made during the specified time span were dismissed, there is always the potential threat of legal action which NCDOT should constantly prepare against.

7.3 Liability Prevention

To eliminate the risk of proven negligence on the state in the area of retroreflectivity and signs, it is necessary to develop viable alternatives such as a sign management plan or formal employee training and properly implement them. More important is the need to keep adequate record that the duties are being performed and to establish a quality control or periodic review to ensure they are being done correctly. *An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs* states, “an inventory is an essential tool for use in tort liability cases. It can provide evidence of the existence of a particular sign at a particular location and document the inspection or maintenance activity associated with the sign…some insurers have recognized the value of sign inventories in reducing liability” (4). If there were ever litigation questioning the adequacy of a sign, an inventory would be a record of when a particular stretch of road was ridden, which signs were deficient, and when they were replaced. If a sign is unable to be replaced at a certain time because of funding or some other reason, “complete written action should be made and filed for use in the event of legal action” (22).

Another report suggests “highway agencies can enhance highway safety and mitigate their exposure to tort liability by establishing a comprehensive risk management program. Management objectives are to make efficient use of available resources, such as money and people.” They also suggest the need for formal training programs, which “ improve workers’ awareness, attitudes, practices, and skills.” Including information about tort liability in the training program is also suggested as a tactic to improve employee effectiveness (31).

Performing night rides to establish which signs need to be replaced is the current NCDOT method of ensuring proper retroreflectivity of the state’s signs. Critical signs (e.g., stop, do not enter, yield) are replaced immediately, however, less critical signs may not be replaced right away due to budget constraints. This would not cause the state to be liable if an accident were to occur. In the case of Talian v. the City of Charlotte, the family of an accident victim claimed the state had a goal to install a needed sign in one year and did not do so due to a complicated bidding process. The court found that “budgeting and setting priorities within the constraints of budgetary limitations are elements of a municipalities exercise of discretion” (32).

The DOT should be aware of the risk of lawsuits. They are going to occur; many of the lawsuits filed are frivolous and have no grounds, but anyone involved in an accident that feels wronged is afforded the right to sue. Administrative and overhead costs necessary to process claims is essentially unavoidable and cannot be reduced or controlled.

The fact that there are going to be standards is a whole new impetus for someone to file a lawsuit. But records show that suits against the DOT are relatively rare; only 45 filed in an eleven-month period, the majority of which were dismissed. And of the cases filed, only 18% (8 of 45) cited signs as the contributing factor. And of those eight cases, at least 75% of those were dismissed (the outcome of the remaining two is unknown). However, NCDOT must maintain an organized sign maintenance and inspection system otherwise many lawsuits will be filed due to poor signing.

8.0 POSSIBLE ALTERNATIVES

The goal of this project is to determine, quantify, and present to NCDOT alternative approaches for meeting the proposed retroreflectivity standards. This goal was accomplished in three phases. The first phase was to develop as many alternative approaches as possible based on modeling the NCDOT system and existing literature. The second phase was to obtain feedback from the NCDOT on the list of proposed alternatives formulated by the research team. The final phase was a detailed evaluation of three to four alternatives chosen as a result of the feedback. The second and third phases will be discussed in later sections. The following section discusses the procedure used to accomplish the first phase, formulating alternative approaches, referred to henceforth as alternatives.

8.1 Components

Many different factors must be taken into consideration when attempting to formulate alternatives to address statewide compliance with the proposed minimum in-service values for retroreflectivity. Current organizational practices, availability of new technologies, cost and labor are some of these factors.

Before alternatives could be established, a list of components was created. Each component defines a small portion of an alternative; several components combined form a complete alternative. One component may be used multiple times; when combined with other components, many alternatives can be created. An extensive list of components was generated using information from the literature review and from brainstorm efforts by the research team. The following list represents all of the components generated and a brief explanation in no particular order. Components 3 and 17 were removed because they were duplicates.

1. Use current sign labeling system to determine sign age
All signs are currently stamped with a manufacturing date and have a sticker that indicates the installation date. The age of a sign can be determined by looking at these indicators. The stickers are easy to read and conspicuously placed. The manufacturing date of each sign is etched into the aluminum at a sign manufacturing plant, but it is inconspicuous and may be difficult to locate in the field.

2a. Establish a sampling method
Some sampling method would be chosen and used to select a sample of signs to perform one or more tasks on (evaluate, inventory, measure, etc.).

2b. Select a sample of signs
Any of the alternatives could be implemented on only the sample. This could help reduce cost and labor, yet still collect numerical data.

The following is a suggested ordering of signs by criticality from "Performance of Traffic Sign Retroreflectivity" (23):

1. Stop, Yield, and One Way
2. Regulatory and Warning Signs indicating hazards that prohibit or require an action or an adjustment in the traveled path. (EXAMPLE)
3. Other regulatory signs (EXAMPLE)
4. Other warning signs (EXAMPLE)
5. Guide Signs (Ex: Green overhead signs)
6. General Information Signs and delineators (Ex: Recreation Area Signs)

4. Conduct nighttime sign inspection by trained observers
This is the current method used by the North Carolina DOT. This procedure is described in more detail in the 'current procedures' section of the report.

5. Use model to predict when sign 'expires'
A sign expires when it no longer meets the proposed minimum retroreflectivity levels. A model could be developed to determine when a sign needs to be replaced based on the sheeting color and type or other designated factors.

5a. Perform study to associate sign age and retroreflectivity
Sheeting types come in many different colors and levels, each of which has a different 'expected life', or number of years before it no longer meets the minimum proposed retroreflectivity requirements. Manufacturers provide their estimates as to how long sheeting will meet requirement. However, some higher grades last well beyond these specified time frames. The state could initiate it's own study to compare the retroreflectivity levels of different color signs made of different grades of sheeting.

6. Measure retroreflectivity with handheld retroreflectometers
There are several models of handheld retroreflectometers available. They generate numerical data, which can be compared to the proposed values.

7. Contract sign services out
Sign maintenance, repair, and replacement could be contracted out to private services on competitive bid. Some companies currently offer total sign management services, including data collection and computer support. This component could possibly transfer the risk from the state to the contracted agency.

8. Compare measured and proposed retroreflectivity values
Any numerical retroreflectivity data collected from in-place signs will be compared with the proposed values.

9. Revise Sign Condition Survey Guidelines
The current sign condition survey guidelines could be updated to help divisions better conform with the proposed standards. More detailed instructions, including any new procedures and training, could be added and redistributed throughout the state.

10a. Develop sign inventory to collect sign data
This would let the state know what signs are where. This could be used to put signs on GIS maps, which could be used for many other things, like collecting statistics on signs to pinpoint areas of high turnover, vandalism, etc., where signs are poor.

10b. Expand current NCDOT warehouse computer sign inventory
Information about signs kept in NCDOT division warehouses is kept in the mainframe computer system. However, signs are removed from the system when they are placed in the field. The mainframe system could be expanded to include additional data fields for information about a sign once it is placed.

11. Integrate sign data and GIS
Data are collected by van or some other method. The data can be input into the current NCDOT GIS system. They can then be queried or sorted as below proposed values, near

proposed values, or above proposed values. The results could be downloaded onto a map showing signs that need to be replaced.

12. Make no changes and pay all potential tort claims
This component suggests that the state has some confidence in the current procedures and is willing to pay the potential claims that could result from signs potentially not meeting the proposed standards if litigation occurs.

13a. Use a retroreflectivity van to measure signs
A retroreflectivity van is able to measure and collect retroreflectivity and other data on signs while moving at highway speeds.

13b. Use computer system in van to collect sign data
Most mobile retroreflectometer vans contain a computer system that gathers data in a database as retroreflectivity is measured.

14. Use protective film in designated areas
Protective film that protects sign sheeting from vandalism could be used in designated areas, such as those with high vandalism (school zones) or areas where adverse weather affects sign sheeting (beaches and mountains) to help keep retroreflectivity values of signs in these areas above the proposed values for longer periods of time.

15. Use palm pilots to collect sign data
Using palm pilots, small handheld computers, during nighttime ride-bys would eliminate the use of paper to record sign data. Software could be developed that would allow data from the palm pilots to be downloaded directly into the North Carolina DOT mainframe.

16. (Re) Establish data submission system
According to the Sign Condition Survey Guidelines, data collected from nighttime ride-bys was to be submitted to the Road Maintenance Unit of NCDOT. However, this practice is now obsolete. The program was a way to monitor that nighttime rides were being performed and signs were being replaced in a timely manner. Re-establishing the program would serve as quality control to ensure signs are actually being replaced and as a statewide collection point for data to be generated into a report showing the states active attempts at compliance with the proposed minimum service guidelines.

18. Generate reports of measured/replaced signs
Keep record of all signs that are measured and replaced. Collect the information on a yearly basis to generate a statewide sign report. The report serves as documentation that an active effort is being made to comply with the proposed standards.

19. Create a certification program for sign inspectors
All sign inspectors are currently required to complete training before working in the field; however, training is left to the discretion of state highway divisions. According to a statewide survey of divisions, the training methods vary. Establishing a state certification program for all inspectors creates a uniform training program that each division follows. The training can still be administered at the division level; however, the certification program would outline exactly what should be covered. Only certified sign inspectors would be allowed to perform nighttime rides.

20. Establish financial incentives
Offer financial incentives to highway divisions with high percentage of compliance with proposed guidelines. Percent compliance could be established by a quality control check or using reports generated as a result of other components and alternatives.

21. Employ auditor(s) for quality control
Hire auditors, either internal or external, to perform statewide quality control checks on sample populations of signs to ensure divisions are meeting proposed standards.

22. Purchase computer equipment
Any computer equipment or software required to implement a strategy needs to be budgeted for and purchased.

23. Identify needed personnel
Many alternatives require new personnel or designation of existing personnel to new tasks. The appropriate personnel should be identified and their responsibilities outlined so that each alternative is being carried through.

24. Coordinate efforts with sign manufacturers
Some alternatives may involve collecting information or tagging signs beginning when they are manufactured. These efforts must be coordinated with the Department of Corrections Sign Shop in Bunn and any other manufacturers who supply signs to NCDOT. Steps may include coordinating computer records or adding steps to the manufacturing process, depending on the alternative.

25. Create maps of NCDOT signs using GIS
Use a geographic information system to create maps of NCDOT signs. (A location reference system, such as GPS coordinates, would be required to accomplish this component.) Sign characteristics, such as, color, size, and retroreflectivity value, could be associated with the signs in the GIS and plotted using different symbols. If the system could be updated consistently, the maps could display signs that need to be replaced. The maps could help sign erectors easily find signs and know all the needed information about the sign.

26. Create computerized version of Sign Condition Survey Report
This would allow the form to be used in a paperless format. The report could be loaded onto palm pilots or desktop computers. Having the report computerized would eliminate the need to manually enter information into the NCDOT mainframe computer.

27. Purchase handheld retroreflectometers
Handheld retroreflectometers allow retroreflectivity to be measured in the field. They are small units that can be carried on a truck and require only one person to operate.

28. Purchase retroreflectivity van/equipment
A mobile measurement unit such as a retroreflectivity van requires the purchase and assembly of a van and many different types of equipment and software including cameras, computers, and more. The van could be purchased solely for the use of the North Carolina DOT or in alliance with another state to share cost.

29. Rent/contract out retroreflectivity van services
Contract an outside company to be responsible for measuring and replacing signs. Because of the high cost of purchasing and assembling a retroreflectivity van, contracting out van services from a company could be a better option.

30. Administer sign observer training and refresher courses each year
Hold a yearly training session, either statewide or in each division, to review sign observer skills. Reviewing proper procedures, samples of different types and colors, and proper record keeping methods, could be some of the skills covered.

31. Contract out training program design and administration
Allow an outside company to facilitate the design and administration of statewide sign observer training.

32. Identify a uniform location reference for signs (mile markers, route numbers, CPS co-ordinates, etc.)
There is currently no location identification method for signs. A uniform reference system should be established throughout the state so that signs can continually be tracked using the method and so that all divisions are using the same reference method.

33. Download/enter data from field into NCDOT mainframe
All field data collected in palm pilots could be transferred into the NCDOT mainframe every day.

34. Specify minimum percentage of signs needing to be in compliance at all times
NCDOT should specify a percentage of each sign type that needs to be in compliance with the standards at all times. This standard could be used as a measurement for maintenance and replacement performance.

35a. Compare results of sample population to all signs
Data collected from only a sample of signs could be compared to all signs. This component would eliminate the need to measure every sign, but, it would require that information on all in-place signs to be recorded in order for a comparison to be made. For example, if all engineer grade yellow signs older than 7 years were no longer in compliance, the system would be able to identify all such signs in the field so they could be replaced.

35b. Replace signs with characteristics similar to signs replaced in sample population
Any signs in the entire population that have similar characteristics to signs that were replaced in the sample population, should also be replaced. It would be assumed that similar signs would need replacing at the same time.

36. Use a paper form to collect sign information
This is currently the method used to record information about signs needing to be replaced. Sign personnel use a standard form to record the message location and urgency of signs that need replacing.

37. Replace signs based on sign age
Compare signs solely based on how long they have been in-place. The estimated life spans of different retroreflective materials would be compared to the in-place life of signs to determine if they need to be replaced.

38. Replace signs whose legibility distances are less than MRVD
Use minimum required visibility distances (MRVD) as a determination of whether a sign needs to be replaced. Any signs not visible at or before the MRVD of that specific sheeting type would be replaced.

39. Replace signs that do not compare with visual samples
Use samples of 'good' sheeting to calibrate sign inspector's eyes before they perform nighttime rides. The samples act as a guide for inspectors to compare in-place signs against.

40. Replace signs identified by model as being expired
This component relies on a predictive model to alert NCDOT as to when a sign would no longer be sufficient. Signs identified by the model would be replaced.

8.1.1 Other Ideas

The following ideas were also considered as components but not included in the previous section for various reasons that are explained below.

- *Use higher sheeting grades*
  Although the goal of the proposed minimum maintained retroreflectivity level requirements is not to prompt use of higher, more expensive, sheeting grades, this option should still be considered. Using high intensity or even diamond grade sheeting on high priority signs, such as 'Stop' and 'Do Not Enter,' could result in longer sign life, a lower replacement frequency, and higher level of visibility for a longer time.

- *Utilize barcodes to track signs*
  A technology such as barcodes was identified in the proposal as impractical because of distance limits of barcode readers. In addition, barcodes is not a measurement technology, only a tool to facilitate tracking the signs for inventory/database purposes.

8.2 Component Categories

All components created were narrowed down; some were too broad and broken down, some were duplicates, and others were not needed. The narrowed components fit into one of three categories, each essential to creating a complete, well-rounded alternative. The categories are data collection/generation, record keeping, and decision-making. Any additional components not encompassed by one of these categories dealt with other issues such as equipment procurement, labor, or other subjects. The 'other' components not fitting into the three categories were considered during a more detailed alternative analysis after the NCDOT research committee reviewed the proposed alternatives. Table 19 shows the narrowed components and their respective categories.

Table 19: Narrowed List of Components and Categories

Component ID	Component	Measurement Method	Data Collection/Storage	Decision making	Other
1	Use sign labels to determine sign age	X			
4	Conduct nighttime sign inspection by trained observers	X			
5	Use model to predict when sign 'expires'	X			
6	Measure retroreflectivity with a handheld retroreflectometer	X			
7	Contract sign services out.	X	X	X	X
8	Replace signs with measured R_A value less than proposed retroreflectivity values			X	
10	Develop a sign inventory to collect sign data		X		
11	Store sign data in a GIS program		X		
13a	Use a retroreflectivity van to measure	X			
13b	Use computer system in van to collect sign data		X		
15	Use palm pilots to collect sign data		X		
16	(Re) Establish data submission system				X
19	Create a certification program for sign inspectors				X
20	Establish financial incentives				X
21	Employ auditor(s) for quality control				X
24	Coordinate efforts with sign manufacturers				X
29	Rent/contract out retroreflectivity van services				X
31	Contract out training program design and administration				X
33a	Download/enter data from field into NCDOT mainframe		X		
34	Specify minimum % of signs needing to be in compliance at all times				X
35a	Compare results of sample population to all signs	X			
35b	Replace signs with characteristics similar to signs replaced in sample population			X	
36	Use a paper form to collect sign information		X		
37	Replace signs based on sign age			X	
38	Replace signs whose legibility distances are less than MRVD			X	
39	Replace signs that do not compare with 'visual' samples			X	

8.2.1 Measurement Method Category

This category answers the question: How do we obtain or generate or measure the desired data? In order to evaluate signs, information about the signs is needed. The information needed varies depending on the chosen method of evaluation, whether it is visual inspection, measurement with an instrument, minimum required visibility distance, or some other method. Each of the components in Table 20 is a way to either collect or generate data required to evaluate signs.

Table 20: Measurement Method Components

No.	Component
1	Use sign labels to determine sign age
4	Conduct visual nighttime sign inspection
5	Use model to predict when sign 'expires' (G)
6	Measure RR with handheld retroreflectometer
13a	Use a retroreflectivity van to measure signs
35a	Compare results of sample population to all signs (G)

(G) = Data generation

8.2.2 Data Collection and Storage Category

The next category answers the question: How do we capture the desired data? When evaluating signs in the field, many types of sign data are available for collection, from 'is the sign reflective?' to numerical retroreflectivity values to sign message. Whatever data is necessary must be captured in a manner that allows for the recording and future retrieval and use of the information. Handwritten forms, palm pilots, or mobile data collection systems are all different methods of record keeping. Data must be collected in two different entities, in the field and in the office. The components in Table 21 address both of these.

Table 21: Data Collection and Storage Components

No.	Component
10	Develop a sign database to collect sign data
11	Store sign data in a GIS program
13b	Use computer system in van to collect sign data (F)
15	Use palm pilots to collect sign data (F)
16	(Re) establish data submission system
33a	Download/enter data from field into NCDOT mainframe
36	Use a paper form to collect sign information (F)

(F) = Field collection

8.2.3 Decision Making Category

The third category, shown in Table 22, answers the question: What factor decides when a sign should be replaced? Depending on the method of measurement of evaluation, different criteria are used to decide if a sign needs to be replaced or not. If an instrument measured a sign, the proposed minimum standards would then determine if the sign should be replaced. If signs were evaluated visually, a different standard would be used. These components cover the replacement criteria that correspond with the measurement and data collection component methods.

Table 22: Decision Making Components

No.	Component
8	Replace signs whose measured R_A are less than proposed values
35b	Replace signs with characteristics similar to signs replaced in sample population
37	Replace signs based on sign age
38	Replace signs whose legibility distances are less than MRVD
39	Replace signs that do not compare with ‘visual’ samples

8.3 Previous Literature on Alternatives

8.3.1 AASHTO

The American Association of State Highway and Transportation Officials (AASHTO) is currently proposing four methods that can be used to achieve compliance with the proposed minimum retroreflectivity standards. The first of these proposed methods is to measure sign with a retroreflectomer on a regular basis (components 6 and 13), compare the measured values with minimum proposed sign retroreflectivity values and replace signs when measured values approach the minimum values (Component 8).

The second method from AASHTO is to utilize minimum nighttime sign legibility distances. This includes performing a nighttime sign inspection (component 4), determining legibility distances of signs (component 10) and comparing the distance values in a supplemental document. Signs would be replaced when measured values approach minimum values.

Nighttime visual sign inspection by trained observers is the third method proposed by AASHTO. This method corresponds to component 4, the current method used by NCDOT to evaluate signs. AASHTO suggests that a ‘calibration’ of inspector’s eyes with sample signs that are near the proposed retroreflectivity limits be used; the inspector can then evaluate signs compared to the samples. Signs would be replaced when the evaluated signs are similar to sample signs. This method has been proven valid by a study by the Washington State Department of Transportation titled *Traffic Sign Retroreflectivity Measurements Using Human Observers*. This method is suggested in Alternatives 1, 2, 3, 4, and 6 (described in a later section), either solely or as a possible data collection method.

The final method proposed by AASHTO is to determine the maximum service life of signs (component 5). This would require the determination of expected life of certain sheeting types in specific geographical areas and the sheeting types in use. A replacement program would then be set up “that ensures signs are replaced prior to the end of service life expectancy” (33). Instruments would be used to periodically verify the accuracy of this method. This method corresponds with suggested alternative 1 in the following section.

8.3.2 TTI/Texas DOT

Research performed by Hawkins of the Texas Transportation Institute (21) evaluated three alternatives: total replacement of all signs, sign inspection and replacement, and sign replacement based on a sign management system (with actual replacement being performed by the state or an outside contractor).

The first alternative, total replacement, involves replacing all signs on a designated stretch of road at regular, predefined, time intervals. No inspection or measurement is performed. "All signs are replaced, regardless of whether they meet the minimum value and how long they have been in the field (21).

The second alternative evaluated was sign inspection and replacement. Signs are either visually inspected or measured with instruments and replaced if they do not look sufficient or if their measured values are below the proposed standard. Hawkins stated that this alternative can be performed by state personnel or by contract workers.

The third alternative evaluated was sign replacement based on a sign management system. In this case, the system "is used to track key sign characteristics such as location, size, color, highway speed, exposure, and others (21)". The system then predicts when signs will no longer meet requirements.

The researchers performed an economic analysis on the three alternatives and concluded "the sign inspection method and sign management methods have essentially the same costs, but that the signs management method can be implemented with fewer personnel"(14). The sign management method also offers the additional benefit of providing " a record of all signing activities"(14).

8.4 Alternatives

An alternative is the combination of one or more components that lead to a solution to the retroreflectivity question. Each alternative will include at least one component from each of the first three component categories - measurement method, data collection and storage, and decision-making.

There were two methods used to create a list of alternatives to present to NCDOT for feedback. First, existing literature was reviewed and alternatives previously mentioned were extracted. Then, using the component categories, all possible alternative combinations were formulated. The following alternatives are thus a combination of suggestions and ideas from existing literature with feedback and observations of the current NCDOT procedure.

8.4.1 Alternatives Generated from Previous Literature

- *Implement a Sign Management System*

Implementing a Sign Management System (SMS) could mean either purchasing an existing software package or creating a system designed specifically for NCDOT. It is anticipated that over time, when the database is completely populated, physical measurement of signs would no longer be necessary; a model within the SMS would determine the 'useful' life of signs and identify when signs in the system need to be replaced. However, there would be an overlap period when night rides would need to continue until the system/database was completely populated. New signs can be entered into the database upon manufacturing. Data on existing signs would need a collection method such as using a mobile system or manual labor. This alternative corresponds with the first AASHTO and the third TTI alternatives.

- *Measure Signs with a Retroreflectometer*

This alternative calls for signs to be measured either manually with a handheld retroreflectometer or using a mobile van system. Signs would be replaced when the measured value is not in compliance with the proposed allowable values. This alternative corresponds with AASHTO alternative three.

- *Nighttime Visual Inspection – Minimum Legibility Distances*

The NCDOT could continue with the current procedure of nighttime inspection of signs, but use the minimum nighttime sign legibility distances or minimum required visibility distance (MRVD) to determine if a sign needs to be replaced. MRVD is the 'distance required for a driver to detect the presence of a sign, recognize the message, decide on an appropriate action (if necessary), and make the appropriate maneuver (if necessary) before the sign moves out of the driver's vision" (21). A team of employees would drive around performing a visual inspection of signs at night, and if the sign is not legible at the minimum legibility distance it should be replaced. This alternative corresponds with AASHTO alternative three and TTI alternative two.

- *Nighttime Visual Inspection – Acceptable Visual Retroreflectivity*

This alternative also involves performing a visual inspection of signs at night. However, whether a sign should be replaced is determined by the inspector's determination of whether the sign has acceptable visual retroreflectivity. The decision is made solely by the inspector based on visual calibration of his or her eyes using sheeting samples. This alternative corresponds with AASHTO alternative four and TTI alternative two.

- *Total Replacement*

Total replacement, which corresponds with TTI alternative one, does not involve any visual inspection or measurement using instruments. All signs on a stretch of road would be replaced at designated intervals.

8.4.2 Alternatives Generated from Component Combinations

Formulating all possible combinations using the components from the first three component categories created additional alternatives. Components 16 and 33 from the data collection category were not used in the alternative generation because they did not directly answer the 'how do we capture the desired data' question. In addition, all combinations beginning with component 35a from the measurement method category were omitted from the final list, because it focuses on only a sample population of signs and the issue of 'which signs will be measured' is a issue common to all strategies, not to be identified by one individual strategy.

Over 200 alternatives were generated from the combinations. Of those, absurd, nonsensical, and duplicate alternatives were removed from the list. Any combinations that overlapped or were similar to the AASHTO and TTI alternatives were noted. The final list of over thirty alternatives is in Appendix F. Figure 8.1 outlines the process that generated these alternatives. The end result is a set of alternatives generated from the existing literature and a set of alternatives generated from the components in the first three component categories, all of which were presented to the NCDOT for feedback.

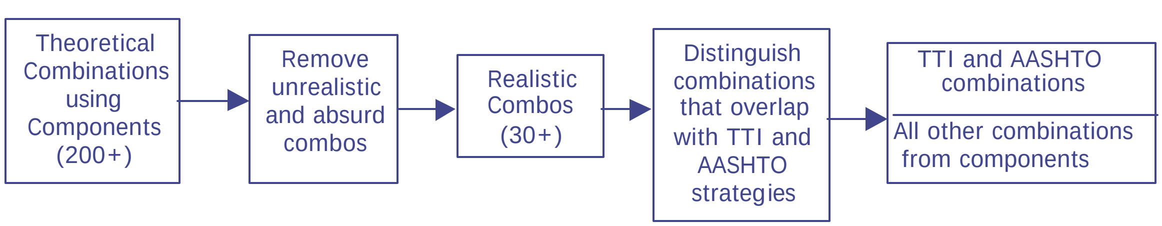


Figure 8.1 Alternative Generation Flowchart

8.4.3 Other Alternatives

- *Continue with current method and implement an official certification and training program for personnel who perform nighttime ride-bys.*

The current visual inspection method would continue. A training program would be administered once a year and all individuals responsible for evaluating signs without the use of equipment would be required to attend. There would be an initial training program, a sort of statewide sign 're-education' program, then refresher courses could be administered each year to review procedure and introduce new components.

The program would be similar to the current procedure described in the Sign Condition Survey Guidelines, which describes a 4-hour training course that should be administered to sign evaluators each year. However, the results of a statewide survey which including questions on training methods of each state highway division revealed varied methods of training ranging from videos to pairing new riders with experienced riders. The Sign Condition Survey Guidelines could be updated and the input and submission procedures for data collected during nighttime rides could be revamped. Guidelines for proper sign storage, transport methods, and other methods that can prevent minor damage to signs (scratches) that decrease the signs life can also be included in the training program.

- *Continue with current sign inspection methods and establish financial incentives for divisions that perform nighttime rides and keep most or all signs maintained to standard (Component 20).*

Bonus funds could be awarded to divisions with exemplary sign maintenance and fines could be established for divisions with numerous signs not in compliance with the proposed standards. An auditor could be responsible for performing random follow-up checks and administering fines for non-compliance. The auditor could also perform random spot checks with a handheld retroreflectometer. This establishes accountability for each division performing nighttime ride-bys.

The original data submission system to the NCDOT Road Maintenance Unit could be reestablished and used to monitor if divisions are actually performing night rides and submitting the data. Bonus monies could be allocated to improving signs or as bonuses to employees responsible for maintaining signs.

- *Keep the current procedure, do nothing additional, and pay a potential tort claims cost.*

The cost of implementing a new program or idea may not be worth the monetary time and effort of the NCDOT. The current night ride method would remain the same.

- *Continue with current procedure and eliminate paper data collection format.*

The current method of visually inspecting signs as been deemed a valid method based on the findings of the Washington State Department of Transportation (14). The data collection and record keeping could be improved greatly by implementing a 'paperless' format.

Each division could purchase palm pilots and equip nighttime ride personnel with them; they would be used to collect the information from night rides currently collecting using paper (15). A computerized version of the Sign Condition Survey Report would be created (14), so the format would be the same as the current format.

The data collected will be transferred from the palm pilots directly into the NCDOT mainframe computer (29). As deficient signs are replaced, the data is entered into the palm pilot (into the appropriate column on the sign condition survey guideline form (see Appendix C)) and again downloaded into the mainframe to update the original data. The time spent on manually entering data into the computer is decreased significantly and a record of night rides being performed is kept.

- *Extend the current warehouse inventory in the DOT mainframe to include data fields that track sign information and location through a sign's useful life.*

This is not a complete alternative; it only addresses extending the current NCDOT inventory. Currently, signs kept in the warehouse are tracked in the NCDOT mainframe computers. But once they enter the field, they are no longer tracked. The current system could be modified to continue tracking signs once they are installed. This information could be used either in conjunction with life expectancy dates of signs or with a model relating sign characteristics to retroreflectivity values to determine when a sign needs to be replaced.

Nighttime ride-bys would continue until all signs have been entered into the computer. When the program is first implemented, there could be a massive effort to replace deficient signs so they are in compliance with the proposed minimum standards. At the same time, the DOT could begin to populate the new system with the new signs.

9.0 RESULTS

On December 5, 2001, the NCDOT research committee met to review and provide feedback on the proposed alternatives. They were presented all of the alternatives from Sections 8.4.1 and 8.4.2. The following is a summary of thoughts and opinions shared by the committee about the proposed alternatives.

- Nighttime rides should be continued regardless of the final strategy.
- The final strategy should result in a database of, at minimum, sign location, type, and inspection history, available to all NCDOT Highway Divisions.
- The final strategy should not use the legibility distance method of determining sign suitability.
- Contracting out sign inspection and maintenance duties is not feasible at this point.
- The final strategy should contain a program of better training, certification, and higher job classification for sign inspectors.
- Large-scale use of handheld or van-mounted retroreflectometers in a strategy is not feasible at this time.
- The final strategy should involve development of better record keeping to help control and defend against lawsuits.

The NCDOT felt that night rides were imperative for identifying vandalized and missing signs regardless of any technologies or prediction models suggested. In addition, they did not feel that using the legibility distance method was necessary to determine if a signs is acceptable visually. They also wanted a database to assist in areas of sign management including visual condition, budgeting concerns, and warranty related issues. They felt that improved training and record keeping were changes that could lead to an improvement in overall sign management in the state. Contracting services out was not a necessity because of the present availability and structure of the labor force that could be designated or altered to meet any alternative suggested. And although the standards are numerical and the only way to produce numerical data is to measure with an instrument, they did not want measurement on a large-scale incorporated into the strategies because of the time required to do so.

The meeting resulted in the narrowing down of the possible alternatives to four specific alternatives that are to be further evaluated in the following sections. The four alternatives are:

1) Maintain the current method (nighttime visual inspection),
2) Improve on current method,
3) Implement a sign inventory management system (no visual inspection), and
4) Combination of #2 and #3

The following sections give a detailed description of what each of the alternatives entails including costs. A comparison of the costs and anticipated effectiveness of each alternative will be made in addition to an evaluation of the accuracy and effectiveness of the current nighttime method in Section 10.

9.1 To Measure or Not to Measure

Measuring all approximately 1,000,000 (5, 6) estimated in-place signs in North Carolina with a retroreflectometer is not realistic. A handheld unit requires up to four readings per sign per color and most retroreflectometer units require calibration for each color and also for different sheeting types.

The Washington State Study established a measurement rate of 10 signs per hour for ground mounted warning and stop sign located on the road shoulder (14). Five measurements were taken per sign for both stop and warning and an additional four measurements were taken on each letter of stop signs. Table 23 is an estimate of the number of work hours that would be required to measure all warning and stop signs in North Carolina. The stop and warning sign counts were extracted from the North Carolina Sign Count Studies. Warning signs were assumed to be all signs with yellow background sheeting.

Table 23: Estimate of Time Required to Measure Stop and Warning Signs with a Retroreflectometer

	APPROXIMATE NUMBER OF SIGNS ON N.C. ROADS	**SIGNS MEASURED PER HOUR**	**HOURS REQUIRED TO MEASURE N.C. SIGNS**
STOP	52,000	-	
WARNING (YELLOW)	373,000	-	
TOTAL	425,000	10	**42,500**

According to these calculations, if the state were to attempt to measure in-place signs, approximately 42,500 work hours would be required for warning and stop signs. The same study estimated that the warning signs only could be measured at a rate of 15 signs per hour. It was noted that the measurement rate “could have been improved only slightly by reducing the number of measurements per sign face to one or two because most of the time was spent traveling between signs and getting equipment out” (14). If only warning signs are measured at a rate of 15 signs per hour, approximately 25,000 hours would be required to measure the 373,000 estimated warning signs on North Carolina roads.

These estimates do not include any guide (green background sheeting) or regulatory signs (white background sheeting), which are also covered by the proposed standards. If signs were measured 8 hours a day and 365 days a year, it would take over 14 person-years to measure all stop and warning signs with a retroreflectometer and over 8 person-years to measure warning signs only. It is neither practical nor feasible to try and measure all signs.

The study’s measurement rates only apply to ground mounted signs on shoulders. The North Carolina sign estimates include overhead mounted signs as well so the time and effort required to measure these signs would be considerably more than for ground mounted signs. Given this fact, the number of hours required to measure all signs in North Carolina would be higher.

Handheld units are not able to identify if a sign is missing, a major concern of the research committee. The accuracy and reliability of these instruments is also questionable. “There can be significant variability among instruments measuring the same object, and the standards do not ensure accuracy of the instruments” (34). Currently, there are no national calibration standards for retroreflectivity, but NCHRP Project 5-16 is currently dedicated to this task (34).

A mobile measurement van would be able to solve many of the problems a handheld unit cannot, such as quick measurement; however, they are not yet ready to be relied on for commercial use. A mobile unit can be expensive regardless of whether it is assembled independently by the state or if a service is contracted to do the work.

A variety of methods are available for retroreflective measurement. Table 24 lists each of these methods and some advantages and disadvantages of each.

Table 24: Comparison of Inspection Methods (Numerical vs. Non-numerical Generation)

Method	Advantages	Disadvantages
Van	*Can collect at near highway speeds *Much choice in technologies *Can carry redundant systems *High accuracy possible (18)	*Primarily uses crew of two collectors *If buying, requires large investment *Slow data collection due to traffic congestion *Skilled crew required (18)
Handheld Unit	*Provides numerical data to compare against proposed standards	*Instrument must be in contact with sign *Multiple measurements required for each sign *Overhead signs very difficult to measure
No Measure (Visual Inspection)	*Can identify missing and vandalized signs *Evaluation rate is fairly quick	*No numerical data generated *Labor and time intensive *Does this method provide sufficient liability prevention?

Whether the proposed minimum values are published as a standard or a guideline will affect how aggressively NCDOT attacks the project and possibly whether numerical measurement is seriously considered or not. A standard is a prescribed set of rules, conditions, or requirements, concerning definition of terms and classification of components, specifications of materials, performance or operation. If the retroreflectivity guidelines are published as a standard, this will mean mandatory compliance, but if they are published as guidelines, they will be ‘suggestions’.

A standard implies more serious liability responsibility for the state whereas a guideline is not as viable in a legal situation. The extent to which the state is concerned with safety will not be affected; however, the amount of labor and money committed to record-keeping and better technology will.

Measuring every sign with a retroreflectometer is not realistic. According to the time estimates in Tables 25 and 26, it would take over 14 person-years to measure warning and stop signs alone. It is possible that measurement could occur periodically on only a sample of signs representative of the entire sign population of the state. Data from the sample could be projected on the entire state sign population to assess their condition. Measuring a sample of signs with a retroreflectometer is discussed in the alternatives.

9.2 Narrowed Alternatives Based on Feedback

9.2.1 Maintain Current Method (Nighttime Visual Inspection)

The first alternative is to continue with the current procedure of performing nighttime visual sign inspections. The current procedure uses acceptable visible retroreflectivity as the judgment criteria for whether the signs should be replaced or not. The premise behind making no changes is that the current system is adequate. Nighttime visual sign inspection is the third alternative recommended by AASHTO.

If all divisions follow the sign evaluation procedures as outlined by the Sign Condition Survey Guidelines, every three years all signs on state maintained roads will have been evaluated and replaced if necessary. Record keeping of the activities is done on a divisional basis. Inspection and replacement notes gathered during the nighttime inspection, and again later as signs are replaced, are hand-written. One division reported that they keep all of the paperwork in file cabinets; after so many years, the files are boxed and kept in storage. Past data that can prove the state has taken an active effort to ensure signs are well maintained may be difficult to gather, but is available if ever needed.

Electronic submission of data was once required as part of the Sign Condition Survey Guidelines. However, this portion of the program is no longer enforced. One significant drawback with the current method is ensuring that every division is doing the best possible job and keeping adequate records. A few divisions may have their own system, however, there is no statewide system of checks and balances or quality control to be sure that the nighttime visual inspections are being performed correctly.

9.2.1.1 Costs

Each Division uses function codes to classify expenditures pertaining to sign related activities. Table 25 lists the function codes related to sign inspection, maintenance, and replacement.

Table 25: NCDOT Sign Function Codes

Function Code	Explanation
510	New Installation
511	Nighttime Surveillance (Labor & Vehicles)
512	(Field) Labor Only
513	Vandalism
514	Maintenance
515	Detours
516	Delineator Posts and Reflector Buttons
517	Logo Work on Primary Systems (installing logo panels)

These codes are used to classify actions in the NCDOT computer system. The codes are also used to cost out all work. Each code includes materials, labor, and equipment costs to perform the specified work, except for 512, which is labor only.

Function code 510 is the code for any new sign installations. Function code 511 is the labor associated with performing nighttime sign inspections. It also includes cost associated with the operation and maintenance of vehicles used for the inspections. Function code 512 would be used, for example, if a bolt needed replacing. Function code 513 would be used to code signs that have paintball stains or other vandalism. Code 514 is for signs needing replacement because they are no longer reflective; these are the signs recorded on the sign condition survey report during nighttime rides. Function code 515, detours, is used for road, bridge, and rail work. Code 516 is for installation of delineators and 517 is for logo (business) signing. There are other codes, such as 529, the function code for signs made in local sign shops, which are not considered in this evaluation, because these include daily task costs not directly associated with sign inspection and replacement. Any signs ordered from Correction Enterprises are charged to a general overhead NCDOT fund and then charged to an individual division once the sign is installed. Any of these charges not associated with the codes in Table 28 are not considered in this evaluation.

Cost data for each of the cost codes listed in Table 25 were collected from two of the fourteen North Carolina divisions over one-year period. The total costs of the two divisions, 6 and 11, were divided by the total miles of these divisions to get a cost per mile. Because all of the divisions vary in size, this cost per mile figure was then projected onto the mileage of the remaining 12 divisions to calculate a total cost to the state. These totals were then divided by the total state mileage (78,083) to come up with per sign costs. All mileage data was taken from NCDOT Highway and Road Mileage data (24). Table 26 displays this data.

Table 26: Cost Data by Sign Function Code for Two North Carolina Highway Divisions

Sign Expenditure Codes	**Miles**	**510**	**511**	**512**	**513**
Division 6 - 1/1/01-12/31/01	-	$58,872	$13,023	$81,637	$278,414
Division 11- 7/1/00-7/1/01	-	$68,365	$13,117	$161,762	$322,179
Division 6 and 11 Total	-	$127,237	$26,140	$243,399	$600,593
Miles in Division 6 and 11	-	12,231			
Cost per Mile	-	$10	$2	$20	$49
Division 1	5050	$52,534	$10,793	$100,496	$247,976
Division 2	4949	$51,484	$10,577	$98,486	$243,016
Division 3	5445	$56,643	$11,637	$108,356	$267,372
Division 4	6117	$63,634	$13,073	$121,729	$300,370
Division 5	6256	$65,080	$13,370	$124,495	$307,196
Division 7	5281	$54,937	$11,287	$105,093	$259,319
Division 8	6721	$69,917	$14,364	$133,749	$330,029
Division 9	5107	$53,127	$10,915	$101,630	$250,775
Division 10	4935	$51,338	$10,547	$98,207	$242,329
Division 12	5979	$62,199	$12,778	$118,983	$293,594
Division 13	5095	$53,002	$10,889	$101,391	$250,186
Division 14	4917	$51,151	$10,509	$97,849	$241,445
Total (including 6 & 11)	65852	$812,284	$166,878	$1,553,865	$3,834,200
Average Costs		$58,020	$11,920	$110,990	$273,871
Cost per Sign ($/signs)		$0.81	$0.17	$1.55	$3.83

514	515	516	517	Total
$48,546	$60,051	$6,648	$3,405	$550,596
$315,487	$41,744	$11,783	$7,123	$941,560
$364,033	$101,795	$18,431	$10,528	**$1,492,156**
12,231				
$30	$8	$2	$1	
$150,304	$42,030	$7,610	$4,347	**$616,089**
$147,298	$41,189	$7,458	$4,260	**$603,767**
$162,060	$45,317	$8,205	$4,687	**$664,278**
$182,061	$50,910	$9,218	$5,265	**$746,261**
$186,198	$52,067	$9,427	$5,385	**$763,219**
$157,179	$43,952	$7,958	$4,546	**$644,271**
$200,038	$55,937	$10,128	$5,785	**$819,948**
$152,000	$42,504	$7,696	$4,396	**$623,043**
$146,881	$41,073	$7,437	$4,248	**$602,060**
$177,954	$49,761	$9,010	$5,147	**$729,425**
$151,643	$42,404	$7,678	$4,386	**$621,579**
$146,345	$40,923	$7,409	$4,232	**$599,864**
$2,323,995	$649,862	$117,664	$67,211	**$8,033,804**
$166,000	$46,419	$8,405	$4,801	**$573,843**
$2.32	$0.65	$0.12	$0.07	**$8.03**

The average cost per division for the nighttime sign inspection only (code 511) is $11,920. The cost per sign to perform the evaluation, based on the sign count estimates from the North Carolina Sign Count studies, is only $0.17.

A 30" stop sign costs $18.51 and has an in-place life of 7 years, which equates to $2.64 per year. Table 27 shows the amount of money that is wasted for every year a sign is replaced earlier than it should be. If a sign is evaluated correctly in Year 2, for example, only $0.17 is spent on that sign performing the evaluation. But if the sign is designated for replacement, when it does not really need to be replaced, the signs value has only diminished to $15.87. After subtracting the cost that was spent regardless performing the inspection, a remainder of $15.70 of the signs value was wasted.

Table 27: Cost per Sign Wasted on Signs Not Needing Replacement

YEAR	Value of Sign	Cost per Sign of Visual Inspection	$/per sign wasted on signs not needing replacement
0	$18.51	$0.17	-
1	$15.87	$0.17	$15.70
2	$13.23	$0.17	$13.06
3	$10.59	$0.17	$10.42
4	$7.95	$0.17	$7.78
5	$5.31	$0.17	$5.14
6	$2.67	$0.17	$2.50
7	$0.00	$0.17	-

The total cost to the state to replace signs that are no longer reflective (code 514) is $2,323,995. The average cost per division is $166,000 and the cost sign is $2.32.

The average total cost of all sign code functions per division was $573,843. The total cost to the state for all sign management function is estimated to be approximately $8 million.

According to NCHRP Report 346, an inspection program should cost $5.00 per roadway mile. This is based on labor rates of $27.50 per hour (including overhead) for a 2-person crew, 50 percent premium pay for overtime and a $1 per mile vehicle and equipment cost. This would be for 6 hours a day at a rate of 25 miles per hour (1). Using an estimate of $5 per mile on North Carolina DOT's 78,083 miles of road yields a total of approximately $390,000 a year for sign inspection alone (code 514). This equates to $0.40 per sign. This estimate is more than twice than the sign count study estimate of $182,000. The higher estimate from the NCHRP Report is probably due to higher labor rates than NCDOT and the fact that NCDOT crews perform nighttime inspections at posted highway speeds whenever possible, which usually exceed 25 miles per hour, resulting in less time spent performing the inspections. Also due to the fact that the estimate is based on a per mile basis instead of a per sign basis.

Looking at an $0.17 per sign cost, a state total of approximately $166,878 a year for nighttime visual inspection only (Code 511) is a small price to pay to ensure high sign quality on North Carolina roads. The maximum tort claim award amount is $500,000. NCDOT expenditures for the preventive maintenance that performing nighttime inspections provides is a bargain. Further evaluation of the percent accuracy the nighttime inspection method provides the state is conducted in Section 10.0.

9.2.2 Improve on Current Method

The second alternative is to maintain the current method, yet improve upon it in several areas. Nighttime visual inspection is a valid method to inspect and maintain signs; however, reforming the training program and encouraging employee performance, employing an auditor to monitor inspection quality in each division, and developing a tort claim database to help identify problem areas are all ways NCDOT could enhance the current inspection method. The end result of these improvements would be a more uniform procedure throughout the state, assurance that inspections are being performed adequately and proper record keeping is being maintained and an active attempt to combat liability possibilities, and the reduction of signs replaced unnecessarily. Improving sign observer training would not only improve the accuracy of signs needing to be replaced, but also the accuracy of signs not needing to be replaced.

9.2.2.1 Training Program

According to the survey submitted to the 14 NCDOT Highway Divisions, current training methods for sign inspectors include a training video, demonstrations, the sign condition survey guidelines, riding with an experienced worker, or a combination of one or more of these. One of the observations of the survey analysis was to create new or update current training to include a comprehensive education program across all divisions and DOT units to attain a goal of safe signs with proper retroreflectivity. The first improvement to the current method is to update the current guidelines and establish a more uniform employee training program. The goal of this alternative is to not only make changes, but to ensure the changes and updates are done uniformly throughout the state so there is less variance in the interpretation of what is and is not acceptable retroreflectivity. A defined training program results in better, more informed employees. Better record keeping helps the state fight liability battles.

A formal training program, similar to the one currently administered by NCDOT for pavement markings (see Appendix B) could be implemented. The goal of the training would be to teach proper sign evaluation practices, educate employees on retroreflectivity and different types of sign sheeting principles and standards, review the different sign types and categories (Table 10), and also teach proper data collection and record keeping. In addition, if some type of technology, such as GIS units and laptop computers is integrated into the sign inspection procedures, the class could teach these skills also. There could also be portions that include instruction on proper sign manufacturing for divisions with in-house sign shops and proper inventory maintenance to help signs in storage last longer.

The training could be held at a location like the NC State Fairgrounds Horse Arena, similar to the pavement-marking program. This would allow ample room to set up example sign assemblies and even bring in signing cars and trucks to demonstrate procedures from a car, as it would be done in the field.

Instructors would be a combination of NCDOT personnel and outside contractors. Outside contractors could include sign sheeting and retroreflectometer personnel. NCDOT personnel could provide information on specific organization procedures. Contractors for retroreflective sheeting could participate to educate employees on specific product information.

According to the survey administered to the 14 Highway Division, most divisions have 12 – 14 sign maintenance personnel. Using an average of 13 employees for each of the 14 Divisions yields a total of approximately 182 employees that would receive the training. The estimate is rounded to a total of 200 to include any employees from cities, other states, or contractors. The training would not need to be administered every year because of cost and to avoid redundancy of information, but probably every other or every third year.

Each division would be allowed to send a maximum number of employees and be required to provide a minimal registration fee, transportation, and lodging. Non-state employees would be charged a higher fee to help cover implementation costs.

The planning and organization of the training would be the responsibility of one or more new staff members with the assistance of the NCDOT training administrator and his staff and other state agencies that assist the DOT with training, such as the Institute for Transportation Research and Education (ITRE). They would be responsible for the entire coordination efforts from collecting the appropriate materials to distributing and collecting registration information to ensuring the proper equipment and setups are in place for the training.

The current training video, produced in conjunction with the sign condition survey guidelines is informative. However, it is of poor quality and contrast. It does not provide the viewer with adequate visual comparison to apply the knowledge in the field. The current video should not be used anymore. The video should be replaced completely by the training program or a new video should be created that could be used as an on the spot training tool for temporary sign inspection employees.

9.2.2.1.1 Competency-Based Pay

Sign erectors have high responsibility and low pay. Implementing a component that recognizes divisions with exemplary sign management boosts employee morale and improves the quality of work being performed. Currently, traffic-engineering employees are able to participate in competency-based pay programs, sometimes referred to as skill blocks, to become proficient in different areas. The employee receives a one-time raise once the skill block is complete. There is currently a skill block for sign inspection for which the employee receives a $520 raise.

Competency-based pay involves two steps: a training class and then demonstrated competency known as OJT, or on the job training. For pavement markings, the training class administered by NCDOT counts as the first step. Employees are then required to evaluate pavement markings correctly 25 out of 40 times in the field. The sign inspection training could function the same way. The state administered training class could count as the class portion. Until recently, there was a limit on the number of employees who could complete the skill block (the limit was 1 per truck). But now that the limit is no longer valid, all employees attending the training would be eligible to complete the skill block.

9.2.2.1.2 Training Costs

The NCDOT Training and Development Unit facilitate a training class for pavement markings every three years. The cost for the 2002 workshop was $25 per person. This cost includes materials, a seat cushion, lunch, and snacks. A portion of the registration costs also went towards facility (the cost of the horse arena is $400/day) and any equipment rentals. Any transportation and lodging was the responsibility of the attendees or their divisions.

A similar program could be achieved for sign inspection for the same cost. If the estimated 200 persons attended at $25 a person, the total cost would be $5000. Non-NCDOT personnel could be charged a higher registration fee to help offset some of the costs. This does not include the overhead costs associated with the employee salary for administering the workshop and for the planning process.

Much of NCDOT's training is contracted out to the Institute for Transportation Research and Education (ITRE) at NC State University. According to Tim Baughman, head of flagger and safety training at ITRE, because ITRE is a North Carolina State agency, all of their work is done on a cost plus fee basis. A flat fee of approximately 28% is added to the at-cost amount of training, development, and materials. This is in comparison to a private company that may charge as much as 150% as a fee.

When ITRE is charged with developing a training program, there are two aspects to be considered. First is the development of the project, which involves trying to estimate the time that would be involved creating and developing the program and producing any necessary material, such as a video. A good quality video costs about $1,000 per minute to create. (The current video is about 14 minutes in length.) Also, NCDOT has a professional grade videography group that could take responsibility for updating the video. The amount of work that has already been done is also taken into consideration. For example, the existing Sign Condition Survey Guidelines would be considered existing work that would provide a framework to build additional training on.

The second aspect is the actual implementation of the training program. The program could be presented by ITRE personnel or turned over to the DOT for their personnel to facilitate, depending on who is most capable. Any materials necessary, such as notebooks or handouts are included as well. Materials can range from $0.50 (ex: a flagger workshop notebook) to $35.00 for a more substantial size notebook.

Mt. Baughman said that a cost plus fee for a training program could range anywhere from $20,000 - $40,000.

There is a substantial cost difference between $5,000 and $20,000. However, the $5,000 estimate to administer some sort of training at the Horse Arena is only the implementation cost. The higher estimate is probably more accurate because it includes research, development, video and material production, and implementation. The $20,000 cost would probably be a one-time cost to create a quality program. Training registration costs could offset this cost. The $5,000 would be a recurring cost each year the training were to be administered and would be completely covered by training registration costs.

9.2.2.2 Auditor/Quality Control/Training Person

Another improvement the state may consider is creating a full-time position for a quality control-auditor type role. This employee would be responsible for verifying the quality of signs across the state. Their duties would include performing random spot checks visually at night or with a retroreflectometer in the daytime, surprise checks to accompany sign inspection crews on night rides to check their evaluation technique, and file checks to see if divisions are maintaining proper records. The same employee could also be responsible for administering training programs. These new quality control tasks would be too much work to add to the responsibility of the current sign inspection and maintenance staff.

If this employee works 50 weeks a year, assuming 2 weeks for vacation, they would work about 2000 work hours. The employee would be classified as a Transportation Engineer I, and would receive an hourly rate of $29.79, which equals $62,000 per year. An approximate breakdown of the 2000 work hours based on the tasks assigned to the position is described in Table 28.

Table 28: Breakdown of Work Hours for Proposed Employee by Task

TASK	DESCRIPTION	NUMBER OF HOURS
In-place Signs Quality Control	Measure a sample of signs in each division with a retroreflectometer.	2.5 - 3 weeks per division = 1400 - 1680 hours
Record-Keeping Auditor	Review nighttime inspection records and plans.	During same time as quality control duties.
Training Organizer/Admin.	Develop, organize, and administer state nighttime sign inspection training program	12 weeks = 480 hours
TOTAL		**1880 - 2160 hours**

The employee could spend two and one-half to three weeks in each division, depending on the size of the division. This time would be spent on two of the tasks, in place signs quality control and record keeping auditor. The quality control aspect would involve measuring a sample of signs with a retroreflectometer in the daytime and doing visual inspections at night. A specified percentage of the measured signs would have to comply with the proposed retroreflectivity standards in order for the division to receive a satisfactory rating for sign inspection practices. The auditor aspect of the position would involve reviewing the records made during the nighttime sign inspections and any maps or plans the division uses to organize their efforts. Whether or not critical signs are replaced in a timely manner, how many signs are not replaced each year, and similar information would be collected.

The employees training duties, although not necessary every year would require a considerable effort, probably 3 months. These tasks would include organizing registration, preparing materials, and some teaching as well. This work would be performed in conjunction with the NCDOT training administrator and staff.

The employee would also need a vehicle, a laptop computer, a cell phone, and a retroreflectometer. The cost of these items is outlined in Table 29.

Table 29: Costs Associated with Employee

ITEM	INITIAL SET-UP COST	ONGOING YEARLY COST
Salary	$62,000	$62,000 + 2% per year
Car	$2,000	$2,000
Cell Phone	$480	$480
Laptop Computer	$1500	$100
Retroreflectometer	$6,000	-
TOTAL	**$74,890**	**$64,580**

The salary is based on the current rate of $29.79 for an NCDOT Transportation Engineer I. The employee would be eligible for a standard 2-4% raise each year. The current state car contract is with Chrysler/Plymouth. The employee could be issued an existing state owned vehicle; a vehicle estimate of $2,000 a year was made for gas and maintenance. A cell phone would be provided at a rate of $40 a month. A standard laptop would cost about $1500 with $100 allotted each year for software upgrades and maintenance. The $6,000 cost for a retroreflectometer was calculated using the average of four models currently available. After an initial cost of approximately $75,000 in the first year, the cost to maintain this position would be $64,600 a year (excluding benefits) plus a standard salary increase each year. This estimate does not take into consideration meals and lodging.

9.2.2.3 Tort Claims Database

In addition to the training program, a tort claims database could be set up by the NCDOT to keep a record of claims that are made and the nature of the claim. The database would include claims filed against the DOT, the reason for the claim (including issues leading up to the claim), the amount of the claim, the legal course of action taken (settled, dismissed, court, etc.), the award amount if any, and other information. Currently, the only way to assess how many past cases have involved sign visibility is to manually search through tort claims kept by the North Carolina Industrial Commission.

A database could provide historical data that could be used to protect the state against future liability claims. It can also be used to generate statistical data about how many claims made are related to signing (or other) issues, whether the sign be damaged, missing, not visible, or some other reason. Reports could be issued to each division on a yearly basis to help DOT personnel identify the causes of claims and situations that lead to claims and identify if any procedures can be changed or updated to prevent similar claims in the future.

Developing a Tort Claims Database would need to involve NCDOT Database Management Services (DMS) whose responsibilities include analyzing, planning, and creating database management systems for DOT entities. Exactly what and how much information would be included in the database is a critical factor in the planning element. Before any system design is ever attempted, an initial planning and analysis phase is needed. A planning phase would typically require 40 – 60 hours of labor at $40 – 60/per hour, which would be $1600 – 3600. The planning period would determine what the objectives and needs of the desired database, such as who will eventually operate and maintain it, and other design and operational issues. The cost of the actual labor, equipment, and other tasks require to actually start a project would be determined during this planning period.

The website of a private database development company lists their rates at $90/hour. Their projects range between $2,000 and $8,000 for a complete system, including training and follow up support. The time to create and implement a project ranges from 2 weeks to 2 months, depending on the level of detail required by the project (35).

According to Don Jerman of the NCDOT Database Management group, an estimated cost of a basic database system is about $80,000 - $100,000. The cost varies based on factors such as what type and how much information is to be stored and how the system is to be integrated into existing systems. This cost includes the actual creation and implementation of the system: one programmer and one supervisor working for three months. This does not include any training, rollout, or operation costs. In addition to the development, ongoing costs would include the cost of an employee to input data and monitor the system, cost of computers, storage, and electricity, to name a few.

In order to develop a more finite cost, several actions would need to be taken. First, a champion, or advocate, for the project, who has the authority to provide funding and make decisions, would need to be identified. This individual would then make a request to Database Management Services to begin a planning phase. A price simulation would be done as part of the planning.

Successful implementation of such a database would involve the cooperation of agencies outside of NCDOT as well. Departments such as the Industrial Services Commission, which plays a role in tort claims management will need to be involved as well as the Attorney General's office, courts and other judicial bodies of the state that work with tort claims against the state.

The Industrial Services Commission currently has some databases set up to search for cases that have been tried before a commission or the full commission; however, the database includes data from all state agencies (DOC, DOE, etc.) and cases are not input with detailed categorizations so detailed queries, such as specific causes of claims, cannot be performed.

9.2.2.4 Increase Sheeting Quality of Stop Signs

As previously mentioned in Section 8, an improvement that could be made on the current system is to use a higher grade of reflective sheeting on 'Stop' signs. This improvement is suggested since Stop signs are high priority in terms of visibility and safety (23). Because critical signs are most important to driver safety, using a higher sheeting grade would ensure that they are visible and not requiring replacement for longer periods of time (assuming they are not vandalized or destroyed).

Currently, Engineer Grade sheeting is used; it costs about $0.69 per square foot and has an anticipated useful life of seven years. High Intensity sheeting, the next highest grade, is currently used by NCDOT but primarily for Interstate signs. It costs about $2.00 per square foot and has an anticipated useful life of 12 years. The highest sheeting grade currently available is Diamond Grade, which costs about $4.00 per square foot. Table 30 shows a cost comparison of using High Intensity or Diamond Grade sheeting instead of Engineer Grade for a 30" stop sign. This sign size would require about 6.25 square feet of sheeting to create.

Table 30: Stop Sign Material Cost Comparison

Sheeting Type	Cost/Square Foot	Cost to Create 30" Stop Sign (6.25 square feet)	Percent Increase Over Engineer Grade
Engineer Grade	$0.69	$4.30	N/A
High Intensity	$2.00	$12.50	190%
Diamond Grade	$4.00	$25.00	464%

Source: Department of Corrections Sign Manufacturing Shop

There would be a 190% increase in material cost if High Intensity sheeting were used instead of Engineer Grade, and a 480% increase if Diamond Grade sheeting were used.

The cost of a 30" engineer grade stop sign, manufacturing included is $18.51. If the state were to upgrade signs to High Intensity sheeting, adding a difference of $8.20 to the cost of an engineer grade stop sign, the new cost per sign would be $26.71. Upgrading to Diamond Grade sheeting would yield a new cost per sign of $39.21. Manufacturing costs would remain the same; the only difference would be in the cost of the sheeting.

The results of North Carolina Sign County Study (Table 16) estimate approximately 51,990 stop signs on roads in North Carolina. Assuming all of these signs were manufactured using Engineer Grade sheeting, the value of the signs is $962,335. If all of these signs were immediately replaced with High Intensity sheeting, the cost would be approximately $1,388,653. If they were replaced with Diamond Grade sheeting, the cost would be approximately $2,038,528.

The life expectancy of a sign made with Engineer grade sheeting is 7 years, but for High Intensity and Diamond Grade is 12 years (these expectancy rates are assumed, not published). During nighttime sign inspection, if the visibility of a sign is questionable, a sticker indicating installation date of the sign, which is placed on the back, is referred to. If a higher sheeting grade were used, the sign would be in place for more years, and since higher sheeting grade is supposed to last longer, it should appear visible for at least 5 years longer than with Engineer Grade.

Table 31 compares the replacement frequency and cost of 51,000 stop signs during a 50-year cycle. The estimates are based on the assumption that all signs are brand new in Year 1 and all signs are replaced in the year in which the sign is expected to 'expire'. Any signs replaced because of accidents or vandalism are not considered. The table represents the value of each sheeting type in Year 1 and then the value in the corresponding year of replacement with an estimated 4% rate of inflation.

Table 31: Cost Comparison of Altered Stop Sign Sheeting

YEAR	0	7	12	14	21	24	28	35	36	42	48	49	TOTAL
Engineer Grade	$962,000	$1,266,000		$1,666,000	$2,912,000		$2,885,000	$3,796,000		$4,995,000		$6,574,000	25,056,000
High Intensity	$1,390,000		$2,225,000			$3,563,000			$5,704,000		$9,133,000		22,015,000
Diamond Grade	$2,040,000		$3,266,000			$5,229,000			$8,372,000		$13,405,000		32,312,000

High Intensity 50 Year Savings:	3,041,000
Diamond Grade 50 Year Savings:	-7,256,000

Many stop signs are already manufactured with high intensity sheeting which is not taken into account in this estimate. The actual frequency and number of signs actually replaced would vary, however, assuming signs stay in place for the majority of their expected life, signs manufactured with High Intensity grade sheeting would stay in place longer, resulting in lower labor costs. Also, there would be some savings by upgrading all Stop signs to High Intensity sheeting. More money would be spent on Diamond Grade sheeting because there is no difference in the expected life or replacement frequency of High Intensity and Diamond Grade sheeting. Diamond Grade is currently only used for fluorescent yellow school crossing and pedestrian signs. It would most likely not be used because NCDOT feels the costs outweigh the benefit and because there would be negative savings.

Upgrading signs to High Intensity sheeting would produce a savings of $3,041,000 (considering inflation at 4%), but only after 50 years. This equates to a maintenance savings of about $61,000 a year, plus savings associated with less labor. This evaluation provides evidence that upgrading all Stop signs on Primary routes to High Intensity sheeting would result in cost savings, better sign visibility, and lower labor costs because signs have to be replaced less frequently. Additionally, there is the added benefit of increased safety and less liability risk. NCHRP project 04-29 is currently underway to develop a decision-making tool to help agencies select the appropriate retroreflective sheeting material for traffic signs. The study will take into account roadway conditions and other factors that affect sign performance; the results may or may not provide support for this suggested improvement.

9.2.2.5 Change Current Inspection Frequency

Why are Interstates and primary roads, which contain the least number of critical signs (stop, red, yellow), evaluated most often? Maybe the Interstates should be evaluated less frequently and secondary roads more frequently. Red signs on Interstates are never 'Stop' and seldom on US Routes. In fact 93% of the stop signs in the primary road sign count estimate were on rural state routes, which although considered part of the primary system, are in rural areas where there is probably significantly less street lighting. The time that is being devoted to doing interstate and primary roads every year, could be devoted to evaluating primary or secondary roads more often.

Although during nighttime inspections on secondary roads the length of time until the next inspection is taken into consideration when evaluating questionable signs, three years is still a substantial time period (3 years is nearly 43% of the guaranteed life of sign sheeting). Being that secondary roads contain the most stop signs (over 98%), it seems as if sign evaluation practices should be changed to make sure that critical signs are looked at more often.

Secondary road sign inspection is much more time consuming because of stop signs, traffic lights, more concentrated traffic flow, and dirt and winding roads. However, if the Interstate evaluation frequency is reduced, this time could be devoted to inspecting secondary roads more often. A frequency comparison was conducted based on all roads being ridden every other year, or 50% of all signs on all road types being evaluated every year. No comparison is made for the primary road system because this is the current frequency.

The new frequency suggestion would include evaluating Interstates every other year instead of every year. The sign evaluation performed in Section 10.0 was altered to see how changing Interstate evaluation frequencies would affect the percent accuracy and the percent of signs not meeting the proposed standards. Table 32 displays the results of the comparison. The comparison is based on warning signs (yellow and orange background sheeting) only.

Table 32: Evaluating Warning Signs on Interstates Every Year (100% each year) vs. Every Other Year (50% each year)

	EVALUATION EVERY YEAR		**EVALUATION EVERY OTHER YEAR**	
YEAR	**% of signs not meeting proposed Standard**	**% Accuracy**	**% of signs not meeting proposed standard**	**% Accuracy**
0	2.37	83.2	10.70	83.2
1	2.26	83.3	10.41	83.2
2	2.14	83.4	10.40	83.4
3	2.04	83.4	9.27	83.4
4	2.01	83.2	9.21	83.4
5	2.00	83.2	7.84	83.6
6	2.14	83.2	7.77	82.6
7	2.15	83.2	9.71	82.6
0	2.13	83.3	9.81	83.1
1	2.10	83.3	9.72	83.1
2	2.08	83.3	9.71	83.2
3	2.08	83.2	9.18	83.2
4	2.08	83.2	9.15	83.2
5	2.11	83.2	8.70	83.2
6	2.11	83.2	8.68	82.9
7	2.10	83.3	9.42	82.9

Table 32 is based on 4,735 warning signs on Interstates and 2,368 signs being evaluated each year (50% each year). Year 0 represents the year in which standards are actually implemented. The numbers shown here represent the second and third seven-year cycles of calculation. In the first seven-year cycle, it was assumed that an equal number of signs were replaced each year. In the second and third cycles, the number of signs replaced was calculated by the spreadsheet.

Based on the evaluation, the percent accuracy, which includes the correct number of signs chosen to stay in place and be replaced, remains about the same. However, once the second evaluation cycle begins, the percent of signs not meeting standards is obviously higher. This is because when the signs are evaluated every year, a non-compliant sign that is overlooked in one year is re-evaluated the next year and most likely replaced. However, with an every other year frequency, a missed sign that is non-compliant is not evaluated again for another two years, but is still in-place and non-compliant in the year it is not evaluated, which leads to an increase in the number of signs not in compliance.

At the end of 2 cycles (14 years), there is a 7% difference in the percent of signs potentially not in compliance, which is equal to about 330 signs. Although this is a large number of non-compliant signs that could be avoided if Interstates were ridden every year, the model used to perform the calculations is based on a 7-year replacement rate. Most signs on North Carolina Interstates are manufacture with High Intensity grade sheeting which has a less frequent replacement rate, so the actual number of signs not in compliance is probably less than 330.

A comparison was then made to compare secondary roads being evaluated every two years (50% every year) instead of every three years (about 33% every year). Table 33 shows the results for warning signs and Table 34 shows the results for stop signs.

Table 33: Evaluating Warning Signs on Secondary Roads Every Third Year (33% each year) vs. Every Other Year (50% each year)

	EVALUATION EVERY THIRD YEAR		**EVALUATION EVERY OTHER YEAR**	
YEAR	**% of signs not meeting proposed Standard**	**% Accuracy**	**% of signs not meeting proposed standard**	**% Accuracy**
0	15.20	80.8	10.70	83.2
1	19.16	82.0	10.41	83.2
2	20.5	82.6	10.40	83.4
3	19.93	83.4	9.26	83.4
4	20.09	83.3	9.21	83.4
5	19.48	83.8	7.83	83.4
6	17.72	84.2	7.76	82.6
7	15.33	83.6	9.71	82.6
0	15.03	82.9	9.81	83.1
1	16.73	82.1	9.72	83.1
2	18.51	82.6	9.71	83.2
3	19.09	82.9	9.18	83.2
4	18.77	83.3	9.15	83.2
5	18.75	83.2	8.70	83.2
6	18.47	83.4	8.68	82.9
7	17.75	83.6	9.42	82.9

Table 34: Evaluating Stop Signs on Secondary Roads Every Third Year (33% each year) vs. Every Other Year (50% each year)

	EVALUATION EVERY THIRD YEAR		**EVALUATION EVERY OTHER YEAR**	
YEAR	**% of signs not meeting proposed Standard**	**% Accuracy**	**% of signs not meeting proposed standard**	**% Accuracy**
0	15.20	80.8	10.70	83.2
1	19.16	82.0	10.41	83.2
2	20.51	82.6	10.40	83.4
3	19.93	83.4	9.26	83.4
4	20.09	83.3	9.21	83.4
5	19.48	83.8	7.83	83.4
6	17.72	84.2	7.76	82.6
7	15.32	83.6	9.71	82.6
0	15.03	82.9	9.81	83.1
1	16.73	82.1	9.72	83.1
2	18.51	82.6	9.71	83.2
3	19.09	82.9	9.18	83.2
4	18.77	83.3	9.15	83.2
5	18.75	83.2	8.70	83.2
6	18.47	83.4	8.68	82.9
7	17.75	83.6	9.42	82.9

A considerable change in the percent of signs potentially not in compliance was made by altering the frequency that warning signs are evaluated at from every third year to every other year. After two cycles (14 years), warning signs changed from 17.75% to 9.42%. The 8.3% difference is equal to about 24,500 warning signs on secondary roads. There was also an 8.3% change for stop signs; the difference is equal to about 4,200 stop signs on secondary roads.

Altering the frequency at which roads are evaluated would increase the sign inspection workload each year. Although Interstates would be evaluated less, the frequency at which secondary roads are evaluated would increase and there are considerably more miles of secondary roads than Interstate roads. At the current inspection frequency, approximately 29,000 miles are evaluated each year. If the altered inspection frequency were adopted, this would increase to 39,041 miles evaluated each year, an increase of 10,000 miles. Adopting the inspection frequency change would most likely result in an increase in the sign inspection costs per year. The cost per mile as determine by Table 29 is $2 per mile. So riding an additional 10,000 miles more each year would create an increase of $20,000 a year to change the frequency of nighttime visual inspection. However, the cost per mile to evaluate secondary roads is higher than for other systems so this estimate is probably low.

As stated before, 3 years is nearly 43% of a signs expected useful life. Is changing the evaluation frequency more efficient than replacing signs that are questionable and may not remain adequate until evaluated again? If on a secondary road, 100 signs are evaluated and 40 of those are questionable (i.e. still visible this year, but maybe not still in the next two years when it will not be evaluated), would riding the same stretch of road more often be more economical than replacing the signs?

If all 40 signs are replaced because it is anticipated they will become inadequate before the next inspection, assuming approximately $20.00 per sign, equals a total cost of $800.00. At a cost of $0.17 per sign to evaluate, only $6.80 more per year would be spent evaluating these signs more often as opposed to replacing them early because of less frequent inspection.

9.2.2.6 Total Costs of Suggested Improvements

Table 35 outlines the total costs of all suggested improvements discussed in Section 9.2.2.

Table 35: Total Costs for Alternative 2

IMPROVEMENT	INITIAL COST	ONGOING COST (per year)
CURRENT METHOD	$167,000/year	$167,000
Training		
Creation and Development	$20,000 - $40,000	-
Cost of Training	-	$5,000
Quality Control Auditor Employee	$74,900	$64,600 [+ 2-4% raise each year]
Tort Claims Database		
Planning and Analysis	$1600 - $3600	-
Creation and Implementation	$80,000 – 100,000	-
System Maintenance	-	$1000/year
Increase Sign Sheeting Quality	(- $61,000/year)*	(- $61,000/ year)*
Alter Inspection Frequency	$20,000	$20,000
TOTAL INITIAL	$363,500 – $405,500	-
TOTAL ONGOING (Per year)	-	$257,600

*not included in calculation

The improvement costs for the initial year and the ongoing costs per year include the current estimated cost of $167,000 to perform nighttime visual inspections. The negative $61,000 of savings estimated as a result of using a higher quality sheeting on all stop signs was not included, nor was the cost to replace all stop signs. A tort claims database would not directly affect the accuracy of the sign inspections; however, it would assist the state in improving its protection against liability claims. The total maximum cost to initially implement these improvements is less than one potential maximum tort claim award of $500,000. At a yearly upkeep cost of $257,600, it would take 2 years to reach $500,000.

9.2.3 Establish a Sign Inventory Management System (SIMS)

As previously discussed in Section 5.2.2, there are Sign Management Systems (SMS), and Sign Inventory Management Systems (SIMS), the later being a subset of the former. An SMS would involve the entire life cycle of a sign in North Carolina (Figure 9.1). Choosing to implement a complete Sign Management System would involve integrating Figure 3.1 with Figure 5.1, a depiction of how a fully integrated Sign Management System would flow. Both figures are depicted below as Figure 9.1.

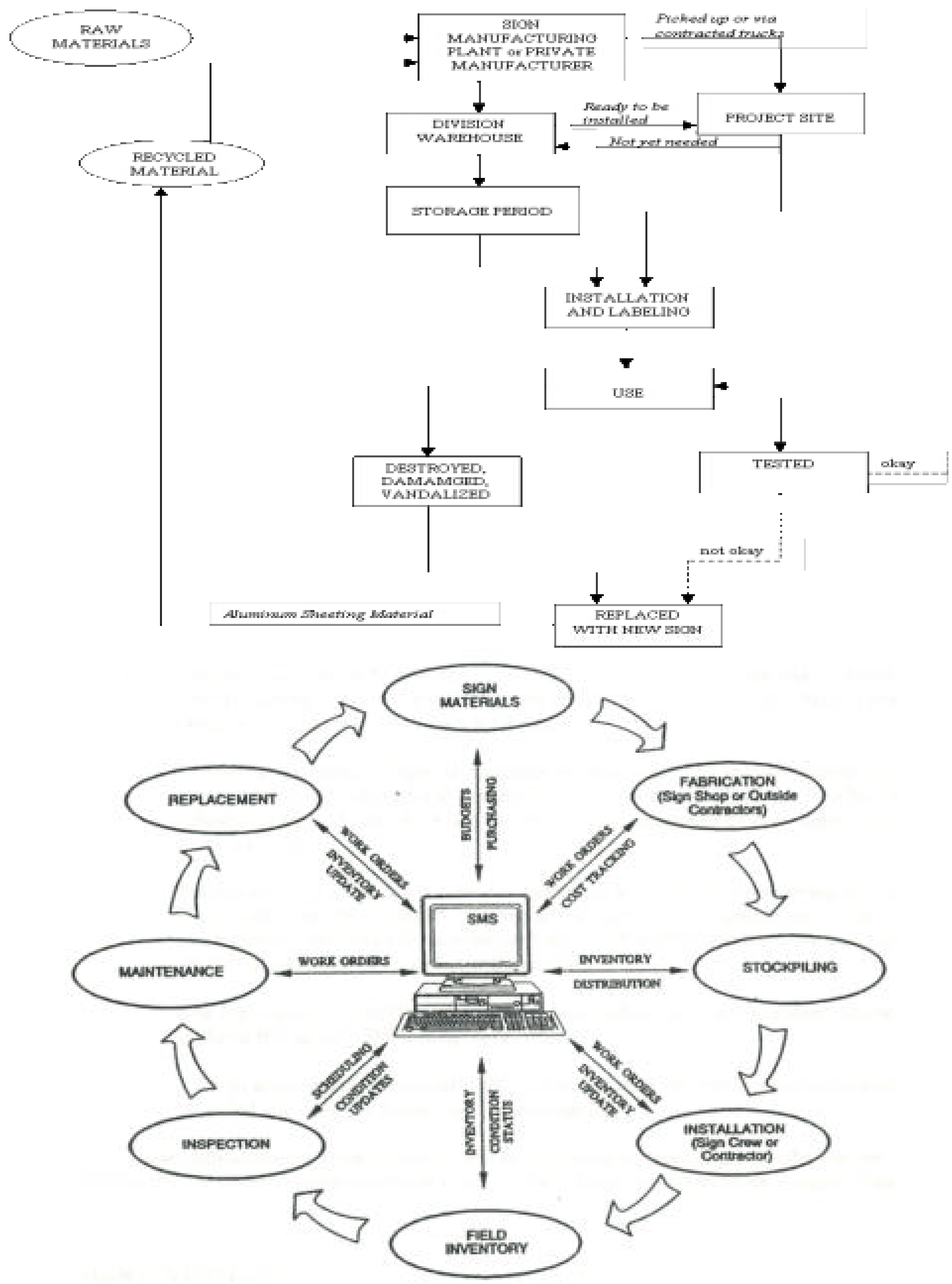


Figure 9.1: Comparison of Life Cycle of a Sign in North Carolina with a Fully Integrated Sign Management System

A complete sign management system is not within the scope of this report but should be investigated by NCDOT in the future. Alternative three is to implement an SIMS, a portion of a Sign Management System. This alternative would be in addition to the current nighttime visual inspection method. The NCDOT research committee noted that relying on some sort of inventory or computer model to predict a signs replacement period might be advantageous and timesaving, but a computer could not know when a sign has been damaged or removed because of vandalism or an accident. They agreed that the most efficient method of determining if a sign is visually adequate as well as not damaged, missing, or vandalized is to perform the nighttime visual inspections.

Certain portions of the life cycle of a sign in North Carolina are computerized and tracked; however, in-place signs are not one of these areas. As previously mentioned, conducting and maintaining an inventory of devices is one of the four basic principles suggested by the ITE Traffic Signing Handbook to "significantly reduce tort liability lawsuits involving traffic control devices" (22). The third alternative suggested by the project team is to establish a sign inventory that would keep record of, at minimum, sign type, sheeting type, and location.

In addition to knowing whether a sign has adequate retroreflectivity, it is essential for sign erectors to know if a sign were missing, so the inventory would act as a guide for sign inspectors. A sign inventory would allow sign erectors and inspectors to know the exact position of all signs, as well as more detailed physical information about the signs. A comprehensive sign inventory can target signs for replacement based on installation dates, identify problems by tracking maintenance records, minimize tort liability by providing evidence of sign existence and maintenance, assist with sign planning and budgeting by knowing how many aging signs are approaching replacement, and maximizing productivity by combining work orders with the inventory (4).

The project committee indicated that the NCDOT's primary interest in a sign inventory would be to help identify missing signs (which are just as much of a liability issue as signs with poor retroreflectivity) and to assist them with creating more efficient budgets for their sign management practices. Very little collection and maintenance effort is wanted. Anything additional, such as pictures and added sign information is an extra bonus.

9.2.3.1 Steps to Preparing A Sign Inventory

An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs (4) lists seven steps to preparing a sign inventory as:

1) Involving Key Personnel
2) Selecting a Location Reference System
3) Choosing Data Elements
4) Selecting Inventory Software
5) Preparing for Data Collection
6) Initial Data Collection
7) Maintaining the Inventory

The development and implementation portions should include an individual or individuals responsible for collecting and entering data, installing, maintaining, and inspecting, signs, and using the inventory. NCDOT already has personnel responsible for several of these tasks. "The success or failure of the inventory depends on the communication between the personnel involved more than any other aspect"(4).

Selecting a location reference system is one of the most important aspects because it affects the manner in which the data will be collected. Some reference systems are route/milepost/distance, link/node/distance, route/intersection/direction/distance, and latitude/longitude (GIS/GPS). The decision as to whether signposts or individual signs should be referenced should also be made (one to one or one to many relationship). This topic will be addressed again in the inventory software section.

McGee et al. identify data elements that are core, or essential for effective sign management and should be included in every inventory. After the core elements, there are critical and desirable elements which "significantly increase the value of the sign inventory" and “may add value to the inventory depending on the needs of the individual user.” Table 36 lists each of the core, critical, and desirable data elements.

Table 36: Core, Critical, and Desirable Sign Inventory Data Elements

CORE	CRITICAL	DESIRABLE
Location (based on selected reference system	Installation Date	Offset
Position (relative to road)	Sign Size	Height
Sign Code (MUTCD)	Sheeting Type	Retroreflectivity
Sign Condition	Backing Type	Inspector
Maintenance Activity	Post/Support Type	Sign ID Number
Inspection/Maintenance Date	Post/Support Condition	Images
	Sign Orientation	Comments
	Traffic Speed on roadway	Any Other Reference Numbers

Source: (4)

An inventory would not replace the current method of nighttime sign inspection. The nighttime sign inspection method would still be used to evaluate the overall condition of signs. The results of the nighttime inspections would be input into the inventory system by indicating whether the sign is or is not visually acceptable, by using, for example, a 0 or 1 for yes or no. A validation system to check the accuracy of night rides using retroreflectometers could be implemented in conjunction with the inventory. A sample of signs would be identified each year and be measured with a handheld retroreflectometer unit. (The measurement of the sample could be included in the duties of the quality control/auditor position if created.) The measured values would be compared with the 0 and 1’s to see if the visual inspections are accurate.

Before data can be collected, a plan of attack needs to be developed. Which signs will be inventoried first? Will there be an inventory priority system? Who will collect the data? How will the data be collected? What equipment is needed? “It is critical that the data collection be organized in a way to allow a subset of the inventory to become operational as quickly as possible” so NCDOT can begin “accruing the benefits from the inventory and demonstrating its usefulness” as quickly as possible (4). The data collection plan could be broken down by road type (Interstate, U.S., N.C), sign type/color, or by division.

The personnel responsible for collecting the data need to be identified. The sign inspection and maintenance personnel in each division responsible for performing nighttime visual inspections could be responsible for data collection on a divisional basis or an independent data collection team could be identified to collect data for all signs statewide. This decision affects the cost of materials and labor required to complete the task as well as the time frame for complete system population. If division personnel perform data collection, more people will be working simultaneously to complete the task and the task will be completed faster. The downside is that more equipment will be required to accommodate all of the different collection teams. If one team is responsible for collecting data statewide, the task will take longer, but less equipment and training would be necessary to complete the task. The cost of labor would probably be about the same with either less people working for a longer period, or more people working for a shorter time period.

Using a phased approach allows task and resources (money, labor, time) to be spread out over time as opposed to trying to pay for and implement an entire system at one time. This is demonstrated in Figure 9.2.

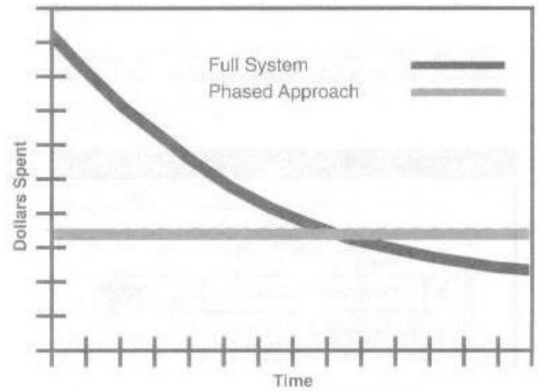


Figure 9.2 Immediate Implementation vs. Phased Approach (38)

Data collection methods include manual field collection, laptop field collection, photologging, and videologging. Manual field collection and laptop field collection are the same except that the first involves inputting data in the office and the second involves inputting data directly into the software in the field. Both methods can use GPS receivers, which were found to be 20 percent faster for obtaining location reference data for urban signs than any other measurement method (4). Photologging and videologging are methods of data collection available in which NCDOT has not expressed interest in exploring. However, cost data for each method is outlined in section 9.2.3.2.1.

Once the system is implemented and populated, it must be maintained. This includes ensuring the system is running properly and that information is input in a timely manner. If a system is not properly maintained, the money and time spent on development and implementation is wasted. Procedures should be set up outlining who is responsible for ensuring the database is being updated and used adequately. System maintenance also requires keeping up with software or hardware updates that may be necessary.

9.2.3.1.1 Off the Shelf Software

As previously described in Section 5.2.1.1, there are many off the shelf sign inventory software packages available. The assessment of available software revealed there are several programs that may be suitable to meet the needs of NCDOT.

9.2.3.1.2 Customized Software

"For state highway departments, customized programs likely will be required due to the need to integrate the sign management system with other information systems and to the large number of potential users at both control and district level"(4). A sample customized sign inventory management system for NCDOT was developed by the North Carolina State University Department of Civil Engineering. The goals of the effort were to determine the feasibility of a sign inventory that would address the issue of retroreflectivity being performed with GPS technology and to determine time and costs related to the creation and implementation of such an inventory.

The study began by identifying fundamental data attributes that should be included in the inventory system. Some of these fundamental attributes were sign location, inspection date, sign condition, and type of sign, all of which were identified as core data elements for an inventory system in Table 36.

A complete list of attributes to be collected for each sign was compiled by assessing the needs of NCDOT. Information collected from various NCDOT Signing personnel was used to create two lists of data attributes, called dictionaries. Table 37 is a listing of the first data dictionary that comprises all attributes that could be collected without getting out of a vehicle.

Table 37: Simple Data Dictionary

Field	Type	Menu	Entry Options	Description
Survey Date	Date	N	Automatic Generation	Date of collection.
Road Name	Text	N	User defined. Manual Entry.	Name of road on which sign is located.
Direction Faced	Text	Y	North, South, East, West, Northeast, Northwest, Southeast, Southwest	Direction sign is facing.
Sign Type	Text	Y	A, B, D, E (Default), F	See Table 8
Sign Sub-Type 1	Text	Y	Warning, Regulatory, Guide, Motorist Info	Category of Sign
Sign Sub-Type 2	Text	Y	Red, Yellow, Fl Yellow-Green, White, Green, Blue, Brown	Sign background color.
Stop	Text	Y	Y, N (Default)	Specifies whether or not sign is a stop sign.
Retro-Reflectivity	Text	Y	Pass, Fail	This is a required entry field.
Multi-Sign Assembly	Text	Y	Y, N (Default)	Specifies whether or not this sign is part of an assembly.
Num Signs Assembly	Numeric	N	1 to 20, User defined. 1 (Default)	Total number of signs in the assembly.
Sign Panel	Numeric	N	1 to 20, User defined. 1 (Default)	Signs are identified left to right, top to bottom on the assembly from 0 to 20.
Overhead Assembly	Text	Y	Y, N (Default)	Specifies whether or not this sign is part of an overhead assembly.
Line of Sight	Text	Y	Adequate (Default), Obstructed	Specifies whether or not this sign has sufficient sight distance available.

Source: (20)

Table 38 is a complete listing of all attributes, some of which require exiting a vehicle to collect, such as the inspection date which must be obtained from the sticker placed on the back of a sign.

Table 38: Complete Data Dictionary

Field	Type	Menu	Entry Options	Description
Survey Date	Date	N	Automatic Generation	Date of collection.
Road Name	Text	N	User defined.	Name of road on which sign is located.
Direction Faced	Text	Y	North, South, East, West, Northeast, Northwest, Southeast, Southwest	Direction sign is facing.
Sign Type	Text	Y	A, B, D, E (Default), F	See Table 8
Sign Sub-Type 1	Text	Y	Warning, Regulatory, Guide, Motorist Info	Category of Sign
Sign Sub-Type 2	Text	Y	Red, Yellow, Fl Yellow-Green, White, Green, Blue, Brown	Sign background color.
Stop	Text	Y	Y, N (Default)	Specifies whether or not sign is a stop sign.
Installation Date	Date	N	User defined. Manual entry.	Corresponds to installation sticker found on back of sign.
Sign Dimensions	Numeric	N	User defined. Manual entry.	Dimensions of sign panel
Sheeting Type 1	Text	Y	Type 1, Type 2, Type 3	Distinguishes between grades of sheeting.
Sheeting Type 2	Text	Y	Glass Bean, Prismatic, Null	To better describe the previous sheeting type.
Post Type	Text	Y	Steel, Wood, Channel	Type of post sign is mounted on.
Retro-Reflectivity	Text	Y	Pass, Fail	This is a required entry field.
Multi-Sign Assembly	Text	Y	Y, N (Default)	Specifies whether or not this sign is part of an assembly.
Num Signs Assembly	Numeric	N	1 to 20, User defined. 1 (Default)	Total number of signs in the assembly.
Sign Panel	Numeric	N	1 to 20, User defined. 1 (Default)	Signs are identified left to right, top to bottom on the assembly from 0 to 20.
Overhead Assembly	Text	Y	Y, N (Default)	Specifies whether or not this sign is part of an overhead assembly.
Line of Sight	Text	Y	Adequate (Default), Obstructed	Specifies whether or not this sign has sufficient sight distance available.

Source: (20)

The locations and attributes of each sign were collected from a vehicle using a Trimble Pro XR GPS Unit and an Advantage laser range finder, both of which are owned by NCDOT. The data collection software used was Pathfinder Office version 2.70. This is the software that comes with the Trimble GPS equipment owned by NCDOT. The data dictionaries were created in the Pathfinder software so that each data field and it's corresponding entry options are available to the user collecting the data.

The road sections on which signs used to populate the sample inventory were congruent with those used in the North Carolina Sign County Studies (Sections 6.3.2.3 and 6.3.2.4). The simple data dictionary was used on most road sections; however, the complete data dictionary was used on one road section. The location reference system utilized in the study was Latitude/Longitude based on GPS coordinate information collected in the field. The study technique involves collecting data in the field utilizing a GPS receiver. This data can be transferred directly from the field unit into the software.

A similar GIS/GPS based sign inventory was implemented in Boulder County, Colorado in 1995. As a result, the need for data entry from paperwork has been eliminated, the information is used to help locate missing signs, employee mileage for sign replacement has been greatly reduced, and paperwork and data entry errors were significantly reduced. Additional results were reduction in the number of hours devoted to paperwork (2 per week), a sense of employee pride and ownership, and increase accuracy of road signs (19).

Any additional costs associated with creating an SIMS utilizing this custom software method would be those associated with labor and vehicles. The GPS and laser range equipment are already owned by NCDOT. This study did not address costs associated with maintenance of the inventory.

The GPS Sign Inventory Study resulted in rates for the minutes per sign required to collect data to populate a customized sign inventory system. Three separate input rates were calculated; two were for collecting data outlined in the simple data dictionary (Table 37) first on Interstate and primary roads, and then on secondary roads. And the third rate was for collecting data that in the complex data dictionary (Table 38), which entails getting out of the vehicle.

For the simple data dictionary, signs located on Interstate and primary routes were inventoried at an average rate of 0.59 minutes or 35 seconds per sign and secondary routes were done at an average rate of 0.75 minutes or 45 seconds per sign. Table 39 calculates the projected amount of time required to populate an inventory with simple data dictionary attributes only.

Table 39: GIS-based Inventory Data Collection Time, Simple Data Dictionary Attributes Only

	Time per Sign (Minutes)	**Estimated Number of Signs**	**Projected Collection Time (Minutes)**	**Projected Collection Time (Hours)**
Interstate and Primary	0.59	400,000	236,000	3,900
Secondary	0.75	615,000	461,000	7,700
TOTAL				**11,600**

Source: (20)

The minutes per sign as calculated by the study was multiplied by the North Carolina Sign Count Studies sign estimates in order to project the number of labor hours required to collect data and populate a customized sign inventory management system with the simple data dictionary attributes only. Approximately 11,600 hours total would be required to populate an inventory with the simple data dictionary attributes. This equates to over 1400 eight-hour workdays and almost 4 person-years.

Results for the complex data dictionary involve getting out of the car to obtain the installation date from the sticker on the back of the sign. The same stretch of a secondary road was evaluated twice, once to collect the simple data dictionary attributes and a second time to collect the complex data dictionary attributes. The simple data took approximately 35 (0.58) seconds per sign to collect and the complex data took 67 (1.11) seconds to collect, a 90% increase.

Assuming an entry-level signing employee or temporary intern has a salary rate of $10 per hour, the cost for two people to complete the 11,600 hours of simple data dictionary attributes collection would be $232,000 plus indirect costs such as equipment, travel time and mileage. A complete copy of the study is included in Appendix J.

9.2.3.2 Sign Inventory Data Collection Costs

Tables 40 and 41 represent various price ranges for manual, photolog, and videolog inventory data collection methods extracted from previous literature. Manual data collection is assumed as a crew of at least two individuals riding by each sign and recording data. Photologging is created by taking one photo image every 0.01 miles, resulting in 100 photos per mile. Each 35-mm still frames of color is used to create positive prints on 35-mm filmstrip and edited onto small reels for viewing on 35-mm stripfilm motion-still analyzers. The resulting film creates a continuously running presentation of the roadway. Videlogging is a video of the roadway created using special van mounted video cameras.

The data in Table 40 represent the inventory data collection costs for roads in urban and rural areas in the state of Minnesota. Costs are represented as dollars per mile.

Table 40: Sign Inventory Data Collection Costs per Mile#1

Area Type	Manual	Photolog	Videolog
Urban	$80 - $135	$45 - $70	$30 - $70
Rural	$15 - $45	$25 - $30	$15 - $25

Source: (1)

Table 41 contains cost data for each of the three inventory methods and includes engineering planning time, field data collection, data extraction and coding, overhead, fringe benefits, travel cost, equipment cost, and materials cost.

Table 41: Sign Inventory Data Collection Costs per Mile #2

Cost per Roadway Mile for Various Inventory Methods			
Area Type	**Manual**	**Photologging**	**Videologging**
Urban area, high density	$134.41	$69.35	$68.88
Urban/suburban area, moderate sign density	$82.61	$46.70	$31.28
Rural/small urban area, low sign density	$43.83	$28.79	$22.11
Rural area, very low sign density	$15.27	$23.47	$16.04

Source: (36)

As of January 2000, the State of North Carolina had 78,083 miles of roadway, 71,106 of which were rural and 6,976 were urban or municipal (24). Based on these mileage counts and the data in Tables 40 and 41, Tables 42 and 43 provide rough cost estimates for sign inventory data collection on North Carolina roads.

Table 42: Cost Estimates for Sign Inventory Data Collection for NC based on Table 43

Range of Cost to Create an Inventory based on Total Miles			
Area Type (NC miles)	**Manual**	**Photolog**	**Videolog**
Urban (6,976)	$558,000 - $942,000	$314,000 - $488,000	$209,000 - $488,000
Rural (71,106)	$1.067 M - $3.2 M	$1.778 M - $2.133	$1.067M - $1.778M
TOTAL (78,083)	$1.625 M - $4.142 M	$2.092M - $2.621M	$1.276M - $2.266M

Table 43: Cost Estimate for Sign Inventory Data Collection for NC based on Table 44

Cost to Create an Inventory for Various Inventory Methods based on Total Miles*			
Area Type (NC miles)	**Manual**	**Photologging**	**Videologging**
Urban area, high density (3,488)	$469,000	$242,000	$240,000
Urban/suburban area, moderate sign density (3,488)	$288,000	$163,000	$109,000
Rural/small urban area, low sign density (35,553)	$1,558,000	$1,024,000	$786,000
Rural area, very low sign density (35,553)	$543,000	$834,000	$570,000
Total (78,083)	$2,858,000	$2,263,000	$1,705,000

*Assumed half of NC urban miles were high density and half were moderate density
** Assumed half of NC rural miles were low density and half were very low density

The costs contained in these tables are data collection costs only; they do not include any long-term maintenance costs associated with the systems or the purchase or creation of any necessary software or hardware.

9.2.3.3 Total SIMS Costs

Adoption and implementation of a sign inventory management system would be a major undertaking for NCDOT. Considerable costs and labor would be involved in order to create a usable, sustainable, system that will be of some benefit in the long run. However, the benefits that a system can provide should be considered as well. A sign management system can assist with the tracking of signs, assist in budgeting, ensure no signs are in place for longer than their anticipated life, provide maps and data to be used during nighttime inspections, and generate statistics about sign replacement.

The costs associated with creating, populating, and maintaining an inventory depends on the combination of software, hardware, collection methods, and maintenance options chosen. Software costs would range from $0 for the existing Trimble Pathfinder software already owned by DOT to $4800 licensing and upgrades costs for off the shelf products evaluated in the software assessment. Data collection costs could range from $228,000 (labor only) to populate an inventory using the GPS Sign Inventory Study method to $1.6 - $4.1 million as determined from existing literature. The wide price range for data collection is due to the differences in collection method (manual, etc.) and labor costs (college interns vs. NCDOT labor). Hardware requirements for the chosen software would need to be determined and if necessary, adequate computers would need to be purchased in order to for NCDOT personnel to be able to access and operate the system. Other equipment that may be necessary, depending on the combination of necessities chosen could include GPS equipment and laptop computers. Labor is included in the data collection estimates. Training sessions would also be necessary to educate employees how to use the new system.

Ongoing maintenance and upgrades costs would also be required. If an off the shelf software program were purchased, licensing and software upgrades would have to be purchased periodically. Continuous upkeep and population of a system, once implemented, could be integrated into the current duties of signs inspection employee. As new signs are installed, it would become standard practice to input data for the sign into the system.

Over time, the "initial costs of developing the inventory will prove to be cost effective over the long run as it will minimize the costs of inspection and allow the responsible office to more effectively manage their system." A well-developed and maintained sign inventory management system will also serve as "a good defense against a negligence suit because it shows an organized attempt to maintain signs" (36).

9.2.4 Combination Alternative (2 + 3)

It has been suggested by NCDOT that even if an inventory were established and maintained, it would not be possible to completely eliminate the visual method, because the inventory would not be able to identify missing signs. So alternative four is a combination of the second alternative, which is to continue with the current method of nighttime sign inspection but make improvements to the training and record-keeping, and the third alternative, implementing a sign inventory. Neither of the two alternatives is dependent on the other, but combining the two could provide NCDOT with the benefits of both. This alternative hopes to prove that long-term benefits and cost savings can be achieved by implementing both still at a feasible cost.

By combining two of the previous alternatives, some actions necessary to each one individually could be combined for costs savings. For example, the training class from alternative number two could be expanded to teach sign inspection employees how to maintain the inventory system and use equipment and hardware necessary to populate and maintain the inventory system. Also, if two and three are combined, then the employee position created from alternative two could be responsible for assisting with inventory data collection and maintenance. The employee could be responsible for overseeing the data collection process and for long-term maintenance of the inventory software and hardware. Their rotational visits to divisions throughout the state, in addition to the duties previously outlined, could include ensuring divisions are keeping the inventory system properly maintained, providing impromptu training for new employees, and ensuring that the hardware in each division is adequate. But most importantly, retroreflectivity values measured from the sample of signs collected by this employee could be input into the inventory system.

9.2.4.1 Costs

The costs would include the total and ongoing costs of alternative 2 as listed in Table 38 and the costs to implement and maintain an inventory as outlined in alternative 3. Table 44 shows these values.

Table 44: Costs Associated with Alternative #4

	INITITAL	**ONGOING (per year)**
ALTERNATIVE 2	$363,500 - $405,500	$257,600
ALTERNATIVE 3		
Software	$0 - $4000	$0 - $800
Data Collection	$228,000 - $2.85M*	-
TOTAL	**$591,500 - $3.26 M**	**~$258,000**

* Average of $1.6 - $4.1 million

This combination alternative is the most costly of the four alternatives examined. However, this alternative would provide the maximum benefits to NCDOT: a sign inventory management system is created, employee training is enhanced with the anticipated results of better visual signs inspection techniques, and a new position is created to ensure the suggested improvements are continued and the inventory system is properly maintained and does not become extinct or out of date.

10.0 QUANTITATIVE EVALUATION OF VISUAL INSPECTION METHOD

There has been speculation as to whether the nighttime visual inspection method is effective in determining if signs are maintaining adequate retroreflectivity levels because it does not provide numerical data. By using data from existing literature and the State of North Carolina, it is the intent of this section to make an effort to predict the number of signs not in compliance after a nighttime visual inspection is performed and to determine if altering the nighttime ride frequencies or accuracy percentages from the Washington state study affect the percentage of signs not in compliance after the inspection.

According to the Washington State Department of Transportation *Traffic Sign Retroreflectivity Measurements Using Human Observers*, the observers made correct decisions on 74% of warning signs and 75% of stop signs (14). The study was based on 17 observers rating of warning and stop signs in a laboratory setting, a controlled highway setting, and an uncontrolled highway setting. Warning and stop signs were chosen because of their "high relative importance" and because they are commonly used. The uncontrolled highway setting took place on two road courses, a rural highway containing 76 signs and an urban highway containing 54 signs. A scale of 0 – 4 (see Table 49) was used by each observer to rate the signs.

Table 45 contains results of the experiment. The table is "broken down by warning and stop signs as well as by rural and urban". The distinction is also made between median and individual. The median figure represents the median judgment of all seventeen observers participating in the experiment; median represents "the most likely rating a trained observer would give a sign". "Any inconsistency among observers was averaged in the median decision". The individual figure represents the average sign replacement decisions for all of the observers. "The trained observer as an individual is only slightly less accurate than the group" (14).

Table 45: Results of Highway Experiment

Observers Decision	Replace		Do Not Replace	
Decision Model	**Replace**	**Do Not Replace**	**Replace**	**Do Not Replace**
WARNING SIGNS				
Rural				
Number of Signs	15	0	0	41
Median	13	9	2	32
Individual	13	10	2	31
Urban				
Number of Signs	11	0	0	19
Median	9	6	2	13
Individual	8	7	3	12
TOTAL SIGNS	26	0	0	60
MEDIAN	22	15	4	45
INDIVIDUAL	21	17	5	43
STOP SIGNS				
Rural				
Number of Signs	9	0	0	11
Median	7	2	2	9
Individual	6	2	3	9
Urban				
Number of Signs	18	0	0	6
Median	14	0	4	6
Individual	13	1	5	5
TOTAL SIGNS	27	0	0	17
MEDIAN	21	2	6	15
INDIVIDUAL	19	3	8	14
COMBINED				
TOTAL SIGNS	53	0	0	77
MEDIAN	43	17	10	60
INDIVIDUAL	40	20	13	57

Source: (14)

The table "summarize[s] the decisions of the observers and the decision model for the highway experiments"(14). It is broken down by warning and stop signs as well as by rural and urban settings.

Figures 10-1 and 10-2 represent the primary results of the uncontrolled highway portion of the study, the objective of which was to compare "the individual observer rating of the signs and the rating of the signs calculated by using the retroreflectometer". The data are based on the median results of 17 observer's ratings of 86 warning signs and 44 stop signs.

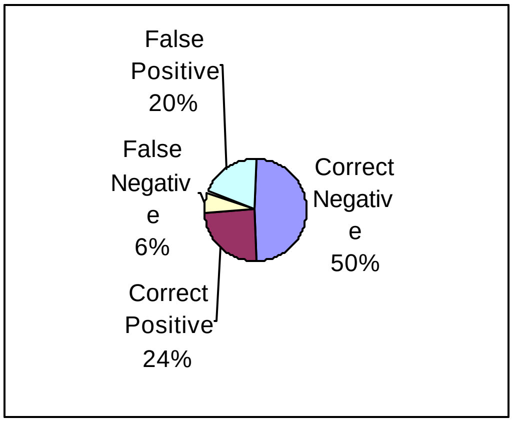


Figure 10-1: Decision Percentages for Warning Signs (14)

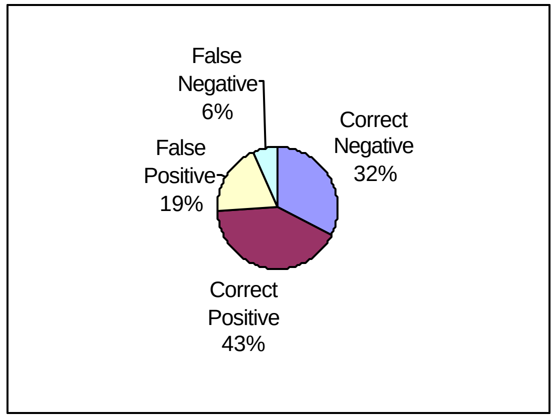


Figure 10-2: Decision Percentages for Stop Signs (14)

In Figure 10-1, of the 74% reported accuracy for warning signs, 50% was the correct decision not to replace a sign (correct negative) and 24% was the correct decision to replace a sign (correct positive). Of the 26% inaccuracy, 6% of the signs should have been replaced and were not (false negative) and 20% of the signs should not have been replaced and were (false positive). Thirty percent of the warning signs, whether evaluated correctly by observers or not, were identified by a retroreflectometer as needing replacement.

In Figure 10-2, of the 75% accuracy for Stop signs, 43% was the correct decision to replace a sign (correct positive) and 32% was the correct decision to not replace a sign (correct negative). Of the 25% inaccuracy, 6% of the signs should have been replaced and were not (false negative) and 19% should not have been replaced but were (false positive) as shown in Figure 10-2. A total of 61% of stop signs needed replacing whether evaluated correctly by observers or not.

Sign sheeting type was not a factor during any portion of the study. This is congruent with North Carolina sign inspection practices because sign sheeting is not considered during nighttime sign inspections, only whether the sign is sufficiently visible or not. The observers in the Washington State study rated the retroreflectivity of signs based on their visual judgments using a scale of 0 to 4. Table 46 lists each rating category, the corresponding SIA (R_A), and a description of the category. Any signs rated 0 or 1 would be replaced and signs receiving a rating of 2, 3, or 4 would remain in place. Although the observers in the study received only limited amounts of training, the "inconsistency among observers was averaged in the median decision" (14).

Table 46: Sign Ratings

Rating	Corresponding SIA value (cd/sf/fc)	Description
0	0-7	Worst retroreflectivity
1	7-19	Low retroreflectivity or other defect, sign ready for replacement
2	19-37	Adequate retroreflectivity, looks okay, some defects but does not need replacement
3	37-70	Good retroreflectivity
4	> 70	Brand new sign

Figures 10-3 and 10-4 are the frequency distributions of the observer ratings for the warning and stop signs, respectively. The X-axis represents the sign observer's ratings and the Y-axis represents the sign ratings as determined by a retroreflectometer.

KEY
36 (18%) = Observations (Percent of Observations)

SIA	Sign Category, Retroreflectometer		Observer Rating 0	Observer Rating 1	Observer Rating 2	Observer Rating 3	Observer Rating 4	
			REPLACE	REPLACE	DO NOT REPLACE	DO NOT REPLACE	DO NOT REPLACE	
70	DO NOT REPLACE	4	0 (0%)	2 (4%)	6 (12%)	23 (45%)	20 (39%)	51 Observations
37	DO NOT REPLACE	3	18 (2%)	124 (15%)	314 (39%)	263 (32%)	97 (12%)	816 Observations
19	DO NOT REPLACE	2	5 (2%)	63 (24%)	125 (47%)	57 (21%)	16 (6%)	266 Observations
7	REPLACE	1	39 (20%)	110 (55%)	36 (18%)	10 (5%)	3 (1%)	198 Observations
0	REPLACE	0	86 (87%)	8 (8%)	4 (4%)	1 (1%)	0 (0%)	99 Observations

Sign Category. Observer Rating

Figure 10-3: Frequency Distribution of Observer Ratings for Warning Signs (14)

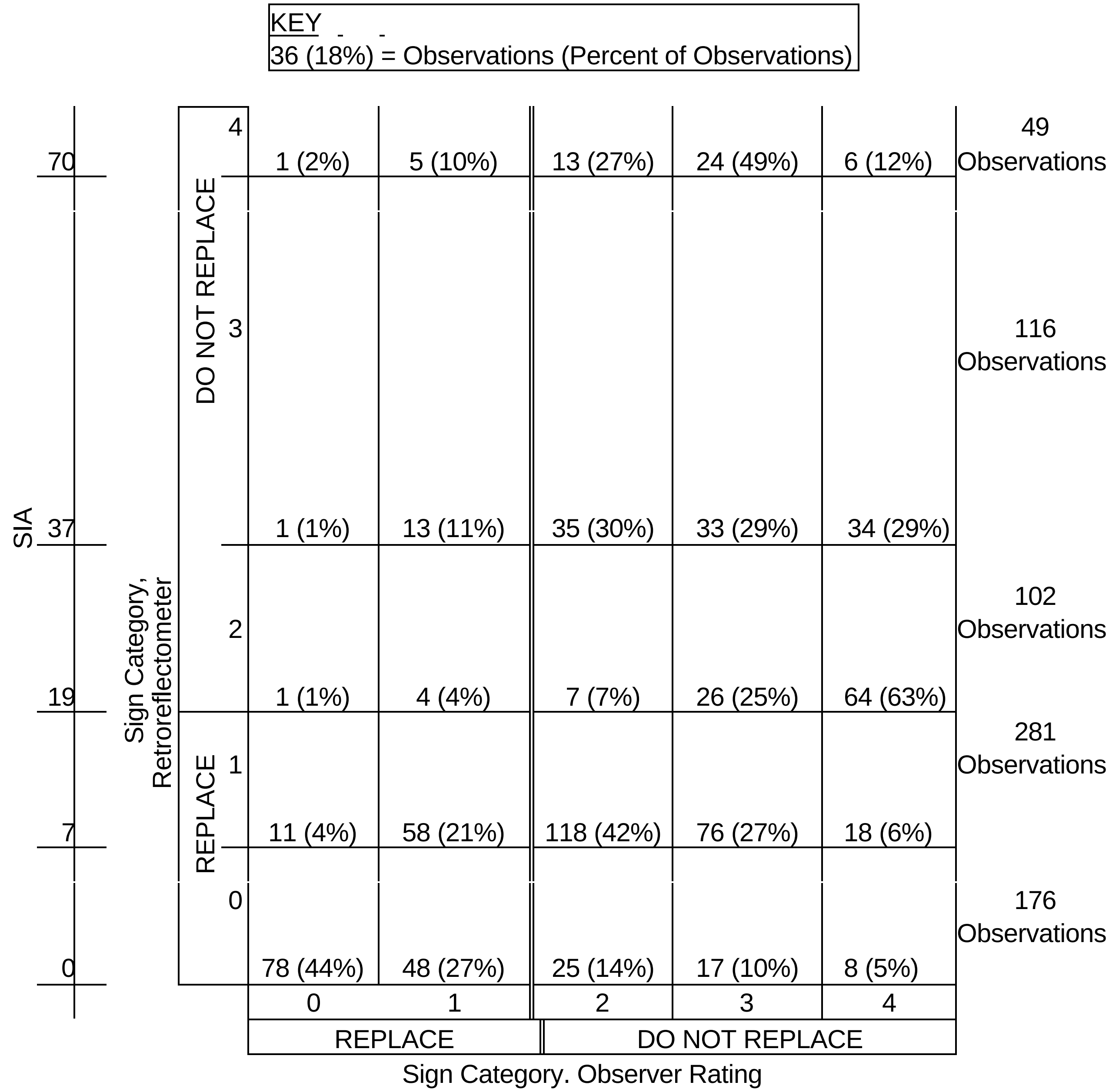


Figure 10-4: Frequency Distributions of Observer Ratings for Stop Signs (14)

The research team used the percentages in Figures 10-1 and 10-2 along with the frequencies listed in Figures 10-3 and 10-4 to try and determine how many noncompliant ("bad") signs are in place at any point in time in North Carolina during a seven-year period assuming NCDOT inspectors perform as well as those in the Washington State study. Seven years was chosen because it is the 'assumed' useful life of a sign manufactured using engineer grade sheeting. Seven years is neither a stated standard nor a written NCDOT policy, however, it is sort of an 'unstated' replacement time frame for signs.

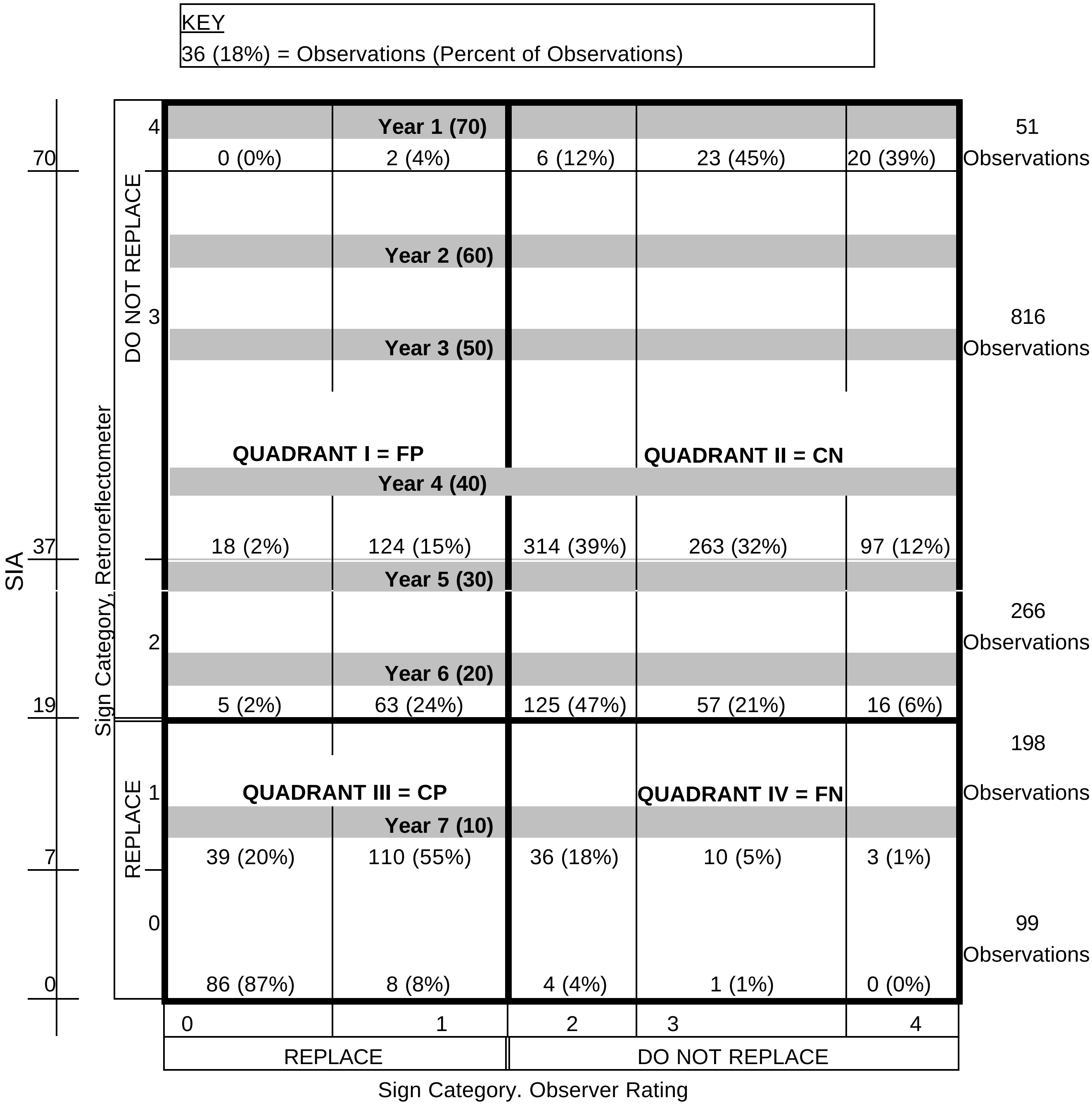
Table 47 lists the estimated counts of 'Stop' and warning signs on North Carolina roads, broken down by road type.

Table 47: Warning Sign Count Estimates for North Carolina based on Road Type

	WARNING		**WARNING TOTAL**	**STOP**
	Yellow	Orange		
Interstate	3,100	1,700	4,800	0
Primary	88,000	10,000	98,000	1,600
Secondary	286,000	10,000	296,000	51,000

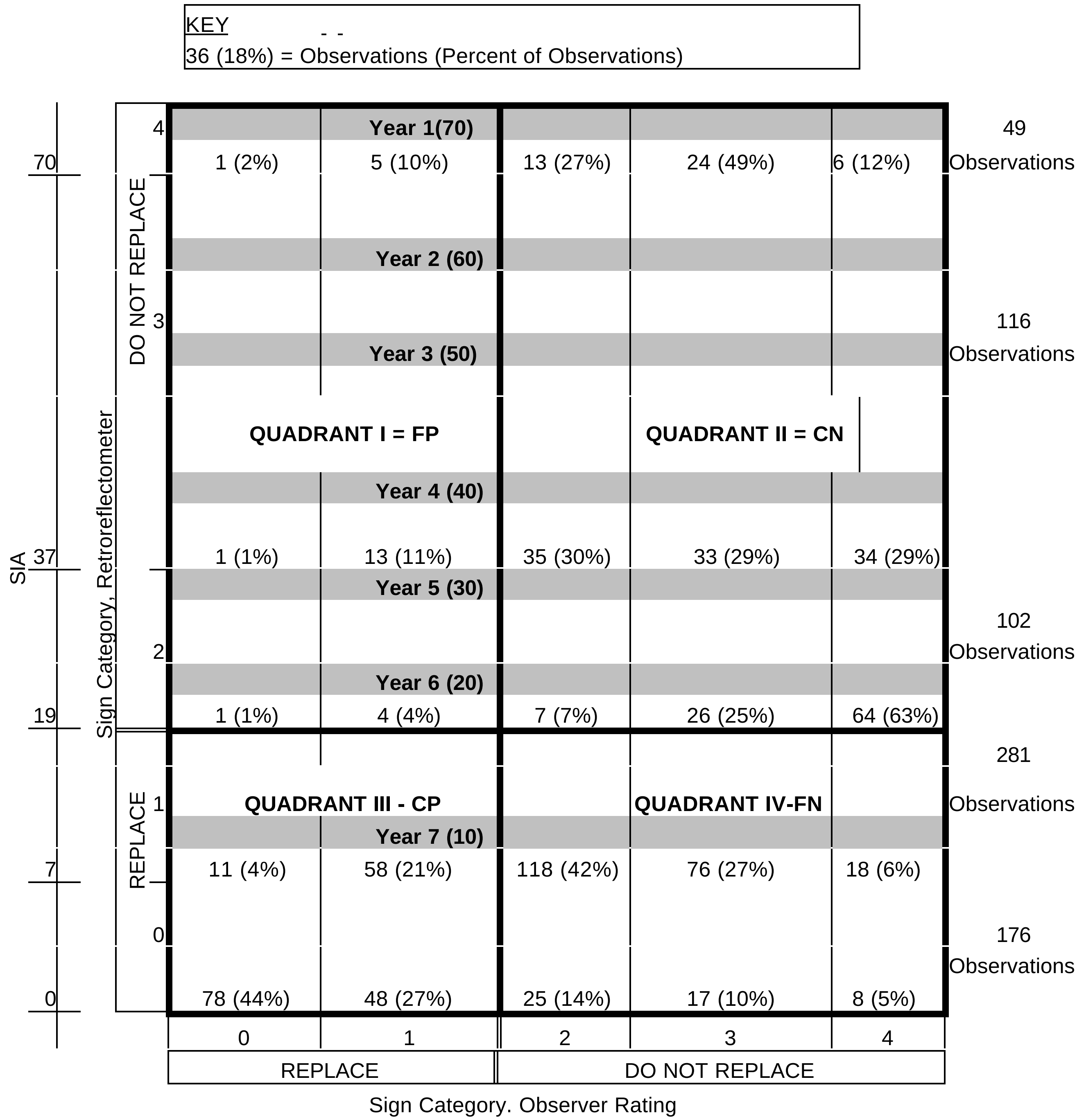
Source: (5)

Estimates of the yearly degradation of a single sign over 7 years were added to figures 10-3 and 10-4. Assuming the maximum SIA (R_A) value of brand new engineer grade warning sign is 70, [established in a study by Mace cited in Washington State study] and it decreases by 1/7 each year for seven years, it would eventually decrease to a value of 10 in year 7. Figures 10-5 and 10-6 show that a sign replaced in year 1 would slowly decrease through the observer rating scale and the retroreflectometer rating scale for warning and stop signs respectively. This degradation estimate is very conservative considering that signs would most likely not degrade at a linear rate and be at an SIA value of 10 in year 7. But this conservancy also accounts for signs that may degrade faster than anticipated due to weather or damage or need replacing before their useful life is up because of vandalism or other damage. The fact that all signs are not manufactured using the same sheeting grade material must also be considered.. Many ‘yellow’ warning signs, are actually fluorescent diamond grade school and pedestrian crossing signs.



Quadrant I: False Positive (FP) = Incorrect Decision to Replace
Quadrant II: Correct Negative (CN) = Correct Decision to Not Replace
Quadrant III: Correct Positive (CP) = Correct Decision to Replace
Quadrant IV: False Negative (FN) = Incorrect decision to Not Replace

Figure 10-5: Degradation Rate of 1/7 per year for Warning Signs Overlaid on Figure 10-3



Quadrant I: False Positive (FP) = Incorrect Decision to Replace
Quadrant II: Correct Negative (CN) = Correct Decision to Not Replace
Quadrant III: Correct Positive (CP) = Correct Decision to Replace
Quadrant IV: False Negative (FN) = Incorrect decision to Not Replace

Figure 10-6: Degradation Rate of 1/7 per year for Stop Signs Overlaid on Figure 10-4

A table was created that projects the percentages from Figures 10-1, 10-2, 10-5, and 10-6 onto the total estimated number of warning (yellow and orange) and 'Stop' signs on Interstate roads in North Carolina in an effort to determine the percent of signs potentially not in compliance during any given year of the seven-year sign life cycle. An example of the entire table and an explanation of each column and calculation are contained in Appendix K.

The same spreadsheet format was used to evaluate visual inspection of warning signs on Interstate roads, primary roads, and secondary roads. In addition, calculations for stop signs on primary and secondary roads were performed. (The same tables were altered to perform the altered frequency evaluations in Section 9.2.2.5.) There were, however, some differences between the calculations for Interstate, primary, and secondary roads because of the different evaluation frequencies. For Interstates the data were carried over to each successive year because they are evaluated every year. But for primary and secondary roads, the data calculations skip every other year and every third year, respectively, because primary roads are evaluated every other year and secondary roads every third year.

For example, on primary roads, the data from year 0 is carried down to year 2; only one-half of signs are considered each year because a different set of signs are evaluated in year 1. And on secondary roads, the data from year 0 is carried to year 3 and one-third of the total number of signs is evaluated each because a different third of signs are evaluated in years 1 and 2.

Each spreadsheet was set up to perform calculations for three consecutive seven-year cycles. The first seven-year cycle is not considered in the following results tables. This is because initially in year 0, it was estimated that an equal number of signs were replaced in years 1 through 7, which is not realistic. But after a seven-year cycle is complete and year 0 begins again, all of the numbers are calculated by the spreadsheet, they are no longer assumed.

The evaluation frequencies used by the North Carolina DOT are based on road mileage, not number of signs. This evaluation method assumes there are an equal number of signs on each group of road segments when the roads are split into one-half or one-third. This is not realistic however, it is not anticipated that this fact affects the results of the analysis.

Table 48 shows the change in percent accuracies and the percent potentially not in compliance as the years progress for each of the evaluations performed. The percent of signs potentially not meeting the standard after inspection only considers signs that need to replaced and are not, but percent accuracy considers those signs as well as signs that should not have been replaced and were.

Table 48: Percent Accuracy and Percent Potentially Not In Compliance

	INTERSTATE		PRIMARY			
	WARNING		WARNING		STOP	
YEAR	% Accuracy	% potentially not meeting standard after inspection	% Accuracy	% potentially not meeting standard after inspection	% Accuracy	% potentially not meeting standard after inspection
0	83.2	2.37	83.2	10.96	83.2	10.70
1	83.3	2.26	83.2	10.41	83.2	10.41
2	83.4	2.14	83.4	10.40	83.4	10.40
3	83.4	2.04	83.4	9.26	83.4	9.27
4	83.2	2.01	83.4	9.21	83.4	9.21
5	83.2	2.00	83.4	7.83	83.4	7.82
6	83.2	2.14	82.6	7.76	82.6	7.77
7	83.2	2.15	82.6	9.71	82.6	9.70
0	83.3	2.13	83.1	9.81	81.8	9.81
1	83.3	2.10	83.1	9.72	83.1	9.72
2	83.3	2.08	83.1	9.71	83.1	9.72
3	83.2	2.08	83.2	9.18	83.2	9.17
4	83.2	2.08	83.2	9.15	83.2	9.15
5	83.2	2.11	83.2	8.70	83.2	8.70
6	83.2	2.11	82.9	8.68	82.9	8.68
7	83.3	2.10	82.1	9.42	82.9	9.42

SECONDARY			
WARNING		STOP	
% Accuracy	% potentially not meeting standard after inspection	% Accuracy	% potentially not meeting standard after inspection
80.8	15.20	80.8	15.20
82.0	19.16	82.0	19.16
82.6	20.50	82.6	20.51
83.4	19.93	83.4	19.93
83.3	20.09	83.3	20.09
83.8	19.48	83.8	19.48
84.2	17.72	84.2	17.72
83.6	15.33	83.6	15.32
82.9	15.03	82.9	15.03
82.1	16.73	82.1	16.73
82.6	18.51	82.6	18.51
82.9	19.09	82.9	19.09
83.3	18.77	83.3	18.77
83.2	18.75	83.2	18.75
83.4	18.47	83.4	18.47
83.6	17.75	83.6	17.75

The percent of signs not meeting standard after inspection is less after two consecutive seven-year life cycles. However, the decrease is not consistent. This fluctuation is caused by the fact that the number of signs being evaluated each year and the number of signs still in place that are not in compliance is not the same.

On primary roads, there are a few years where there are significant increases in the percent of signs potentially not in compliance from one year to the next. For years 0 through 6 for warning signs on primary roads, there is a consistent decrease in percentage. But from years 6 to 7, there is an almost 2% increase. Further inquiry into the spreadsheet revealed that the jump is caused not because the number of signs needing replacement that are not replaced increases (this number, represented by column Z, is the same from year 6 to 7), but because the number of signs that are potentially not in compliance that are not in the 50% of signs to be evaluated this year increases.

The potentially non-compliant signs in the 50% not evaluated this year were installed in year 0 and are seven-years old. Previous to year 0, the results were based on an equal number of signs being replaced every year. However, in year 0, a new cycle is created in which a true representation of half of all signs being evaluated each year begins. And this means that more signs are considered every year, so the number that was potentially not replaced in the previous evaluations also increases. This sign total is added to the number of signs that were evaluated and not replaced in order to determine the percent of signs potentially not in compliance regardless of whether they were evaluated in the current year or not.

A noticeable change for secondary roads is the increase in percent of signs potentially not in compliance over years 0, 1, and 2. This is because a different set of signs is evaluated in each of these years. Any signs that were not replaced and should have been in year 0 are not evaluated in year 1. But because they are still not in compliance and must be considered, they are added to the total of signs potentially not in compliance after the evaluation in year 1. This is done once again in year 2. This is what causes the increase in years 0, 1, and 2. This trend also affects the second cycle because it is also seen in years 0, 1, and 2 in the next and all subsequent cycles.

Because the spreadsheet is intended to represent an ongoing cycle, the percent of signs potentially not in compliance will continue to fluctuate for several reasons. One is because the percent of false negatives is always 25% based on Figures 10-1 and 10-2 so it will never be 0%. Also, the spreadsheet cannot establish the point where all signs being replaced in previous years (spreadsheet column F) equals or exceeds the number having been replaced since year 0, which probably effects the fluctuation in the percent of signs potentially not in compliance.

The table also reveals that the percent accuracy of the sign inspections levels off around 83% every year. This is expected because the majority of signs not needing replacement that are correctly identified are evaluated at this percentage range (columns L, M, N, and O).

10.1 Altered Accuracy Percentages

The 74% and 75% accuracy numbers were achieved from a combination of multiple observers on one sign set. However, the observations were taken within a time frame of less than one year. Because NCDOT evaluates their signs at ongoing frequencies, their accuracy would be much higher overall. It is assumed that because the observers used in the Washington State Study, from which the accuracy percentages were extracted, were amateurs that the accuracy rate of the sign observation personnel in North Carolina would be greater.

This assumption is also supported by the fact that it is not uncommon for observers to refer to the inspection sticker on the back of a sign to determine when the sign was installed, leading to a decrease in the amount of signs replaced prematurely. In addition, it is assumed that if a training program were implemented, the percent accuracy would improve as well. The evaluation spreadsheets were re-formulated using increased percentage accuracies. Table 49 includes the altered percent accuracies for warning and stop signs, respectively. The original percentage is included in parenthesis. The following table corresponds with columns L, M, N and O on the evaluation spreadsheet.

Table 49: Adjusted Percent Accuracies for Warning and Stop Signs

(D) Sign is _ years old	**(J) Estimated SIA Value of signs replaced in year X ***	**(K) Rating a Sign Should Receive from an Observer**	**(L) Signs installed in this year need replacing**	**(M) % of signs needing replacement correctly identified (CP)**	**(N) % of signs needing replacement incorrectly identified (FN)**	**(O) % of signs NOT needing replacement correctly identified (CN)**	**(P) % of signs NOT needing replacement incorrectly identified (FP)**
9	0	0	Y	96.5 (95)	3.5 (5)		
8	0	0	Y	96.5 (95)	3.5 (5)		
7	10	1	Y	82.5 (75)	17.5 (25)		
6	20	2	N			81.8 (74)	18.2 (26)
5	30	2	N			81.8 (74)	18.2 (26)
4	40	3	N			88.1 (83)	11.9 (17)
3	50	3	N			88.1 (83)	11.9 (17)
2	60	3	N			88.1 (83)	11.9 (17)
1	70	4	N			97.2 (96)	2.8 (4)

*Adjusted percentage (original percentage)
*According to Figures 10-5 and 10-6

Decreasing the percent incorrectly identified (columns M and O) by 30% and then adjusting the percent identified correctly accordingly (100% - column M or O) was the method used to calculate the percentage increases.

The expected result was an increase in the percent accuracy (column EE) and a decrease in the percent of signs potentially not meeting the standard after evaluation (column FF). After two complete sign inspection cycles (14 years), increasing the percent accuracy produced the unexpected result of also increasing the percent of signs potentially not in compliance as shown in Table 50. The percent accuracy, however, did increase as expected.

Table 50: Comparison of Percent Potentially Not in Compliance for Original and Altered Accuracy Percentages

Road Type - Sign Type	**Percent of signs potentially not in compliance for original accuracy percentages**	**Percent of signs potentially not in compliance for altered accuracy percentages**	**Differenc e**	**Percent Change**
Interstate – Warning	2.15	1.78	0.37	1.72%
Primary – Warning	9.42	10.70	-1.28	-13.5%
Primary – Stop	9.41	10.69	-1.28	-13.6%
Secondary – Warning	17.75	19.27	-1.52	-8.6%
Secondary – Stop	17.75	19.27	-1.52	-8.6%

A closer look was taken at the spreadsheet to determine why there were more signs not meeting the standard each year even though the accuracy of inspectors was improving. After reviewing the altered accuracy spreadsheets, it was discovered that the number of signs needing replacement and being replaced each year did improve. However, the number of non-compliant signs in-place and not evaluated in the year being evaluated increased. This is caused by a chain reaction of calculations in the spreadsheet, which is explained in the following paragraphs.

Increasing the percent accuracy (Table 50) causes the total number of signs replaced correctly (column W) to go up and the total number of signs replaced incorrectly (column X) to down, as anticipated. As a result, the total number of signs replaced overall decreases. This means that there are more signs replaced in a specific year still in place in the following years.

The spreadsheet also takes into account the number of signs not in compliance that are not evaluated in the current year. So, for warning signs on primary roads, beginning in year 6, the signs installed in Year –1 are now seven years old but are not evaluated in the current year 6. So the number of signs installed in year –1 that are still in place in the current year 6 are neither in compliance nor evaluated this year.

But, because in all years prior to year 6 the signs installed in year –1 did not need replacing, any signs that were replaced were replaced incorrectly. When the percentages are altered, less signs installed in year –1 are replaced (the false negatives decrease) which means more signs installed in year –1 are in place in year 6. This also means are more signs that are seven years old and not in compliance that are not evaluated in year 6 because of the every other year frequency on primary roads. This larger number is added to the total number of signs that should have been replaced in the current year (column Z) and the signs that should have been replaced in the previous year and were not (column AA) to equal the total signs potentially not in compliance in year the current year 6 (BB). So, the percent of signs potentially not in compliance increases.

Table 51 is a comparison of columns extracted from the original and altered spreadsheet for warning signs on primary roads.

Table 51: Comparison of Selected Data from Year 6 for Original Percentages and Altered Percentages

Current Year n	(C) Signs installed in Year X	(E) Number of Signs Newly Installed in Year X	(F) Total Installed in Year X replaced before year n	(G) Number of signs from Year X still in place in year n
Year 6 – Original %	-1	7,055	3,458	3,579
Year 6 – Altered %	-1	7,055	2,576	4,479

Table 51 (con't)

	(W) Total signs replaced correctly	(X) Total signs replaced incorrectly	(Y) Total signs replaced	(Z) Total that should have been replaced and were not	**(AA) Total signs that should have been replaced in previous years and were not that were not evaluated in the current year**	(BB) Total signs potentially not in compliance in year n	(CC) Total signs evaluated incorrectly
Year 6 – Original %	4,731	8,742	13,493	249	**4,980**	5,229	8,991
Year 6 – Altered %	5,.395	6,077	11,473	196	**5,591**	5,787	6,273

	(EE) % evaluated incorrectly	(FF) % potentially not in compliance not meeting standard after evaluation
Year 6 – Original %	81.8%	5.29%
Year 6 – Altered %	87.3%	5.86%

As shown in Table 51, the total signs replaced correctly (column W) increases and the total signs replaced incorrectly decreases (column X) as expected. But, because fewer signs in years prior to the current year 6 were replaced incorrectly for the altered percentage table (column F), there are more signs installed in year –1 still in place in the current year 6 (column G). (I must note that the signs installed in year –1 that are not evaluated this year do not have a chance to be replaced because they 'expire' in the current year but are not evaluated in the current year).

The total of column AA (which also accounts for signs that should have been replaced the previous year and were not) is added to the signs that should have been replaced in the current year (column Z) and were not to create a total number of signs potentially not in compliance in the current year (regardless of whether they were evaluated or not) (column BB).

Column BB is divided by the total number of specified signs on the specified road type (warning signs on primary roads in this example) to determine the percent of signs potentially not in compliance (column FF). The percent accuracy is calculated using the total number of signs evaluated correctly for the current year (column X plus column Z). So the percent accuracy does increase.

In order to see that increasing the percent accuracy does improve the overall condition of signs on North Carolina roads, the total number of signs evaluated correctly and incorrectly must be looked at. The percent of signs potentially not meeting the standards does not accurately depict the condition of signs.

So although the percent of signs potentially not in compliance appears to increase as a result of altering the percent accuracies to reflect improvement, in reality, less signs are replaced incorrectly and more signs are replaced correctly. The spreadsheet does not account for observer judgment because a human observer may take into consideration that a signs may not be evaluated for another year or two depending on the designated frequency for the road type they are on. The spreadsheet is unable to make such determinations.

10.2 Quantitative Evaluation Conclusions

The nighttime visual inspection method seems to adequately identify the signs that are not meeting the standards. But it is overly effective in that many more signs that do not need replacing are replaced prematurely, costing the state extra money. If in one year there are 500 stop signs replaced that did not need replacing, and each signs is approximately $18.50, then $9,250 would be wasted replacing signs unnecessarily. This amount is minimal in comparison to the $2.5 million dollars spent to replace signs that are no longer reflective. In addition, premature sign replacement accuracy is probably better on NC roads because for questionable signs, the installation date sticker on back of each signs is checked, a procedure that was not done by the observers in the sign study. So, the percent accuracy of NC sign observers is assumed to be higher than that which was calculated. Plus, it is better to be overly cautious when the opposite scenario is the state's liability risk.

The spreadsheets do not account for signs that are replaced prematurely due to vandalism or accidents. The spreadsheet also cannot account for evaluator judgment in situations where a sign may be replaced early because it will not be evaluated again for 1 or 2 years.

Although signs being replaced when they do not need may cost extra money, the replacement ensures continued visual adequacy. The remaining inaccuracies accounts for signs that should have been replaced and were not, or the percent of signs not meeting the standards, leaving a liable sign still in place.

The accuracy of the visual inspection method plateaus at about 83%. This is close to the average accuracy rate over seven years among all SIA values. Although 83% accuracy may not seem very high, this percentage not only takes into account the signs that should be replaced and are not, but also the signs that should not be replaced and are. So the inaccuracy also accounts for false negatives.

Also, 83% accuracy is the worst-case scenario. The study from which the percent accuracies were obtained used persons with training administered specifically for the purpose of the study, not full time sign personnel. In North Carolina, experienced personnel perform the evaluations each year and they use additional evaluation techniques such as taking into consideration that a sign on a secondary road may not be evaluated again for another two years and may need replacing now to ensure it does not go bad during those two years. Also, they may get out of the car to check the installation date on the sticker on the back of the sign or see if it may only need cleaning. So, it is anticipated that the percent accuracies for North Carolina would be higher.

However, over time, the number of signs that potentially do not meet the standard drops, which is the most important factor. One hundred percent accuracy is not possible with any measurement method, but visual inspection at a reasonable frequency with trained observers does provide a low percentage of in-place signs not meeting the proposed standards.

11.0 CONCLUSIONS AND RECOMMENDATIONS

Ensuring proper retroreflectivity of all signs, whether covered by the standard or not, is an important issue to state agencies. Signs play an integral part in driver safety during the day, but more importantly at night when retroreflectivity is most important because of the decrease in natural light sources.

This paper, through extensive literature review and research, has attempted to evaluate the current North Carolina DOT sign inspection methods and formulate new or improved alternatives to these methods in order to ensure compliance with the forthcoming retroreflectivity standards, improve driver safety, and reduce the potential of tort claims and liability against the state.

In Section 4, a review was made of retroreflective measurement methods, including handheld and mobile units. Information technologies such as GPS, GIS, and sign inventory software were evaluated in Section 5 to determine if they might be applicable to an alternative solution. Section 6 discussed general information about signs. More importantly, it included data used to create estimates of the number of signs in the State of North Carolina, including two independent studies performed specifically on North Carolina roads. Section 7 focuses on liability and the possibility of the state being exposed to increase tort claims and litigation due to the forthcoming standards. It was concluded that in the past, very few claims have been filed relating to negligent sign maintenance, but any additional efforts made to increase driver safety is a protective measure against liability. Any costs related to implementing an alternative is easily worth the cost when compared to a potential $500,000 maximum claim award amount.

Section 8 explains the methodology used to formulate alternatives suggested to the NCDOT research committee. Section 9 explains in detail four alternatives selected as a result of committee feedback; a detailed description of what each entails, including cost, is outlined. The four alternatives were:

1) Maintain the current method (nighttime visual inspection),
2) Improve on the current method,
3) Implement a sign inventory management system, and
4) Combination of #2 and #3

These four alternatives are representative of ideas deemed acceptable by NCDOT. There may have been one or more other alternative options that were not acceptable to NCDOT, but may still be possible options for meeting the task of ensuring maximum compliance with the forthcoming retroreflectivity standards. No matter what alternative or sign evaluation method is chosen (visual or numerical), it is impossible to achieve 100% accuracy of all signs at all times. However, it is possible to be very close.

The evaluation of the visual sign inspection method (Section 10) revealed that a thorough and accurate visual sign inspection program could serve adequately to ensure that signs have proper visibility (and meet the proposed standards). It is anticipated that the experience of NCDOT personnel would result in higher accuracy rates, leading to decreases in the percent of signs potentially not in compliance after the visual inspections.

Many of the suggested improvements in alternative 2 could also lead to a decrease in the percent of signs not in compliance after visual evaluations, such as altering the frequencies at which signs are evaluated. Secondary roads comprise 60% of all signs, yet are evaluated the least often. Secondary roads also contain the highest percentage of stop (98%) and orange and yellow warning signs (75%) signs that should be evaluated more often. Evaluating all roads every other year (50% each year), does not make much of a change in the quality of signs on Interstates and there was a considerable difference in changing secondary roads from every third to every other year. Even the estimated $20,000 a year increase in spending on nighttime visual sign inspections seems justified when compared to a potential $500,000 liability maximum.

The SIMS software assessment did not result in the recommendation of any single software that seemed most appropriate for NCDOT's objectives.

11.1 Objectives Met by Alternatives

Table 52 lists the desired objectives of the alternatives and indicates which alternatives meet the objective. A 'y' indicates yes an alternative meets the objective and an 'n' means no the alternative does not meet the objective. All of the objectives are congruent with the wants of the NCDOT research committee as expressed in the December 5, 2001 feedback meeting and the goals and objectives of my project.

Table 52: Alternative Objectives

OBJECTIVE	**1**	**2**	**3**	**4**
Minimizes/Reasonable Cost	N	N	N	N
Improves/increases compliance with proposed standards	N	Y	Y	Y
Use Technology	N	Y	Y	Y
Reduce required labor	N	N	N	N
Integrates current resources and procedures	Y	Y	Y	Y
Helps do other functions (data can be used for other purposes)	N	N	Y	Y
Generates numerical retroreflectivity data	N	Y	N	Y
Continues Nighttime Ride (Identifies missing and vandalized signs)	Y	Y	Y	Y
Creates a Database	N	N	Y	Y
Does Not Use Legibility Distance Method	Y	Y	Y	Y
Does Not Contract Out Sign Inspection or Maintenance	Y	Y	Y	Y
Contains Program of Better Training/Certification for Sign Inspectors	N	Y	N	Y
Does not use handheld or van-mounted retroreflectometers	Y	Y	Y	Y
Includes better record keeping to defend against liability claims	N	Y	Y	Y
'Y' TOTAL	5	10	10	12

Of the objectives evaluated in Table 52, one of the most important us 'includes better record keeping to defend against liability claims.' Continuing with the current method, alternative 1, is the only alternative that does not meet this objective. None of the alternatives reduce the amount of labor required, however, using the same amount or more labor may lead to reduced costs in other ways.

Alternatives 2 and 4 were identified as 'yes' for generating numerical retroreflectivity data. This is not for the entire population of signs in North Carolina, only for a sample of signs that would be measured by the new employee. The research committee noted that they would like for the signs legibility distance method not be used nor for sign inspection services to be contracted out; all of the alternatives meet these objectives.

The overall desired outcome of the chosen solution is to ensure all signs in the state of North Carolina possess adequate retroreflectivity at all times. Each alternative has a varied approach to meeting the overall desired outcome of achieving maximum compliance.

11.2 Recommendations

Based on the results and conclusions, the research team suggests that alternative 4, the combination of alternative 2 (make improvements on current method) and alternative 3 (implement a sign inventory management program) be adopted and implemented by NCDOT. Although most costly, it achieves the most desired objectives.

Alternative 4 would create a sign inventory management system, improve sign inspector training (with the anticipation that it increase inspector accuracy), and even have a sample of signs being measured with a retroreflectometer, thus creating numerical values to be compared against the standard, as well as other improvements.

It is also recommend that the GPS-based inventory method be implemented to create the sign inventory management system. Much of the necessary equipment and software is already owned by NCDOT and, using a team of interns at a low labor rate, this could be done for a considerable amount less than some estimates generated from existing literature. The cost of this inventory method is approximately $228,000 for software, equipment, and data collection. Using this method makes the estimated cost of implementing alternative 4 equal to the lower end of the estimated range (Table X) at $581,000 - $622,000.

A SIMS also serves other purposes such assisting the state with asset management associated with GASB34. A SIMS can also be used as a record-keeping tool that stores record of sign maintenance and inspection showing that a serious effort is made to inspect and replace signs in a timely manner. This could serve as protection against liability by showing an aggressive attempt to achieve compliance with the standards. Other benefits of an SIMS include the capability to use laptop computers on nighttime rides to help sign inspectors identify missing signs and running queries to evaluate all signs in a location where there may be a high number of accidents to determine if an additional signs or a higher sheeting grade may help reduce accidents. Also, if the system were to include such details as sheeting material lot numbers, signs in different areas can be traced back to matching lot numbers to identify deficient lots.

Funding sources and labor allotments should be seriously evaluated prior to actual implementation of this alternative. Merely suggesting new ideas and alternatives is not any good without the proper manpower and funding to support it. If funds are not available in subsequent years to keep the proposed alternative functioning, then choosing to implement the program is a waste of money.

The research team also recommends the progress and accuracy of the selected alternative as monitored by the new staff member be compiled and formally submitted to state sign engineers; this would be beneficial to the state to determine if the alternative is evaluating signs sufficiently. A sample of signs could be measured with a retroreflectometer upon implementation of the alternative and again at random year intervals to determine if an increasing number of signs are meeting the standard or not. The state would need to determine a minimum acceptable percent accuracy and ensure that this % accuracy is being met. If an improvement in the condition of the signs is not seen, the improved training should be discontinued because it is a waste of money if the same or similar accuracy rates can be achieved without it. If there is an improvement, keep administering the training and continue to perform evaluations periodically.

In addition, future investigation into linking the entire life cycle of a sign to a computer system should be made. This would mean a sign being tracked from its creation at the Bunn manufacturing facility through storage and installation all the way through replacement.

11.3 Suggested Research

The following is a list of possible studies related to the topic identified during the course of this research:

- A study researching specific causes of accidents due to signing, finding out how many were not visible, and trying to pinpoint the retroreflectivity of the signs involved for analysis.
- An investigation of areas and sign types of high vandalism to determine the cost-benefit, if any, of using protective film in these areas and also the effect of using higher sheeting in areas of low vandalism.
- A study on the feasibility and benefits of Sign Management Systems and Sign Inventory Management Systems and whether a state could actually inventory numerous signs, whether it is worth the time, cost, and effort, and if it is possible to track a signs throughout an entire life-cycle.
- A follow-up analysis about how changing the training program and making other improvements affected sign quality by comparing pre-change and post-change signs conditions and retroreflectivity values.
- A corresponding study to address pavement markings.
- A study to investigate the incorporation of pavement marking and sign evaluation as one process.
- A study to determine whether implementation of a Sign Inventory Management System can completely replace the nighttime visual inspection method.
- Evaluation of the effectiveness (time, compliance) of other methods such as contracted services, mobile van units and large-scale handheld retroreflectometer measurement.
- A study to determine the cost-benefit, if any, of double-checking all signs designated for replacement with a retroreflectometer.

REFERENCES

(1) Black, K.L., McGee, H.W., and Hussain, S.F., *Implementation Strategies for Sign Retroreflectivity Standard.* NCHRP Report 346, Transportation Research Board, Washington, D.C. (April 1992).

(2)AASHTO Retroreflectivity Policy Resolution, Minimum Levels of Retroreflectivity for Signs (December 9, 2000)

(3) McGee, Hugh W., and Taori, Sunil, "Impacts on State and Local Agencies for Maintaining Traffic Signs Within Minimum Retroreflectivity Guidelines" *BMI*, Vienna, VA (1998)

(4) McGee, Hugh W. and Paniati, Jeffrey A., *An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs*, USDOT, FHWA Research and Development. McLean, VA (1998).

(5) Kirtley, Nathan, and Rasdorf, William M., *North Carolina Sign County Study #1*, North Carolina State University (2001).

(6) Palmquist, Marc, *North Carolina Sign Count Study #2*, North Carolina State University (2002).

(7) Federal Highway Administration Traffic Safety Research Program, "Minimum Sign Retroreflective Guidelines," FHWA RD 97-074, http://www.tfhrc.gov/humanfac/rd97-074/rd97-074.htm.

(8) Huckaby, E., Brown, L., Sears, C., Kittle, L., and Ward, L. "Ensuring Effective Traffic Control Devices with the Millennium Edition of the Manual on Uniform Traffic Control Devices." ITE Journal Vol.71, No.7, (July 2001): 27-32.

(9) American Society for Testing Materials, ASTME 808-99a: Standard Practice for Describing Retroreflection, Annual Book of ASTM Standards (1999).

(10) Hasson, Patrick, "Retroreflectivity: An Essential Tool for Improving Visibility," U.S. Department of Transportation, Federal Highway Administration, Midwest Resource Center (1999). http://mrc.fhwa.dot.gov/articles/ksart2.htm.

(11) Austin, Richard L. and Schultz, Robert J., "Guide to Retroreflection Safety Principles and Retroreflective Measurements" Gamma Scientific and Advanced Retro Technology (April 2001).

(12) Langdon, Kent et al., Sign Condition Survey Guidelines, North Carolina Department of Transportation (1993).

(13) CA Corporate Tie Product Information, http://www.cai.com/products.

(14) Lagergren, Edwin A., *Traffic Sign Retroreflectivity Measurements Using Human Observers*, Washington State Department of Transportation, WA-RD 140.1(December 1987).

(15) Hatzi, Peter, “Retroreflectivity ‘Right Back At You!” U.S. Department of Transportation, Federal Highway Administration, http://www.library.unt.edu/gpo/OTA/featproj/fp_te29.html, June 30, 2001.

(16) Long, David, "Michigan DOT Reflects on Signs," TR News 192 September/October (1997): 24 -25.

(17) Clarke, Keith C., “Getting Started With Geographic Information Systems” University of California, Santa Barbara. Prentice Hall, Upper Saddle River, New Jersey (1999).

(18) Hummer, Joseph, Karimi, Hassan A., and Khattak, Aemal, “Collection and Presentation of Roadway and Inventory Data,” *NCHRP Report 437*, Transportation Research Board, National Academy Press, Washington D.C. (2000).

(19) GIS in Action. “Boulder County, Colorado, Sign Maintenance Receives Big Dividends from ArcPad.

(20) Arnold, Jon, *GPS Sign Inventory Study*, North Carolina State University (2002).

(21) Hawkins, Jr., Gene, Carlson, Paul, J., McCaleb, J. Bradley, McIlroy, Charles. R., *Impact of Minimum Retroreflectivity Values on Sign Replacement Practices.* Texas Transportation Institute, Texas A&M University, TD100: TX 97-1275-1 (October 1996).

(22) Institute of Transportation Engineers, *Traffic Signing Handbook*, Institute of Transportation Engineers, Washington, D.C., Chapter 2, Pages 23-44 (1997).

(23) Wolshon, Brian, and Degeyter, Robert, “Performance of Traffic Sign Retroreflectivity,” *IMSA Journal* (July/August 2000.

(24) North Carolina Department of Transportation. *Highway and Roadway Mileage*. Division of Highways, Geographic Information Systems Unit (January 2000).

(25) “Crashes By Relation to Junction, Traffic Control Devices, and Crash Severity” Traffic Safety Facts, Congressional Information Service, Inc. (1999).

(26) Rawlins, Wade “Bill Raises State’s Liability Limit.” *Raleigh News and Observer* 3 Jul 2000.

(27) Lewis, Russell M., “Practical Guidelines for Minimizing Tort Liability.” Transportation Research Board, National Research Council, Washington D.C. (Dec. 1983).

(28) North Carolina General Statutes. Chapter 143. Article 31. 143-291.

(29) Interview with Don Davis, NCDOT Legal Tort Claims. July 12, 2001.

(30) NCODT Traffic Safety Systems Management, conversation with Mr. Chris Oliver, June 25, 2001

(31) Lewis, Russell M., “Managing Highway Tort Liability,” Transportation Research Board, National Academy Press, Washington D.C. (1994).

(32) Morris, Mark W., "Tort Liability: A Manual for North Carolina Local Governments. Institute for Transportation Research and Education" (1994).

(33) Federal Highway Administration. "Nighttime Visibility of Traffic Signs: Current Thinking" PowerPoint Slide Presentation (September 2001).

(34) National Cooperative Highway Research Program (NCHRP), Project 5-16 National Calibration Standards for Measuring Retroreflectivity. http://www4.nationalacademies.org/, updated 4/19/2000.

(35) Technique Development: Database Development website, http://www.techdev.com/dbdev.htm. (March 18, 2002).

(36) Retroreflectivity of roadway signs for adequate visibility: a guide. Bellamo – McGee, Inc.

(37) Cai, Hubo, *Software Evaluation of Sign Inventory Management System,* North Carolina State University (2002).

(38) Getting Started in Public Works Asset Management: A Guide to Selecting, Implementing, and Maintaining an Asset Management System. CarteGraph Systems Inc. (2000)

APPENDIX A

PROPOSED MINIMUM IN-SERIVCE GUIDELINES FOR RETROREFLECTIVITY

The Federal Highway Administration is expected to release minimum required levels of sign retroreflectivity. The minimum levels are for four sign sheeting background colors: red, yellow or orange, green, and white. The following appendix consists of four tables, one for each color, and an additional table that individually identifies the warning signs encompassed by the yellow or orange standard. Each table includes different minimum retroreflectivity values based on sign size, sheeting type, and traffic speed.

Table 1 **Minimum Retroreflectivity Guidelines for Warning Signs with Yellow or Orange Background and Black Legend**

Legend	Material Type	Sign Size (in)		
		>=48	36	<=30
Bold Symbol*	ALL	15	20	25
Fine Symbol and Word	I	20	30	35
	II	25	35	45
	III	30	45	55
	IV and VII	40	60	70

Table values in cd/lx/m2
* see Table 5

Table 2 **Minimum Retroreflectivity Levels for Black/(Black-and-Red)-on White Regulatory/Guide Signs**

Material Type	Traffic Speed (mi/h)					
	45 or greater				40 or less	
	Sign Size (in)					
	>=48	30-36	<=24	>=48	30-36	<=24
I	25	35	45	20	25	30
II	30	45	55	25	30	35
III	40	55	70	30	40	45
IV and VII	50	70	90	40	50	60

Table 3 **Minimum Retroreflectivity Levels for White-on-Red Regulatory Signs**

Sheeting Color	Traffic Speed (mi/h)					
	45 or greater				40 or less	
	Sign Size (in)					
	>=48	30-36	<=24	>=48	30-36	<=24
White (legend)	35	45	20	35	30	35
Red (background)	8	8	8	5	5	5

Table 4 **Guidelines on Minimum Retroreflectivity Levels for White-on-Green Guide Signs**

	Sheeting Color	Traffic Speed (mi/h)	
		45 or greater	40 or less
Ground- Mounted	White (legend)	35	25
	Green (background)	7	5

Table 5 Warning Signs with Bold Symbols

MUTCD Code	Sign Type
W1-1	Turn
W1-2	Curve
W1-3	Reverse Turn
W1-4	Reverse Curve
W1-5	Winding Road
W1-6	Large Arrow
W1-7	Double Arrowheads
W1-8	Chevron
W2-1	Cross Road
W2-2	Side Road
W2-4	T Intersection
W2-5	Y Intersection
W3-1a	Stop Ahead
W3-2a	Yield Ahead
W3-3	Signal Ahead
W4-1	Merge
W4-2	Lane Reduction
W4-3	Added Lane
W6-1	Divided Highway Begins
W6-2	Divided Highway Ends
W6-3	Two-Way Traffic
W8-5	Slippery When Wet
W11-2	Advanced Pedestrian Crossing
W11A-2	Pedestrian Crossing
W20-7a	Flagger Ahead

APPENDIX B

MEETING VISITS AND SUMMARIES

Several visits were made to different NCDOT departments and to other organizations that play a vital role in the sign manufacturing and maintenance process. This appendix presents a summary table that outlines the meeting, location, date, and a brief note about the meeting. Following the table are summaries of information and ideas acquired during each meeting or visit.

MEETING	LOCATION	DATE	NOTE
Department of Corrections Sign Shop	Bunn, NC	March 3, 2001	The primary manufacturing facility for all NCDOT signs.
NCDOT Signing Engineers	Raleigh, NC	March 9, 2001	
Technical Advisory Committee Meeting	Raleigh, NC	March 15, 2001	1st meeting of the NCDOT steering committee overseeing the project
NC Division of Highways Division 6	Fayetteville, NC	May 9, 2001	A visit to a NC Division of Highways to observe their inventory and sign shop
FHWA SMARTS Van	Raleigh, NC	May 24, 2001	The FHWA van is fully equipped for mobile sign retroreflectivity measurement.
NC Division of Highways Division 11	North Wilkesboro, NC	June 13, 2001	A visit to a NC Division of Highways to observe their inventory and sign shop
NCDOT Tort Claims	Raleigh, NC	July 12, 2001	A meeting to obtain information on liability and claims made against NCDOT
Technical Advisory Committee Meeting	Raleigh, NC	December 5, 2001	2nd meeting of the NCDOT steering committee to present proposed alternatives and obtain feedback.
Night Ride Observance NC Division of Highways Division 11	North Wilkesboro, NC	January 30, 2002	Accompaniment of two sign inspectors to observer the procedures of a night ride to evaluate signs.
NCDOT Training Administrator	Raleigh, NC	February 25, 2002	Discussion with NCDOT training administrator to find out about common training formats.
Technical Advisory Committee Meeting	Raleigh, NC	May 29, 2002	Final meeting of NCDOT steering committee to present conclusions and results.

DEPARTMENT OF CORRECTIONS SIGN SHOP

Friday March 3, 2001
Bunn, NC
Contacts: Danny Stanley and Chuck Congleton
(919) 761-3610

Correction Enterprises is a corporation run by the North Carolina Department of Corrections (DOC). They have several industries manned by prisoner labor, one of which is a sign shop at the prison in Bunn, NC. The Bunn sign shop supplies the majority of the signs for the state Department of Transportation. The NC Department of Transportation receives 90% of its signs from this business.

There are three types of reflective sheeting used. The first type is Engineer Grade. The sign shop uses 800,000-900,000 square feet per year. The cost is $0.69/square feet and has a useful life of 7 years; rural signs are made from this material.

The next type of sheeting is high intensity. 150,000-200,000 square feet are used per year and the cost is about $2.00 per square foot. The useful life is 12 years and it is used mostly for interstate signs.

The third type of reflective sheeting used at the Bunn sign shop is Diamond Grade. It is significantly more expensive at $4.00 a square foot. It used for the new fluorescent school crossing and pedestrian signs only because of the price; the costs outweigh the benefits.

There are two methods for making signs. One is creating the sign background by first placing reflective sheeting on the aluminum backing; then each letter is cut out and placed on the sign according to a sign layout sheet generated by NCDOT design engineers. The second method is screen-printing. Because of the high availability of cheap labor at the facility, in addition to the actual screening process, the actual screens themselves are created from scratch. Signs with intricate graphic designs and lots of colors are usually screened.

The workers do every step of the sign making process manually. This includes cutting and piecing together aluminum substrate, cutting out letters from dye cuts, making screens, and quality control. The signs can be produced at much lower prices than private sign manufacturers because of the cheap prisoner labor.

Signs are tested using several methods during and after completion to ensure they are of the highest quality. Retroreflectometers are used to measure completed signs. Sign testing is also done during manufacturing; someone stands on a tower above an assembly line and looks down on the signs to ensure they look even. Also, a light machine, which consists of a high-powered strobe, is used to shine light on completed signs to detect any flaws in the sheeting. Incoming aluminum and reflective sheeting are also inspected.

There is no sort of identification system (bar codes, transponders, social security numbers) used by the sign shop to monitor signs as they go through the creation process. Data regarding signs is all hand recorded, beginning with request to make the signs (sign layout sheets in the case of special orders). The use of bar codes is being investigated. This would enable signs to be linked to the date it was made, reflective sheeting material lot numbers and other information. Such a system would not be possible right now because all entities involved currently use different systems. Another concern with the automation of information collection is the type of computer access prisoners would have access to. A consultant had put together a software solution to integrate Enterprise computer systems (internal only). The system went to bid but is currently on hold because of the state budget situation.

One method used to mark signs is stamping. The date on which signs are made is etched into the back of each sign; the useful life begins with this date. This helps determine sign age. (In addition, the DOT places stickers on the signs when they are actually placed.) [It was later learned, that the Divisions use these stamps to determine if a signs should be replaced if a visual test is questionable.]

Some signs (like stop signs and yield signs) are stockpiled by the signs shop for emergencies and also because of the high demand from the division. However, in some divisions, signs are ordered and placed in a spot. Then they are re-ordered, and the newer order is placed in front of the existing stock. Older signs get pushed to the back and then 7 years have passed and the useful life of a sign is up and it has never been used. Divisions do not actually pay for stockpiled signs until they are placed. So they order signs and order signs and order signs that may not really be needed because they are only paying for the ones they use (opinion of sign shop people).

Signs go from the sign shop directly to the DOT Divisions. They do not deal with small municipal sign shops. Some cities use their own small shops to create smaller signs that may be specific to their town (ex: Welcome to Bunn). Flexi-sign software is used to layout the signs. (The DOT uses Guide Sign.)

NCDOT SIGNING ENGINEERS MEETING

Friday March 9, 2001	(919) 250-4145
NCDOT Century Center	Joe Hummer, Stephanie Vereen,
Contact: Ron King – DOT	William Rasdorf
Susan Kunz – DOT	

NCDOT design engineers formulate message when requests come in from division people or traffic area field people. The GuideSign program generates the layout sheet with all of the information and dimensions and spacing. They also use an in-house Excel program. The layout sheets indicate size, sheeting, location, type of installation, and message. These layout sheets are then relayed to the Bunn Sign Shop to be used as a design template.

The Bunn sign shop produces 90% of the signs for the state. The other 10% are done by private manufacturers or produced by small city or division sign shops.

For new directional signs (green background with white letters) or road improvements, signs are requisitioned through signing according to contractor's schedules; four months is usually allotted. Plan sheets of the roadway show where the signs are actually to be placed on the roadway.

The contractor is responsible for placing a month/year sticker on the lower corner of the sign closest to the road on the back of the sign. The sticker indicates the year and month that the signs was actually installed. This is in addition to the etched date placed on the back of the aluminum substrate at the Bunn sign shop. The Bunn sign shop manufactures these stickers as well. Some municipalities manufacture their own signs. They are also required to place a month and year sticker on the signs they make when they are placed. Both of these date methods help to determine how long a sign has been used and whether or not it needs to be replaced.

Night rides to assess Retroreflectivity are done on new intersections or projects under design or construction. The individual divisions are supposed to perform nighttime ride-bys every six months. (It is not known how often this procedure is actually performed.) The stickers are not checked during these ride-bys. During the rides, a 12,000-watt bulb is flashed at a distance of 50 feet.

The current Secretary of Transportation is concerned with maintenance however pavement markers/markings have priority over signs (budget-wise). Signs are installed on aluminum or wood supports. If they are square, it is aluminum laid on something else (green and brown guide signs). The age may not be able to be determine because the date may have be on the under layer. If the signs have a rounded edge, it is completely aluminum.

NCDOT and Correction Enterprises are trying to coordinate some sort of software system so the signs request forms can be e-mailed. SignTrack was a software program that was investigated once. It allows you to inventory as you design the signs. Signing engineers estimate there are about 3.5 million signs in the state of North Carolina. There is a Materials and Test Unit responsible for inspecting brand new signs. It consists of two people. They are not responsible for the continuous evaluation of signs during their useful life.

Key issues to generating a solution to the maintenance of the adequate retroreflectivity levels for signs in North Carolina are MONEY (budget, not enough in maintenance), MANPOWER (very limited), and TECHNOLOGY (expensive, non-existent, software linkage capabilities).

TECHNICAL ADVISORY COMMITTEE MEETING

Thursday, March 15, 2001
NCDOT Century Center
Mustan Kadibhai
(919) 715-2467

Ron King (Chair) – Signing
J. Dean Ledbetter – (Co-chair)
Division 11
Mohammed Mustafa
Moy Biswas – Research Manager
Forrest Robson - GIS Unit
John Permar – Traffic Engineer Field Operations
Ray Goff – Division 6 – Fayetteville
Tom Thrower – Division 10 – Charlotte
Mustan Kadibhai
S. Vereen, J. Hummer, W. Rasdorf

$230,000 was spent for vandalism replacement alone one Division. “Signs don’t stay up long enough for them to get old” was the sentiments of Division 6 engineer Ray Goff. Paintballs and shotguns are a big problem for sign replacement. Paintballs destroy the retroreflectivity of a sign.

In addition, sign erectors are some of the lowest paid positions in the entire DOT. They do not get paid overtime; instead they receive compensatory time. This causes them to work ‘seasonally’ because they end up with time off because of the compensatory time. In many division, trucks and equipment are old and run down. The sign erectors are on call seven days a week. Some potential solutions identified in the meeting are GIS linkage, training for sign erectors, and proper equipment for sign erectors.

Currently, night riding is the process used to check retroreflectivity of signs. Secondary roads are done every 3 years, primary roads are done every 2 years, and Interstates are done every year. On the nighttime drives, stop signs must be replaced within 24 hours, warning signs as soon as possible, guide and other signs as time and money allows. They look at the sign and it is either yes for replace or no it is okay until next time (which could be 1-3 years). [It is questionable which divisions actually perform these rides on a consistent basis.]

Some thoughts and opinions expressed in the meeting were:

- GOAL: A Sign Inventory with retroreflectivity as an attribute
- True Inventory (everything) vs. Minimum Requirement Inventory (sample)
- Need to focus on maintenance, not just place, label, and leave the sign
- Small sign shops need to be able to implement the same program

Once again, key issues drawn from the discussion were money and manpower. Currently, the manpower allocated for sign maintenance is based on a study done in the 70's that compared the number of sign erectors vs. signs per mile. So outdated criteria is being used to determine today's numbers.

Some municipalities manufacture their own signs; Charlotte, Greensboro, Fayetteville, and Winston-Salem are a few of these. Job reports are turned in each week by sign erectors saying they completed placement of signs. None of the divisions represented at the meeting own a retroreflectometers.

Questions and concerns generated from this meeting:

- What are the division's roles in facilitating compliance with the MUTCD Standards
- What data should be included in the system we are going to propose?

It was also noted that the current state administration seems to have a focus on maintenance, this is favorable to our objectives.

NC DIVISION OF HIGHWAYS, DIVISION 6

Wednesday May 9, 2001
Fayetteville, NC
Contact: Ray Goff, Division Engineer
(910) 486-1493

Kent Langdon
Jerome Locklear, Signing Supervisor
Stephanie Vereen, William Rasdorf
Brad Hibbs, FHWA

Sign erectors are one of the lowest paid positions in the DOT. They need map-making skills, are on call 24 hours a day, and are not supervised; they must be trustworthy and self-motivated. A typical crew consists of a sign erector, a helper and two temporary workers. There is a high turnover rate of temporary employees; this leads to lost time because there is constant training of new personnel. Division 6 currently has 6 crews responsible for sign installation and inspections. Statewide signs inspectors with the Materials and Test unit are John Schleitch and Wayne Johnson.

"Expired" signs whose life is over before it was ever installed are discarded. The sheeting is removed and the aluminum is recycled back to the sign shop or back to manufacturer. This rarely happens in Division 6 because they have a system to move the oldest signs out first. The signs are used from left to right. So when you use the last sign on the right, the next oldest sign will be all the way on the left.

It is impossible to keep track of how many signs are actually out there and where they are, signs are constantly being added on a daily basis.

There is a distinction between signs that are maintained by the county and/or city and those maintained by the division. County road name signs (white on green or blue) and street name signs are maintained by the city and/or county. Signs inside corporate city limits are also maintained by that city. The DOT will post one white on green "35 mph unless otherwise posted" sign immediately inside city limits. All other black on white speed signs are done by cities.

Vandalism is the most expensive cause of sign replacement. In Division 6, vandalism alone cost over $250,000. This is over half of the sign maintenance budget. There is no criminal punishment for defacing and vandalizing signs. Paint balls destroy signs. Eggs are also detrimental because the acid and protein break down the sign sheeting. They may look okay in the daytime but not at night.

When accidents occur, the drivers insurance is required to pay for the cost of the sign replacement. However, there is a tedious process to place the claim and the money is returned to the general DOT fund, not directly to the division whose budget the replacement actually comes from.

A video made by Kent Langdon was used to train sign inspectors about what to look for when doing night rides. They cannot find the original tape however they have the raw footage and will recreate a tape (the original tape was later found). In addition, there is a Sign Condition Survey Guideline, which outlines the procedure for inspecting signs that was formulated. (It was initially implemented as a statewide program however no one ever the used the data so it is no longer done.)

A standard sign truck costs about $40,000. This includes the truck and all of the needed equipment, post pull on front, auger, crane, and other tools.

FHWA SMARTS VAN VISIT

Thursday May 24, 2001
NCDOT Century Center
Contact: Frank Julian
404-562-3689

Sign placement awareness is an important aspect when measuring retroreflectivity. The entrance angle of light into signs and sign height, or observation angle, should be taken into consideration when measuring. R_a, is the coefficient of retroreflectivity. GASB34 is an asset management plan created by the Federal government. It relates states assets to their total worth; the more assets a state has, the higher the state's bond rating. North Carolina has already performed this assessment; signs were included in the inventory. The high rate of vandalism as a reason for missing signs is mentioned. There are anti-theft deterrents for "high-theft" signs (the yellow-green school and pedestrian signs). A special shaped bolt that makes removal of signs impossible without a special tool is available.

The van requires 2 people, a driver and a computer operator. It is the operator's job to locate the signs manually using a standard computer mouse. The computer screen displays a video stream of the roadway; the movement of the mouse controls the camera motion. The operator focuses a green box on the computer screen on the next sign. Measurements are automatically taken at a distance 200 ft using naval laser range technology. A 0.2 observation angle (0.5 is more realistic to an actual driver in a car.) is standard. There is no set entrance angle. It is then the operator's responsibility to use the mouse and locate the next sign and the process is repeated.

A turret is mounted on top of the van. It houses a xenon flash tube (a basic airport runway light), a laser range finder, and 3 cameras (2 black and white, a 75 mm for smaller signs and a 50 mm for larger signs, and 1 color camera). The entrance angle of the light from the flash tube cannot be controlled; the observation angle can be controlled. The picture the black and white cameras shoot is equivalent to what the driver's eye might actually see at night. [Note: handheld retroreflectometers that are placed directly next to a sign do not reflect what driver sees (entrance angle).]

The van collects a large variety of data. A database is created that includes a digital color picture (Figure B-1), a black-and-white image of what the sign would look like at night (Figure B-2), retroreflectivity characteristics, GPS co-ordinates and room for comments. Other information collected includes the speed of the van and the time and date of the measurement. The information is stored in a database and all of the data can be post-processed either in the van, or on other computers.

Figure B-1: A Black and White Image of How A Sign Would Appear at Night Generated by the
FHWA SMARTS Van

Figure B-2: A Color Image of the Same Sign Generated by the FHWA SMARTS Van

The van can operate in daytime hours only (but it measures what the driver would see at night). It cannot be operated in inclement weather. Rough and poor road conditions make aiming difficult. In setting where signs are closely placed, it is difficult to get all of them. Also when left, right, and overhead signs are in the place, multiple passes would be required to get all of them (this could be costly). In reality, in high congestion areas, signs to be shot would have to be prioritized. Also, larger green on white signs are more noticeable to the data collector than smaller more inconspicuous signs such as mile markers or lane ending signs.

Some obstructions experienced while driving in areas where a road was curvy were: a tangent of 200 feet was not available to see sign; street-side parking obstructing signs; trees and bushes in the way; and do not enter signs (reverse facing signs). Multiple signs in a row caused problems; the van was set on return to center, so successive signs were missed because it kept returning to center. The return to center function can be deactivated but the chances of the view getting disoriented are greater. The software is set to look for the brightest signs, which is not ideal.

There are two programs associated with the van. One is for the recognition software used in the van. It is designed to look for retroreflective objects with sharp edges (sometimes backs of trucks and license plates can interfere). Up to 153,000 pixels can be evaluated using software associated with the van (with a handheld retroreflectometer, 1 shot is equivalent to 1 pixel). Retroreflectivity values can be obtained for both legend and background colors. Average, high, and low retroreflectivity values for a sign are given. Further queries and analysis can also be performed. There is no way to remove 'trash' or misfired shots from the database. The other program is for analyzing the data. It is called Sign Evaluator Software. Data can be exported to Lotus or Excel. The current software, (name), is only designed to run on a 200 MHz processor. The actual cost per mile to fund the van is unknown. The cost of the actual van itself is about $210,000. This does not include continuous maintenance and upgrades.

NC DIVISION OF HIGHWAYS, DIVISION 11

Wednesday, June 13, 2001
North Wilkesboro, NC
Contact: Dean Ledbetter
(336) 903-9129

Tim Foster
Dwayne Bauguess
Lorraine Jennings
Stephanie Vereen

The primary method of establishing sign retroreflectivity is the night ride method. (Interstates ridden every year, primary every other year (1/2 each year), and secondary are done every three years (1/3 each year)). A clarification of compensatory time for employees was made; they receive up to 10 hours of compensatory time each week and each hour over 50 is billed as overtime.

In reference to the Sign Inventory Program that was established and now defunct (see Appendix C), Corporate Tie was a program designed to transfer data within the DOT mainframe computer before electronic mail and the Internet. [Jennifer Brandenburg at the State Maintenance Unit was in charge of the electronic submission program.] Dean Ledbetter and Roger Hawkins of Division 3 were on a committee (chaired by Jennifer Brandenburg) that reviewed the sign survey software.

It is possible that evidence of an attempt to monitor retroreflectivity levels could in fact reduce liability to the state. An increased workload is a main concern of any program that may be implemented. Some suggested solutions were to have a retroreflectivity van for the interstate and primary roads and still use the night ride, but also integrate handheld retroreflectometers. Currently, any sign that is questionable is replaced; these signs could be measured using a handheld instrument. (Other divisions use the manufacturing date in this situation.)

Employees not properly performing night rides are a concern; division supervisors perform periodic spot checks.

Sampling was suggested as a possible alternative. There may not be enough consistency to create a "fair" population (i.e. weather conditions across the state, location, time of placement, and proximity to night rides/chance of replacement). There is also the question of what if a sign not included in the sample was involved in an accident/case.

Dirty signs are sometimes a problem. Amorex is one sign cleaner used to clean signs. Vandex is another cleaner that removes graffiti and paint. However, it cannot be used on high intensity signs because it will eat through the sheeting. A suggestion was once made to utilize the services of the Roadside Environmental Unit, who are responsible for landscaping. They have tanks and trucks that spray chemicals; they could fill them water and spray the signs to clean them.

Division 11 experiences large amounts of snow. Large amounts of snowfall hinder access to a sign and the pressure of snow makes signs leans. According to Mr. Ledbetter, a greater problem with the snow is the fact that snowplows throw snow and dirt onto the signs faces, which interferes with the ability of light to be reflected back from the sign. As far as sign placement, large ground mounted signs are surveyed in place, but only to attain proximity, not for exact placement angles. Form 990 is used to report signs damaged by accidents and mowers. All monies collected from mowing contractors because of damaged sign claims are returned to a general state fund. But the division must expense the cost (labor and material) to replace the sign.

Possibly a public education campaign could be implemented to alert the public to how much money is spent on replacing old and vandalized signs. In Ash County, which is located in Division 11, the courts require vandals to come and apologize to the sign engineers and repay the cost of the sign they vandalized. This is a sole action on the part of the Sheriff's Department.

Although some signs may seem less important, such as signs that say the name of a bridge or a dedicated road, they can be a hazard if they are in very bad condition. Drivers may struggle to see a sign that is no longer reflective and endanger themselves when the sign says nothing of usefulness to the driver.

Using higher grades of sheeting in areas where there is high vandalism (rural and secondary roads) is difficult because the turnover of signs is so high so money is wasted. But in urban areas where signs are less accessible to vandals, a higher sheeting grade may be worth the investment.

3M manufactures a clear sheeting that can be put on top of the high intensity sheeting where spray paint can be scraped off with a credit card. This could be very costly but there may be a cost trade-off. It has been suggested to the Bunn sign shop to add this as a step in the sign creation process and to only increase the cost of the sign by the cost of the clear sheeting material.

The current state sheeting contract is with Avery, however, the sign supervisors are not at all pleased with the quality. The National Highway Project provides money for pavement markings, markers, LED signals and signs; pavement markings and markers get money first, they green signs are covered. The System Preservation Fund is special state money that goes to painting. This helps to free up Division money for more painting and signs.

Division 11 has seven signs crews (this could only be one person at times.) Another problem mentioned was that signs are sometimes damaged on the trucks. Any wrap is removed from the signs before they are placed on the truck; if it were to rain, the paper would stick to the sheeting and ruin it. The signs often scratch against each other and against the holders on the truck when being placed and removed. Plastic separators can be used to protect the signs however they are very thick; trucks that do not return to the inventory warehouse everyday must carry enough signs to last them and the separators do not allow this.

It was suggested that the current method of evaluating the retroreflectivity of signs remain yet add a handheld retroreflectometers to the truck. The suggestion to integrate signs where two or three separate ones are required to relay one message (north, route marker, and arrow), into one sign because one cannot be replaced, the contrast would be too great so they all must be replaced anyway. This would reduce labor and cost.

As far as money is concerned, all activities are coded to road type and location (primary urban, etc.). Primary and urban monies are interchangeable, but secondary monies are not; any overages run into the following year's budget.

NCDOT TORT CLAIMS

July 12, 2002
Raleigh, NC
Contact: Don Davis
(919) 716-6820

The purpose of this meeting was to acquire information about liability issues and the retroreflectivity standards and also to see if there are any records to be used to estimate the number of tort claims made against the state because of signs.

The NCDOT is sued 2000 – 3000 times per year. This is the entire DOT, including areas like school buses. 95% of cases are settled with the state, dropped, or settled with another party before they reach trial. But every claim filed cost money.

The state of North Carolina has a contract with Traveler's Insurance for state vehicles (33,000 vehicles, 14,000 school buses). There are six state claim adjuster's/representatives that take care of all general liability claims (falls, signs, etc.)

According to Mr. Davis, if there is a standard that DOT is familiar with and they knowingly do nothing about an inadequate sign, it is considered negligence. However, funds' not being available is not negligence. Sign erectors are not responsible for signs that could not be replaced because of budget allocations; sign erectors do not have the authority to allocate the funds.

TECHNICAL ADVISORY COMMITTEE

Wednesday December` 5, 2001	Tom Thrower
Raleigh, NC	Brad Hibbs
Contact: Mustan Kadibhai	Stephanie Vereen
(919) 715-2467	William Rasdorf
Ron King (Chair)	Joseph Hummer
Dean Ledbetter (Co-Chair)	Hubo Cai

The purpose of the meeting, was to present the sign management alternatives developed by the NCSU research team and obtain NCDOT feedback on the alternatives, in accordance with project tasks 4 and 5 as outlined in the project proposal. The main points and feedback from the meeting were as follows.

The NCSU research team began by presenting issues common to all strategies, such as which signs do we measure (all, none, sample), who should measure the signs (state personnel or contracted services), and when the signs should be measured (time and frequency). Next, existing strategies from AASHTO and the Texas Transportation Institute (TTI) were discussed. The strategies are as follows:

AASHTO:

1. Determine max service life of signs (no inspection)
2. Measure sign with retroreflectometer
3. Minimum sign legibility distance
4. Acceptable visual retroreflectivity

TTI:

1. Total replacement (no inspection)
2. Sign inspection – visual or instrumental
3. Sign replacement based on a SMS (no inspection)

Then, strategies formulated by the NCSU research team were presented; similarities with the AASHTO and TTI strategies were noted. These strategies were:

- Implement a sign management system (AASHTO #1, TTI #3)
- Measure signs with a retroreflectometer (AASHTO #2)
- Nighttime visual inspection – minimum legibility distances (AASHTO #3, TTI #2)
- Nighttime visual inspection – acceptable visual retroreflectivity (AASHTO #4, TTI #2)
- Total Replacement (TTI #1)

Next, a list of possible strategies was formed from components, individual factors of a strategy covering measurement method, data collection and storage, and decision making, were presented for review and discussion.

Whether the proposed minimum values are implemented as a standard or a guideline will affect how aggressively NCDOT attacks the project. A standard will mean mandatory compliance but guidelines will be 'suggestions.' The issue of liability was also discussed. New tort claims laws and increases in the maximum award amount have already caused an increase in tort claims against the state. The final strategy should involve better record keeping to control and defend against tort claims and lawsuits.

Measuring all signs with a retroreflectometer is an unrealistic option. One of the needs of the chosen strategy is to identify missing signs as well as signs whose retroreflectivity is not adequate. A handheld would not be able to do this; it also would not be able to reach overhead guide signs. The reliability of handheld retroreflectometers is still questionable and they are not able to measure retroreflectivity, color, and fluorescence. In addition the nighttime visual inspection using sign legibility distance is not a suitable method of evaluation.

The project committee seems to agree that even if a different measurement method (a van for example) were adopted, the visual method is still most feasible and should be continued.

So the final strategy should result in a database or inventory system of some kind that includes at least sign location, type and inspection history that is available to all divisions (and accessible to sign inspectors on laptop for mobile use). A database would also be helpful lawsuit defense because it would serve as a record-keeping method. It also serves as a budgeting tool.

A sign certification or training program for employees of some sort should also be a part of the final strategy. Sign erectors have high responsibility and low pay. An incentive or training program would increase employee moral and performance resulting in better sign maintenance.

NIGHT RIDE OBSERVANCE

January 30, 2002
Division 11 - North Wilkesboro, NC

Tim Foster, NCDOT
Lorraine Jennings, NCDOT
Stephanie Vereen, NC State
Jon Arnold, NC State

Night ride observance of signs is the procedure outlined in the Sign Condition Survey Guidelines (Appendix C) to determine whether signs are visually adequate. A visit was made to North Carolina DOT Highway Division 11, located in North Wilkesboro, NC, to accompany two of their sign personnel on a night ride. They perform night rides from November through February because it becomes dark earlier.

Each night ride consists of a 2-person crew, a driver and a recorder. Both persons work together to evaluate signs. No samples are evaluated before the ride begins. The NCDOT Sign Condition Survey Training Video is viewed in November prior to the night ride season. Most inspectors are experienced; new or temporary employees are always paired with an experienced observer. There are no formal evaluation criteria; visual assessment and experience are used. The recorder is also responsible for navigating the map. A map highlighted with the section to be ridden is used to navigate; as each road is ridden, it is highlighted in a separate color. Division 11 has a very organized mapping system to identify which road sections should be ridden in which years.

Each crew takes a car or a small truck; they try to avoid using the signing trucks because they are large and cumbersome and difficult to maneuver, especially on dirt roads. A late model Ford Taurus was used for the ride. Secondary roads in Wattauga County were scheduled to be ridden. Once the crew enters the assigned section for the evening, the crewmember reading the map begins to navigate the driver. Roads are ridden in both directions. However, on many through secondary roads, where signs are sparse end and would not require the crew to come back on the same road, the crew will slow the car and shine a light back on signs in the opposite direction and evaluate them this way.

The procedure is to follow the map and evaluate all signs. Green street signs and 911 emergency signs are maintained by the county and orange construction signs and any signs in a construction zone are not evaluated because these will all be either replaced or removed when construction is complete. Signs are evaluated at posted speed limits, using the headlights of the car as the light source. A flashlight is shone on signs that the cars headlights do not hit (which is not a proper evaluation technique and should not be done). If a sign is questionable, the crew will get out of the car. Some signs are just dirty, but the sheeting is in perfectly good condition. The sticker indicating the installation date of the sign is also checked. The manufacturing date that is etched on the aluminum is not used. If the sticker indicates the sign is older than 7 years, it is noted for that sign to be replaced.

For example, a bridge end sign was questionable so we got out of the car and examined it closely. This sign was just covered with dust. The sticker indicated the sign was installed on December 11, 1997, so it was still in the allowable 7 year time period. On another road, a curve ahead sign which should have been black on yellow appeared to be black on white. Checking the sticker on the back of the sign from the car with a flashlight indicated the sign had what was considered and 'old' installation sticker. That type of sticker, identifiable by its shape, was used over 7 years ago; older stickers are smaller than current stickers. The sign inspectors knew the sign needed to be replaced because the sheeting had obviously lost color and because it had been installed over 7 years ago. The sign inspection crew will usually stop to give the recorder time to properly record the sign information.

A stop sign, although still legible, had dull sheeting and several nicks so it was recorded to be replaced. Because it is a stop sign, it was given a code of 1, which indicates it will be replaced the next day. If a sign is questionable, the sign inspectors must also take into consideration whether the sign will last for three years, until the next inspection, because secondary roads are only ridden once every three years.

The recorder uses the Sign Condition Survey Report table contained in the Sign Condition Survey Guidelines (Appendix C) to record signs needing to be replaced. However, some signs do not need replacement but require action. These signs are recorded on a separate sheet of paper and will be labeled with other actions codes. For example, signs with light vandalism can be cleaned, so they are given a 513 code. This action is also done for missing signs. The sign cannot be given a 1,2, or 3 rating as described in the Sign Condition Survey Guidelines, so they must be included on another sheet.

Employee quality is definitely an important factor in the condition of signs. The same employee may work the same county for many years and be very familiar with the roads and take great pride in ensuring the signs in the area he or she is responsible for are excellent. But some employees are not as meticulous in their work. Also new and temporary employees do not feel as great a sense of pride and responsibility for maintaining the signs that results in a lower work standard and poor sign replacement practices. The two sign inspectors on this ride commented that they enjoy the work and take a lot of pride in what they do.

Physical sign characteristics, other than retroreflectivity are evaluated during night rides. Some signs were the wrong height or position or may have been bent or obstructed by bushes. During the night ride, a black on white weight limit sign still had a little retroreflectivity left, but the weight numbers were not cut neatly in the font usually used on these signs; this sign was written down to be replaced. Sign placement is also noted. During the ride, several stop signs were not installed a proper location or height; these were noted on the separate sheet of paper. Also, some bridge end reflectors were not placed properly so these were also noted.

At the end of the ride, the entire highlighted section on the map was not yet complete. Many of the secondary roads in this section of the county were dirt and wound through mountains the driving is slow. Although sign densities are low in areas like these, they are very important because there is little to no lighting in these areas.

Ten signs were recorded on the Sign Condition Survey Report; one code one (a stop sign), six code two, and three code three ratings. Twelve signs were recorded on the separate piece of paper that noted sign cleanings, twisted signs, missing bolts, and other physical conditions that did not require sign replacement, but still needed attention.

The sign inspectors are pleased with the current method and do not suggest any changes. They think a retroreflectometer would be useful for training purposes only.

NCDOT TRAINING ADMINISTRATOR
February 25, 2002
Horse Arena
Jim Kellenberger, Training Administrator
(919) 733-7384

On February 25, 2002, a meeting was held with Mr. Jim Kellenberger, the training administrator for the NCDOT Division of Highways. NCDOT was in the process of conducting training and certification for pavement markings. The training was for state personnel and outside contractors to learn about pavement marking equipment (how to operate and troubleshoot problems), retroreflectometers, and other pavement marking information.

This particular class was held every 3 years. For NCDOT personnel, the class is the first step in achieving the skill block (competency based pay) for pavement markings. After attending the class, they must demonstrate competency within the class known as OJT, or on the job training. For pavement markings, OJT means they must evaluate pavement markings correctly in the filed 25 out of 40 times. For outside contractors attending, the class provides them with pavement marking certification that is valid for 3 years.

The training for pavement markings was being held in the State Fairgrounds Horse Arena Facility. This location was chosen because of low cost ($400/day) and the ability to bring large pavement marking application trucks into the arena for demonstrations and teaching. Trainers include industry and NCDOT personnel. This particular training was being held for two days; 150 different people each day, for a total of 300 people (with over 100 people on a waiting list). The class is also held two other times at different locations across the state.

The registration cost for this training event was $25 per person. Either the division or the outside contractor pays this cost and are additionally responsible for any transportation and lodging costs. The cost is broken down as follows:

- Meal - $8.50
- Break Snacks - $2.00
- Instructor Shirts - $1.00
- Seat Cushions - $2.00
- Materials – no cost

In addition, the cost of the facility and other miscellaneous expenses is covered by the $25. Donations are sometimes collected for snacks and other items. For the 300 people in attendance, $7500 dollars in fees were collected.

This type of event usually requires three full time NCDOT personnel working for 3 months to organize everything. They are responsible for acquiring facilities, distributing registration information, organizing instructors, collecting materials, and other duties.

There is not standard NCDOT training outline. Programs are designed and tailored according to the needs of the topic. What is being taught and what the goals and desired outcome of the training program are questions that must be considered separately for each different class. Training costs can start at about $1,000 and can increase up to any amount, depending on locations, number of participants, and many other factors.

APPENDIX C

SIGN CONDITION SURVEY GUIDELINES

Kent Langdon of the North Carolina DOT wrote a training manual entitled "Sign Condition Survey Guidelines" in 1992 as a result of a Traffic Services Supervisors Meeting. The objective of the guidelines is to enable NCDOT personnel to "systematically review all highway systems to identify those signs which should be replaced because of inadequate legibility, reflectivity, or installation."

The report is divided into several sections, each providing instruction on a certain aspect of assessing the conditions of signs on division/state maintained roads. The guidelines include instructions on a nighttime ride procedure, on training, and on data management. They also include a sample form to be used to collect data during the rides.

SIGN CONDITION SURVEY GUIDELINES

The state highway system in North Carolina consists of 77,000-plus miles of maintained roadways, with an estimated 1.6 million roadside signs. A systematic approach to review the condition of these signs is addressed as follow.

<u>OBJECTIVES</u>

To systematically review all highway system signage to identify those signs which should be replaced because of inadequate legibility, reflectivity, or installation. A visual inspection will be made without the aid of electronic measuring devices.

<u>PROCEDURES</u>

Each state maintained route will be ridden in each direction during nighttime hours in order to identify signs, which are not performing and should be replaced. Since most inadequate signs cannot be identified during the daylight hours, each division will devise their own method of marking the deficient signs during the survey. This may be accomplished by spot painting the sign face or pavement edge, referencing the sign to the nearest road, or other method chosen by the division.

The route number, sign size, message, comments if necessary and an action code will be recorded on the sign condition survey report form. The action codes are:

Code 1- Red Signs (Stop, Do Not Enter, etc.) Immediate Action
Code 2 – Yellow Signs (Yield, warning signs, etc.) As soon as possible
Code 3 – Other (Informational, etc.) Schedule as needed

It is suggested that the surveys be conducted by sign erectors and their helpers, or other competent staff. To reduce overtime, crews should report to work later in the day and work into the evening. This type of schedule would allow for some routing sign maintenance work, as well as nighttime surveys. Recommended work hours would be 2:00 p.m. – 10:30 p.m.

<u>RAILROAD PAVEMENT MARKINGS</u>

Railroad pavement marking symbols are to be evaluated in conjunction with the nighttime sign visibility survey.

<u>FREQUENCY</u>

Inspection frequency is dependent upon the highway system under review. The schedules are:

SYSTEM	PERCENT REVIEWED ANNUALLY	INDIVIDUAL ROAD REVIEW FREQUENCY EVERY YEAR
Interstate	100%	Year
Primary*	50%	2 years
Secondary (paved and unpaved)	33 1/3%	3years
Urban**	50%	2 years

*To include all –y- lines intersections regardless of system

** Excludes cities with municipal sign maintenance agreements. (See attached sheet for listing of cities with agreements.)

SCHEDULE

Sign surveys will be conducted during the months of November, December, January, and February each year. By March 15th, all reporting is to be completed.

TRAINING

A training course has been developed to train all participants who will be involved in the nighttime sign survey program. The training will assist each sign evaluator in determining whether or not signs should be replaced.

All Division Traffic Engineers and their assistants (or other equally capable individuals) will receive this training. They in turn will train their employees on procedures. Training materials will be provided. This course will be approximately four (4) hours in length.

SIGN SURVEY REPORT FORM

The sign survey report form is designed to gather the necessary information (see procedure section) on signs, which should be replaced. The far right-hand column is provided to indicate the date signs are replaced. A copy of this form is attached.

DATA MANAGEMENT

As survey data is collected, it will be keyed into the computer program prepared for this activity. The program will allow query of data to assist the engineer in managing sign replacement needs. Once the survey is completed, all computer data is to be forwarded via Corporate Tie to the Road Maintenance Unit – Racf-ID T1H6205.

APPENDIX D

PROJECT CONTACT LIST

This appendix contains a table with the names, telephone numbers, e-mail address, and company or organization of persons involved with this project or having information that may be of use to it.

FIRST	LAST	PHONE	FAX/PAGER	COMPANY/AGNECY	NOTES/E-mail
Ben	Farlow	336-475-7550		Precision Scan	Precisionscan @ compuserve.com
Brad	Hibbs	919-856-4354		FHWA	Extension 145
William	Stone	919-733-2611		NCDOT Warehouse - Super	
Chuck	Congelton	919-716-3600		Correction Enterprise	
Mike	Martini	336-475-6600		Flint Trading Company	Retroreflectometers
Ron*	King	919-250-4143	919-250-4195	NCDOT - Signing Engineer	ronking@dot.state.nc.us
Susan	Kunz			NCDOT - Signing Engineer	skunz@dot.state.nc.us
Dean*	Ledbetter	336-903-9129	336-667-4549	NCDOT - Division 11	dledbetter@dot.state.nc.us
Tom*	Thrower	704-982-0101	704-982-3146	NCDOT - Division 10	tthrower@dot.state.nc.us
John*	Permar	919-733-5418	919-733-2261	NCDOT - TEB	jpermar@dot.state.nc.us
Forrest *	Robson		919-250-4188	NCDOT - GIS	frobson@dot.state.nc.us
Moy *	Biswas	919-715-2465	919-715-0137	NCDOT - Research	biswas@dot.state.nc.us
Ray *	Goff	910-486-1493	910-486-1959	NCDOT - Division 6	rgoff@dot.state.nc.us
Mohommed *	Mustafa	919-715-2462	919-715-0137	NCDOT - Research and Analy.	mustafa@dot.state.net
Mustan *	Kadibhai	919-715-2467	919-715-0137	NCDOT - Research and Analy.	mkadibhai@dot.state.nc.us
Garyn	Perrett	435-755-9837		Sign Management Software	
Mike	Whitten	770-643-0960	888-926-5257/p	Avery Dennison	mewhitten@worldnet.att.net
Kent	Langdon	919-486-1493		NCDOT - Div. 6 Traffic	
Jerome	Locklear	919-486-1452		NCDOT - Div. 6 Sign Super.	
Tom	Gobel	910-733-3725		NCDOT - Road Maint. Unit	
Frank	Julian	404-562-3689		FHWA	FHWA Van
Steve	Spankey	651-736-5207		3M	
Don	Davis	919-716-6820		NCDOT Legal - Tort Claims	
Linda	Lancaster	919-515-8563		ITRE - submit Quart. Reports	Campus Box 8601
William	Schaler	919-715-4232	919-715-0137		wschaller@dot.state.nc.us

APPENDIX E

DIVISON QUESTIONNAIRE AND RESPONSES

A questionnaire was developed to determine the familiarity and fulfillment of the Sign Condition Survey Guidelines (Appendix C) and the nighttime ride sign evaluation procedures used throughout the 14 North Carolina Highway Divisions. Questions about sign evaluation procedures, manpower commitments, sign inventory and other aspects were included. The questionnaire was distributed via e-mail on Monday, July 30, 2001 to the Division Traffic Engineer of each division. 70% of divisions responded. The complete survey and responses to it are presented in this appendix.

A questionnaire was distributed via e-mail on Monday July 30, 2001, to each of the 14 state Highway Divisions. The purpose of the questionnaire was to assess the familiarity of the Sign Condition Survey Guidelines, which were formulated and distributed as protocol in 1992, and also to determine to what extent they are followed. About 70%, or 10 of 14 divisions responded to the questionnaire. The questions and responses were as follows.

1.Several years ago, a report entitled Sign Condition Survey Guidelines was distributed to each division in the state dealing with performing nighttime ride-bys in order to assess the condition of signs throughout the state. How familiar are you with this report?

Very Familiar – 8
Not familiar with – 2

One of the divisions reporting familiarity with the Guidelines was directly involved with the creation and original implementation of them. The two divisions who responded that they were not familiar with the report still performed nighttime rides and recorded the results.

---

2. Does your division perform any type of nighttime rides to assess the condition of signs? (If no, skip to question 12 please)

Yes – 10
No – 0

One division reported they had not performed nighttime rides since 1999. Another indicated performing rides since 1990, before the Sign Condition Survey was originally established.

---

3. Does your division currently follow the nighttime ride frequencies outlined in the Sign Condition Survey Guidelines (interstates are ridden every year, primary roads every other year, and secondary roads every third year)?

Yes - 9
No – 1

One division reported they evaluated secondary roads every other year instead of every third year. And another noted that they evaluated primary roads every year.

---

4. If not, how often does your division perform nighttime sign assessments?

N/A – 9
Every other year – 1

The one division responding that they did not follow the frequencies as outlined in the Sign Condition Survey Report noted that they performed nighttime rides every other year. They made no indication of what road types were done.

---

5. What time of the year does your division perform nighttime sign assessments?
Responses ranged as follows:

In the fall, October to November, November to February, November to March, January to March, Late fall into winter, December to February, January and February

6. In your division, how much labor is required to perform nighttime sign assessments each year?

MANPOWER USED
7 sign trucks, 2 employees/truck, 6 hrs/wk for 20 weeks = **1680 hours annually**
40-60 hours per 2-person crew **640-960 hours annually**
11 workers from December to February **X hours annually**
Six 2-person crews for 2-3 weeks **480-720 hours annually**
1400 hours annually
Six 2- person crews for one week **240 hours annually**
12 people, 6 vehicles, 3-4 weeks **720-960 hours annually**
48 – 60 hours per county per year. 7 counties = **336-420 hours annually**
600-700 hours annually

* Assumed four hours per day.

One division did not provide a response.

7. What types of training does your division provide for the workers who perform the rides (workshops, videos, demonstrations, etc.)?

Video and other – 6
Demonstrations - 2
Sign Condition Survey Guidelines – 1
Ride with an experienced worker – 1

Other includes short refresher training, experienced workers sharing with newer workers, TSU lessons (part of Transportation Worker training involved in the Skill Based Pay Program),

8. During nighttime sign assessments, does your division mark or flag signs needing replacement? If yes, how does your division do this?

Spray paint dot in corner – 5
Mark with square stickers – 3
None – 2

Divisions that indicated using spray paint used white or orange colored paint or did not indicate a color. One of the division that used square stickers, alternated between red, blue, and orange stickers each year. One of the divisions that used spray paint, also used orange flagging ribbon.

---

9. During nighttime sign assessments, what type of documentation does your division use to record that a sign needs to be replaced? How do you document that a sign is replaced?

Needs to be replaced

Sign Condition Survey or some type of form – 10

Sign is replaced

Sign Condition Survey or some type of form – 10

---

10. During nighttime sign assessments, how does your division determine which deficient signs require replacement immediately and which ones will be replaced later as fund become available?

Marking them with a 1, 2, or 3/Priority code from Form,
Stop immediately, yellow in two days, all others as able – 10

---

11. Does your division use handheld retroreflectometers to assess sign conditions?

Yes – 0
No – 1

One division reported that they submitted a suggestion to use them four years ago.

---

12. Does your division currently maintain a sign inventory?

This question was meant to inquire about a computer inventory; however, some answers were in reference to physical inventory so this question was disregarded.

---

13. If yes, what type of data management or software, if any, does your division use?

None – 1
N/A – 4
NCDOT mainframe – 5

---

14. Is your division currently able to manufacture signs in house?

Yes – 10

One division could make all signs except A. Another indicated only being able to make 5% of signs, all of which 72” x 30” or smaller. Another indicated they could make signs up to 96”.

APPENDIX F

ALTERNATIVES GENERATED FROM COMPONENTS

A set of alternatives was formulated to present to the NCDOT committee for comments and feedback. In the process of formulating alternatives, a list of components, defined as one part of an alternative was created. The components were categorized and one component from each category was combined to form alternatives. This index includes the complete list of alternatives generated from components. This list was presented to the NCDOT committee, in addition with the AASHTO and FHWA alternatives, to be narrowed down to a list for further evaluation.

#	Strategy Description	Strategy Comparison
	1 Use sign labels to determine sign age (on sample population)	
1	10 Develop a sign database to collect sign data (on all signs)	
	35a/35b Replace signs with characterisitics similar to signs replaced in sample population	
	1 Use sign labels to determine sign age	
2	10 Develop a sign database to collect sign data	
	37 Replace signs based on sign age	
	1 Use sign labels to determine sign age (on sample population only)	
3	15 Use palm pilots to collect sign data (in sample population)	
	35a/35b Replace signs with characterisitics similar to signs replaced in sample population	
	1 Use sign labels to determine sign age	
4	15 Use palm pilots to collect sign data	
	37 Replace signs based on sign age	
	1 Use sign labels to determine sign age (on sample population)	
5	36 Use a paper form to collect sign information (on sample pop. only)	
	35b Replace signs with characterisitics similar to signs replaced in sample population	
	1 Use sign labels to determine sign age	
6	36 Use a paper form to collect sign information	
	37 Replace signs based on sign age	
	4 Conduct visual nighttime sign inspection (on sample population only)	
7	10 Develop a sign database to collect sign data (on all signs)	TTI 2, AASHTO 3
	35a/35b Replace signs with characterisitics similar to signs replaced in sample population	AASHTO 4
	4 Conduct visual nighttime sign inspection	
8	10 Develop a sign database to collect sign data	TTI 2, AASHTO 3
	38 Replace signs whose legibility distances are less than MRVD	
	4 Conduct visual nighttime sign inspection (on sample population)	
9*	15 Use palm pilots to collect sign data (on all signs)	TTI 2, AASHTO 3
	35b Replace signs with characterisitics similar to signs replaced in sample population	AASHTO 4
	4 Conduct visual nighttime sign inspection	
10	15 Use palm pilots to collect sign data	AASHTO 3
	38 Replace signs whose legibility distances are less than MRVD	
	4 Conduct visual nighttime sign inspection	
11	15 Use palm pilots to collect sign data	AASHTO 4
	39 Replace signs that do not compare with 'visual' samples	
	4 Conduct visual nighttime sign inspection	
12	36 Use a paper form to collect sign information	AASHTO 3
	38 Replace signs whose legibility distances are less than MRVD	
	4 Conduct visual nighttime sign inspection	

13	36 Use a paper form to collect sign information 39 Replace signs that do not compare with 'visual' samples	AASHTO 4
14	5 Use model to predict when sign expires (on sample population) 10 Develop a sign database to collect sign data (on all signs) 35a/35b Replace signs with characterisitics similar to signs replaced in sample population	TTI 3
15	5 Use model to predict when sign expires 10 Develop a sign database to collect sign data 37 Replace signs based on sign age	AASHTO 1, TTI 3
16	5 Use model to predict when sign expires 10 Develop a sign database to collect sign data 35a/ 35b Replace signs (stored in program) with charact similar to signs replaced in sample pop.	AASHTO 1, TTI 3
17	5 Use model to predict when sign expires 13b Use computer system in van to collect sign data (on sample population) 35b Replace signs with characterisitics similar to signs replaced in sample population	AASHTO 1, TTI 3
18	5 Use model to predict when sign expires 13b Use computer system in van to collect sign data 40 Replace signs identified by model as being expired	AASHTO 1, TTI 3
19	6 Measure RR with handheld retroreflectometer 10 Develop a sign database to collect sign data 8 Replace signs whose measured RR are less than proposed values	AASHTO 2
20	6 Measure RR with handheld retroreflectometer (on sample population) 10 Develop a sign database to collect sign data (on all signs) 35a/35b Replace signs with characterisitics similar to signs replaced in sample population	AASHTO 2
21	6 Measure RR with handheld retroreflectometer 35a/ 35b Replace signs (stored in program) with charact similar to signs replaced in sample pop. 8 Replace signs whose measured RR are less than proposed values	AASHTO 2
22	6 Measure RR with handheld retroreflectometer 36 Use a paper form to collect sign information 8 Replace signs whose measured RR are less than proposed values	AASHTO 2
23	13a Use a retroreflectivity van to measure signs 10 Develop a sign database to collect sign data 8 Replace signs whose measured RR are less than proposed values	AASHTO 2
24	13a Use a retroreflectivity van to measure signs (on sample pop) 10 Develop a sign database to collect sign data (on all signs) 35a/35b Replace signs with characterisitics similar to signs replaced in sample population	AASHTO 2
25	13a Use a retroreflectivity van to measure signs 35a/ 35b Replace signs (stored in program) with charact similar to signs replaced in sample pop. 8 Replace signs whose measured RR are less than proposed values	AASHTO 2

26	13a Use a retroreflectivity van to measure signs 13b Use computer system in van to collect sign data 8 Replace signs whose measured RR are less than proposed values	AASHTO 2
27	13a Use a retroreflectivity van to measure signs (in sample pop - on going) 13b Use computer system in van to collect sign data (on all signs - once) 35b Replace signs with characterisitics similar to signs replaced in sample population	AASHTO 2

APPENDIX G

AAHSTO RETROREFLECTIVITY POLICY RESOLUTION

In 1998, AASHTO requested that FHWA delay rulemaking on the proposed minimum in-service guidelines for retroreflectivity. FHWA agreed and the AASHTO Standing Committee on Highways formed a Retroreflectivity Task Force. The Task Force formulated the following resolution. It includes suggestions to assure adequate night visibility should not impose undue burdens on highway agencies as well as four suggestions for methods to evaluate retroreflectivity of signs. The AASHTO Standing Committee on Highways and Board of Directors approved the proposal in 2000.

AASHTO Retroreflectivity Policy Resolution approved 12/9/00:

POLICY RESOLUTION

TITLE: MINIMUM LEVELS OF RETROREFLECTIVITY FOR SIGNS

WHEREAS, the American Association of State Highway and Transportation Officials (AASHTO) is aware of the congressional mandate for the Secretary of Transportation to revise the Manual on Uniform Traffic Control Devices to include a standard for the minimum level of retroreflectivity that must be maintained for pavement markings and signs, which shall apply to all roads open to public travel, and

WHEREAS, AASHTO concurs that it is desirable to maintain an adequate level of retroreflectivity for both traffic signs and pavement markings to enhance safety for motorists during hours of darkness and during adverse weather conditions, and

WHEREAS, AASHTO is concerned about additional liability for transportation agencies if the Federal Highway Administration (FHWA) establishes the proposed minimum levels of retroreflectivity, and

WHEREAS, AASHTO greatly appreciates the opportunity afforded by FHWA to consider recommendations from AASHTO prior to publishing proposed rulemaking for minimum retroreflectivity for both signs and pavement markings, and

WHEREAS, AASHTO established a "Task Force on Retroreflectivity Guidelines" composed of members from federal, state and local transportation agencies, and from several transportation and industry associations; and the Task Force has studied the various issues related to FHWA's suggested guidelines for sign retroreflectivity, and has provided interim findings and recommendations;

THEREFORE, BE IT RESOLVED that based upon the findings and recommendations of the Task Force, AASHTO agrees that:

It is desirable to assure adequate night visibility of traffic signs. Regular assessments of the adequacy of retroreflectivity or the planned replacements of signs to assure adequate night visibility is necessary.

BE IT FURTHER RESOLVED, that efforts to assure adequate night visibility should not impose undue burdens on highway agencies, and to that end, AASHTO recommends that FHWA consider the following relative to the retroreflectivity of traffic signs:

1. The minimum requirements need to be presented in a simple and unambiguous format to assure that they can be easily and properly applied.
2. Tables defining minimum retroreflectivity requirements should not appear in the MUTCD to help protect agencies from unnecessary tort liability and to simplify future changes to this evolving process of evaluating sign retroreflectivity.
3. Alternative methods to assess night visibility need to be fully developed.
4. Agencies should have the option to select from the four proposed methods or combination of these methods best suited to their needs and resources.
5. Agencies should have a 6-year period to implement the methods.

FURTHER, it should be noted that the AASHTO Task Force on Retroreflectivity Guides will evaluate forthcoming FHWA findings and recommendations relative to minimum retroreflectivity values for additional types of signs and for pavement markings as they become available, and will provide comments at that time.

FHWA editorial note:

The four methods in No. 4 in the resolution are for evaluation processes and are briefly described as follows:

1. Measure sign retroreflectivity with instruments and compare to numeric values in tables
2. Conduct nighttime sign inspections and compare sign legibility distances to distance values in a table
3. Conduct nighttime sign inspections by trained observers that would know how to subjectively evaluate signs
4. Knowing how long certain retroreflective materials last in a certain geographic area, replace signs on a schedule to insure replacement prior to the sign reaching the end of it's service life

APPENDIX H

TORT CLAIMS SPREADSHEET

A visit was made to the North Carolina Industrial Commission to gather a list of the tort claims filed against the North Carolina Department of Transportation. The following spreadsheet contains a list of all Docket numbers, plaintiff names, claim amounts, and claim dates for all claims filed against NCDOT from November 14, 2000 to January 14, 2002. The files are public record and each file was reviewed to determine the outcome, award amount, if any, and whether the claim involved signs and in what respect. Some files were in use and not present in the records; these cases are indicated on the spreadsheet as 'file missing'. The spreadsheet was used to calculate the minimum, maximum, and average claim amount (not necessarily the award amount, but how much the plaintiff was seeking).

Docket No.		Plaintiff Name	Amount of Claim	Date of Claim	Award Amt / Outcome	File Missing	Signs cause of claim
TA	16754	Kimberly Bullard	$150,000	11/22/00		x	
TA	16772	Sheila Lingle	$500,000	12/13/00	D		Y
TA	16776	Danny Wright	$10,000 (?)	12/14/00	D		
TA	16777	Ryder Transportation	$48,480 (?)	12/14/00	D		
TA	16790	Sheila Call	$30,000	12/28/00		x	
TA	16809	Douglas Wilson	$40,000	1/12/01		x	
TA	16811	Dylan Efird, Dec'd	$250,000	1/12/01	D		maybe
TA	16837	Ernestine Young	$1,937	1/25/01	D		
TA	16838	Claire Wunder	$100,000	1/26/01		x	
TA	16856	State Farm Insurance	$4,006	2/13/01		x	
TA	16876	Melissa Suarez	$500,000	2/28/01	D		
TA	16877	Shearon Garcia	$300,000	2/28/01	D		
TA	16934	Derek Taylor	$500,000	4/3/01		x	
TA	16941	Candice Colelli	$1,043	4/9/01		x	
TA	16956	Karen Royal	$1,000	4/23/01	D		
TA	16960	Russell Sells	$250,000	4/24/01	$80,596		
TA	16965	Robert Smith, Jr	$150,000	4/25/01		x	
TA	16986	Ronald Greenwood	$113,806	5/14/01		x	
TA	16987	Herlan Kay Porter	$229	5/14/01	?		
TA	17001	Donna Campbell	$250,000	5/23/01	$37,500		
TA	17006	Erica Reeves	$500,000	5/29/01		x	
TA	17009	Rebecca Cabeen	$50,000	5/30/01		x	
TA	17022	Ruby Haney	$4,502	6/6/01	?		
TA	17027	Anita Freeman	$10,000	6/11/01	?		
TA	17044	Gail Crawford	$52,000	6/26/01	?		
TA	17061	Michael Perez	$10,000	7/6/01	?		
TA	17066	Lisa Harrison	$3,787	7/12/01	D		
TA	17069	Nicholas Warger	$250,000	7/16/01	D		Y
TA	17070	Nationwide Mutual Ins.	$4,537	7/16/01		x	
TA	17079	Gregory Sloan	?	7/17/01		x	
TA	17088	Nicholas Barone	$2,023	7/25/01	D		
TA	17091	Victoria Davis	$10,000	7/30/01	D		Y
TA	17092	Ashley Whitaker	$20,000	7/31/01	D		Y
TA	17097	Bettyann Sellers	?	8/1/01	?		maybe
TA	17098	Priscilla Faulk	?	8/1/01	?		maybe
TA	17120	Jordan Lipton, MD	$463	8/20/01	?		
TA	17132	Patricia Stanley	$500,000	8/24/01	D		Y
TA	17139	Kellie Crabtree	$500,000	8/30/01		x	
TA	17140	McKenzie Crabtree	$500,000	8/30/01		x	
TA	17156	Derek Pate	$187,600	9/8/01	D		
TA	17170	James and Ruth Long	$3,619	9/17/01	D		
TA	17174	Michael Zahn, Dec'd	$500,000	9/18/01	D		
TA	17231	Yumi Matsukawa	$500,000	10/29/01	D		
TA	17235	Michael Moore	$500,000	10/30/01	D		
TA	17236	Beatrice Britt	$500,000	10/30/01	D		
		Maximum Claim Amount	$500,000	45			YES = 5
		Minimum Claim Amount	$229				Maybe = 3

	Average Claim Amount	$193,764						

CLAIMS IN PROGRESS AT TIME OF INQUIRY

TA	17286	Tyreena Moore, Dec'd	$10,000	12/17/01
TA	17301	David and Jane Goodwin	$500,000	12/31/01
TA	17306	Jason M. Reyonlds	$500,000	1/8/02
TA	17310	Lona Lowery, Dec'd	$500,000	1/10/02
TA	17311	Jason Lowery. Dec'd	$500,000	1/10/02

APPENDIX I

SIGN INVENTORY MANAGEMENT SYSTEM (SIMS) SOFTWARE ASSESSMENT

A software assessment was of existing off-the-shelf sign inventory management system software was created by the North Carolina State University Department of Civil Engineering. The objective of the assessment was to determine how appropriate available SIMS software are for NCDOT by evaluating them based on a set of quality parameters such as cost, functionality, data items, training and technical support. The entire text of the assessment is included in this appendix.

SOFTWARE EVALUATION OF SIGN INVENTORY MANAGEMENT SYSTEM

There are many off-the-shelf software for sign inventory management system (SIMS). It is very possible that some of this software might be quite appropriate for NCDOT to adopt for sign inventory management purposes instead of developing customized software from scratch. In order to make such a decision, a thorough knowledge about the existing SIMS software is needed.

Purpose/Objective

The objective of this software evaluation is to determine how appropriate most SIMS software is to NCDOT by evaluating them based on a set of quality parameters such as cost, functionality, data items, training and technical support, etc.

Methodology

In the study we identified existing sign inventory management software using three primary information sources: 1) Web search using keywords such as SIMS, SMS, Sign Management, Sign Inventory, etc.; 2) search in MCTRANS (1999-2000 catalog, McTrans fall 2000) and PCTRANS (2001 software catalog) transportation software clearinghouses; and 3) a search of advertisements in the *ITE Journal* (July 2001, October 2001, November 2001, December 2001, January 2002). For each software package, detailed information was obtained and an evaluation was made based on a predetermined set of criteria.

SMS and SIMS

A sign management system (SMS) is defined as a coordinated program of policies and procedures, which ensure that the highway agency provides a sign system that meets the needs of the user most cost-effectively within available budgets and constraints [McGee and Paniati 1998]. A comprehensive SMS consists of the elements for various stages of the life cycle of signs shown in Figure K-1. A well-implemented sign management system will identify worn-out signs, minimize requirements for field inspection and inspection costs, plan and budget resources properly, be usable as a liability defense, track problem areas, and anticipate future needs (3).

From Figure K-1, it is clear that a sign inventory and management system (SIMS) is an essential component of an SMS. An SIMS encompasses only the inventory management aspect of SMS. It keeps information about the signs, which may be either in-warehouse or on-road. While it is beneficial to know the information about the signs in-warehouse, the essential functionality of SIMS is to keep information about signs on-road. In the context of this research, an SIMS serves the five main purposes listed bellow: [McGee and Paniati 1998]

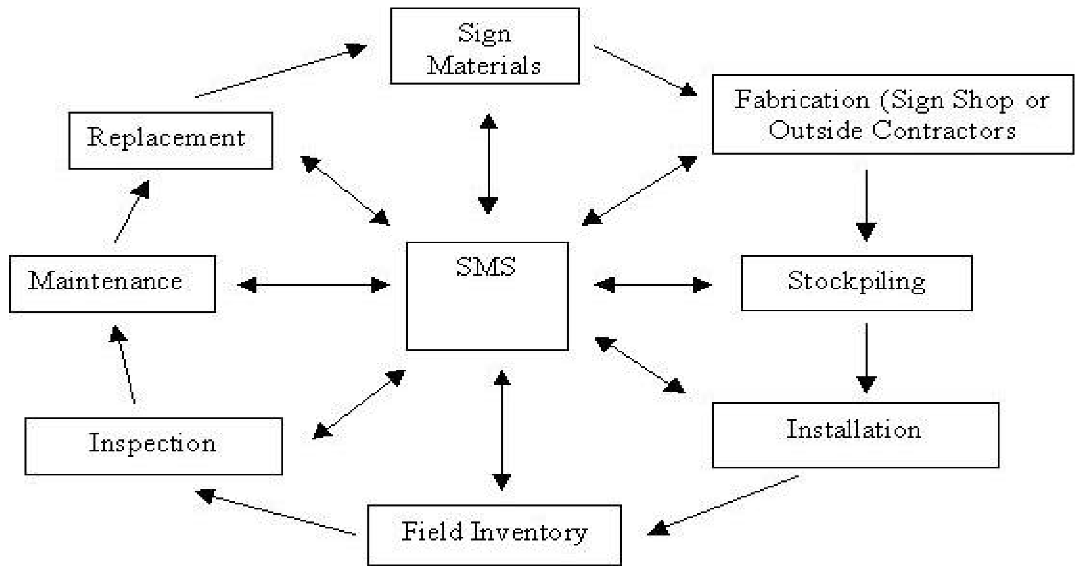


Figure K-1: A Comprehensive Sign Management System (SMS) [McGee and Paniati 1998]

(1) Targeting signs for replacement
A comprehensive SIMS can track the installation dates of traffic signs, which in turn can be combined with other sign information to enable the users to identify those signs that are most likely in need of replacement.

(2) Identification of problems
A comprehensive SIMS keeps working records of inspection and maintenance activities. Problem areas can be identified based on the working records. Physical countermeasures can be utilized at high vandalism sites. Also, further studies about these areas can be conducted to provide detailed information. In addition, a well-maintained SIMS is important for identifying and replacing missing signs.

(3) Minimizing tort liability
A SIMS provides evidence of the existence of a particular sign at a particular location and documents the inspection or maintenance activities associated with the sign, which is very useful in tort liability cases.

(4) Planning and budgeting for sign replacement.
SIMS provides information such as the number of signs on-road, the location and condition of the signs based on inspections, the age of sign. This helps to develop a regular program of sign replacement. This program can include identification of signs to be replaced, estimation of material needs, scheduling of replacement, etc. An SIMS enables the allocation of limited resources in a cost-effective manner.

(5) Maximizing productivity
An SIMS provides inventory information, which, when combined with work orders, allows the manager to monitor the productivity of signing activities and to effectively schedule both emergency and regular maintenance activities.

Table K-1 lists the software that we found using the methodology mentioned earlier. By examining the software identified, we found that all of them could be categorized as SIMS based on the above definitions of SIMS and SMS, even though some of them are advertised as SMS. No software was found to be capable of managing every element of the complete sign life cycle. All the software identified concentrates on on-road sign inventories. As a deviation, it is worth pointing our here that in software selection, in-depth examination is desirable before accepting what the vendors say about their products. In many cases, the advertisements or descriptions are misleading. The sales marketing personnel may not be computer engineers or transportation engineers. Unfortunately, it is these persons that extract product information that they believe to be important from the sales and marketing point of view, while ignoring important product features.

Software No. 15 in Table K-1, FHWA Sign Management System (FHWASMS) is in a different situation. FHWASMS is advertised as a sign management system. However, it only includes three basic elements for comprehensive sign management – inventory, inspection, and maintenance/replacement. The emphasis is still the inventory and management of on-road signs. For this reason, we also categorize FHWASMS as an SIMS.

Table K-1: SIMS Software

No.	Software Name	Company	Information Source
1	SIGN*view*	CarteGraph Systems, Inc.	http://www.cartegraph.com
2*	SIMS 3.0 Professional; SIMS 3.0 Express	Advanced Data Technologies	http://www.adtcorp.com
3	VIMMS	Vulcan, Inc.	http://www.vulcaninc.com
4	Sign Inventory and Replacement	3M	http://www.3m.com/us/safety/tcm/solutions/prg_sms.jhtml
5	SIMS99	UNH T2 Center	http://www.t2.unh.edu/pwms/
6	SIGNMASTER™	MasterMind Systems, Inc.	http://www.mastermindsystems.com
7**	Sign Management System	GeoDecision	http://www.geodecisions.com/
8	SIMS		MCTRANS, 99-00 Catalog, p 22
9	TOSSSI		MCTRANS, 99-00 Catalog, p 23
10	North Dakota Sign Management System, Version. 4.0		MCTRANS, 99-00 Catalog, p 29
11	Sign Inventory System		MCTRANS, 99-00 Catalog, p 29
12	SIGN^3		MCTRANS, 99-00 Catalog, p 29
13	SIS		PCTRANS, 01 Catalog, p6
14	WIN-SIGN		PCTRANS, 01 Catalog, p10
15***	FHWA Sign Management System	FHWA	[McGee and Paniati 1998]

*This one is not included in the evaluation as provided in the later sections because the vendor is no longer selling the SIMS products.
** This one is customized software, not off-shelf. It is not included in the evaluation.
***This one is evaluated based on summary information in the Appendix of reference [McGee and Paniati 1998]. Some information is still missing.

It is clear that not all software we found is evaluated. The reasons for not including software No. 2 and 7 in Table K-1 are listed right under Table K-1. In addition to that, all software except software No. 9 from MCTRANS and PCTRANS is not included in the detailed evaluation. Table K-2 lists the system requirements for each software. It is clear that these are pretty old ones. Taking into consideration of the rapid developments in computer technologies, there is no reason for us to spend time on evaluating the outdated software. We have also contacted MCTRANS and PCTRANS. It turns out that there is no available vendor support for the software listed in Table K-2. Only limited installation help is provided by MCTRANS and PCTRANS.

Table K-2: Computer System Requirements for Software Packages Advertised in PCTRANS and MCTRANS

No.	Software Name	System Requirements
8	SIMS	MS Windows 3.1+
10	North Dakota Sign Management System, Version. 4.0	IBM PC/MS-DOS 3.3+, dBASE III+ or IV
11	Sign Inventory System	IBM PC/MS-DOS 2.0
12	SIGN^3	IBM PC/MS-DOS 2.0+, dBASE III
13	SIS	DOS 3.0+, 512k RAM
14	WIN-SIGN	Windows 3.0+

Quality Parameters

In this section, 6 sets of quality parameters are provided and described in detail. These 6 sets of quality parameters are developed in such a way that we take into consideration the requirements and admirable features an SIMS might have, then some specifications of the software we found are examined carefully, and finally we come up with the comprehensive 6 quality parameter sets.

These 6 sets of quality parameters will be used to assess how ready a particular SIMS software package is for use. Data matrix parameters determines what data items (information about on road signs) are stored in the system. Data acquisition, input, and exchange parameters describe how raw data are collected and input into the system, how the data can be analyzed, and how information is communicated. System functionality parameters determine how capable and powerful the system is. System requirements specify the computer system requirements from the software. Ease of use evaluates the friendliness of each software based on its user interface design. Costs and technical support parameters provide information about the cost to run and update the SIMS software and the availability of technical support.

Quality Parameter Set 1 ---- Data Matrix

Data matrix parameters determine what data items (attributes about a sign) the SIMS software can store. They are described in detail in the following.

(a) Location: the location of a specific sign. It can be either an absolute location (geographic coordinates), or relative location (with respect to a specific location referencing system), or both of these two.
(b) Installation date: the date when the sign was installed in the field.
(c) Type: the type that the sign is categorized into.
(d) Size: dimension of the sign.
(e) Facing direction: the direction towards which the sign is facing.
(f) Substrate material: what material was used to manufacture the sign substrate.
(g) Grade and manufacturer of reflective sheeting: manufacturer and grade information about the reflective sheeting.

(h) Video or picture: the capability of the system to store video or picture information for a specific sign.
(i) Survey date: the date when the sign was inspected.
(j) Condition: the sign examination result, i.e. how good the sign is.
(k) Record of inspection/maintenance activities: the capability of the system to record inspection and maintenance activities related to a specific sign.
(l) Others: other data items/attributes that can be stored in the SIMS software being evaluated.

Quality Parameter Set 2 ---- Data Acquisition, Input, and Exchange

This set of parameters aims at providing information about how the data are collected in the field, input into the system, analyzed to answer questions, and communicated among different users.

(a) Data acquisition: what methods does the system enable to collect data (bar coding, GPS + rangefinder, manual reading information, etc.)?
(b) Data transfer: how the field data are transferred into the system. This can be done in real-time using network connections, with automatic batch processing such as downloading GPS data for a set of signs, or by manually input information into the system. In manual input, tools such as sign libraries and forms can be used to improve efficiency and reduce errors.
(c) Data interchange: how does the system enable data and information communications in organization (electronically/in paper format, raw data/report, etc.)

Quality Parameter Set 3 ---- System Functionality

This set of parameters evaluates the capabilities of SIMS software. Generally, this set of parameters determines what the SIMS can do.

(a) Replacement forecasting is the capability of forecasting signs to be replaced either using a forecast model or ad hoc rules. Based on the data items in the inventory and the forecasting model, the system either supports or does not support forecasting analysis. A system that supports forecasting either supports it explicitly, i.e., a specific module/tool is available for setting rules and run the analysis, or implicitly, i.e., instead of using a forecasting module, a query can be used to retrieve signs that need replacement considering data items in the inventory.
(b) Data analysis: what questions can the system answer using given data? For example, priority analysis tells the user what signs are most critical for replacement. This parameter encompasses parameter (a) because parameter (a) is just one of the many analyses that an SIMS can perform. However, replacement forecasting is attracting much attention. A successful replacement forecasting model saves both time and money. This is the reason why this functionally elects and becomes parameter (a).
(c) On-road sign inventory: the capability to store information for on-road signs. The information here means the attributes as specified in quality parameter set 1.
(d) In-house sign inventory: the capability to store information for in-warehouse signs and sign parts.
(e) Schedule for inspection, maintenance, and replacement: the capability to generate inspection, maintenance, and replacement schedules based on the data items in the database and certain rules.

(f) Real-time check: the capability of comparing retroreflectivity readings with stored standards and determining the sign condition automatically in the real-time mode. For a system that does not have real-time check, it is still very possible that there are built-in retroreflectivity standards in the system but manual checking (manually comparing retroreflectivity readings with standards).
(g) Customization: the extent to which the system can be customized, especially in the area of replacement forecasting. For example, some systems allow the user to specify the rules or parameters that can be used to forecast the replacement estimate. Some systems can build deterioration equations for signs within a particular geographic area specified by the user.
(h) Help system: built-in sign library, help documentation, tutorial, etc.
(i) Action documentation: the capability of documenting activities that happened, are happening, or will happen to a specific sign. This parameter overlaps with parameter (k) in set (1).

Quality Parameter Set 4 ---- System Requirements

This set of parameters determines what are the hardware, software, and supporting accessory requirements in installing and running the SIMS software in computer.

(a) CPU/Processor: the requirements for CPU/Processor, for example, 486 or higher are requested to run the software.
(b) RAM: requirements for random access memory. RAM is the high-speed memory available. Generally, software that runs many transactions simultaneously needs higher RAM than others.
(c) Hard disk: the disk space needed to install the software. The disk space needed to store data is not included because it depends on how much data will be stored.
(d) Operating system: the operating system that the software supports.
(e) Other supporting software: software needed to run the SIMS program, for example, database (Oracle, DB2, Sybase, etc.) and GIS (ArcGIS, MapInfo, etc.).
(e) Accessories/others: printer, plotter, sound card, network connections, CD-ROM, CD-Rewriter, etc.

Quality Parameter Set 5 ---- Costs and Technical Support

This set of parameters determines the costs to run, maintain, and update the SIMS software. Also, the availability of technical support and training is determined.

(a) Cost for license: the cost to get a license to install and run the software.
(b) Cost for updating and maintenance: the cost of updating and maintenance.
(c) Training: availability and costs.
(d) Technical support: what level of support is available. Examples include 24-hour services, help desk, in-house training, etc.

Quality Parameter Set 6 ---- Ease for Use

This set of parameters evaluates the user-friendliness of the system based on its interface design.

(a) Interface design: the visual feeling of the interface, the complexity of the interface, the availability of hints, etc.
(b) Menu design: the completeness and organization of menus and submenus.

Results
Based on the quality parameter sets, the software identified to be suitable for evaluation was evaluated one by one. For some reason, the vendor of SIGNMASTER^{TM} won't provide any detailed information. We evaluate this software package based on the information as shown on its website, which leads to lots of N/As in the evaluation result tables. The evaluation results are summarized in Tables 3 to 8, one table for each set of quality parameters.

Evaluation Result based on Quality Parameter Set 1 ---- Data Matrix

Table K-3 shows the result of software evaluation based on quality parameter set 1 ---- data matrix. Each quality parameter occupies one column. Each software occupies one tuple, or is one record.

Table K-3. Evaluation Result based on Quality Parameter Set 1 ---- Data Matrix

No.	Software	Location	Installation Date	Type	Size	Facing Direction	Substrate Material	Grade and Manufacturing of Sheeting	Video/ Picture	Survey Date	Condition	Record of Activities	Others
1	SIGN*view*	Both	Yes	Yes	Yes	Yes	Yes	Yes	Picture	Yes	Visibility, RR Value	Yes	Jurisdiction (Owner), history, detailed information about supports
3	VIMMS	Both	Yes	Yes	Yes	Yes	Yes	Yes	Picture	Yes	Yes	Yes	Data dictionary is available for existing data items. Customized data items can be developed.
4	Sign Inventory and Replacement	Both	Yes	Yes	Yes	Yes	Yes	Yes	Video	Yes	Yes, RR Values	Yes	Almost 50 attributes
5	SIMS99	Both	Yes	Yes	Yes	Yes	Yes	Surface material	No	Yes	Day, night	Work description	Owner, designation, description, obstruction, shape, memo, post information
6	SIGNMASTER™	Both	Yes	Yes	Yes	Yes	Yes	Yes	Picture	Yes	Yes, RR Value	Yes	Information about supports, multiple location referencing
9	TOSSSI	Both	Yes	Yes	Yes	Yes	Yes	Yes	Picture	Yes	Condition	Yes	Labor and material cost for each sign, barcode, a sign code database, work order, issued completed date for work orders.
15	FHWA SMS	Relative only, but 3 methods of measure	Yes	Yes	N/A	Yes	Yes	Yes	No	Yes	Yes, RR Value	Yes, history	Some data elements are required, some are not required. However, other elements can be required and entered into the sign record.

Observations for this quality parameter set are listed as bellow.
(1) All software packages have store space for location, installation date, sign type, size, facing direction, substrate material, sheeting information, survey date, sign condition, and work history. Though FHWA SMS does not require sign coordinates, the coordinates can be acquired and entered into the system.
(2) Sign Inventory and Replacement (No. 4) enables the use of video to record sign information, extract that information automatically, and input that information into system automatically. All packages except SIMS99 and FHWA SMS incorporate the use of picture.
(3) Four out of seven packages are designed to store retro reflectivity readings. All packages store the sign condition.
(4) All packages allow for customized data attributes. Examples listed in the *Others* column demonstrate this. Based on the data list from NCDOT, it is observed that all software packages are capable of dealing with sign inventory issues from the data storage point of view.
(5) It is concluded that there is no big difference for the evaluated software packages from the data item point of view.

Evaluation Result Based on Quality Parameter Set 2 ---- Data Acquisition, Input, and Exchange

Table K-4 shows the evaluation result for all software based on the second quality parameter set. Again, each quality parameter becomes a column while each software occupies one tuple.

Table K-4: Evaluation Result Based on Quality Parameter Set 2

No.	Software	Data Acquisition	Data Transfer	Data Interchange
1	SIGN*view*	Coordinates, manual	Fast-Capture™ data entry optimization	Report
3	VIMMS	Coordinates, manual	Automatic Transfer, Manual	Report
4	Sign Inventory and Replacement	Coordinates, video taping	Automatic extraction	Report
5	SIMS99	Coordinates, manual	Manual (forms)	Report
6	SIGNMASTER™	Coordinates, manual	Manual (forms)	Report, graphs
9	TOSSSI	Coordinates, manual	Manual	Report
15	FHWA Sign Management System	Manual	Manual	Report

The observations acquired based on the approaches that are used to acquire data, transfer data, and exchange data are listed as bellow.
(1) Location information can be either acquired using GPS (for coordinate information) or manually (relative position, for example, along road A, from section S1 to S2, right side).
(2) Sign Inventory and Replacement (No. 4) uses video tape to record and extract sign information, all other packages require users to get sign information manually (for example, facing direction, dimension, type, etc.).
(3) Only VIMMS (No. 3) allows for automatic transfer of coordinate information. Only Sign Inventory and Replacement allows for automatic information extraction from video tape.

(4) For manual data input, tools are available to help data input and assure the correctness. For No. 1, 5, and 6, these tools and forms are readily available. For No. 9 and 15, customized tools need to be developed.
(5) All software packages enable the generation of customized reports.

Evaluation Result Based on Quality Parameter Set 3 ---- System Functionality

Table K-5 shows the evaluation result according to quality parameter 3, which concentrates on the functionality of the SIMS. Each parameter becomes the heading for a column and each software becomes a record in the table.

Table K-5: Evaluation Result Based on Quality Parameter Set 3 -- System Functionality

No.	Software	Replacement Forecasting	Data Analysis	On Road Inventory	In House Inventory	Schedule Support	Real-time Check	Customization	Help System	Action documentation
1	SIGN*view*	Implicit	Queries	Yes	Yes	Yes	Record RR readings only	A little bit	Multiple sign libraries	Yes
3	VIMMS	Explicit	Sign aging, remaining life and current condition analysis	Yes	No	Yes	Yes	Quite	Built-in selectable items for data field	Yes
4	Sign Inventory and Replacement	Implicit	Queries	Yes	No	Yes	Record RR readings	A little bit	Sign library	Yes
5	SIMS99	Implicit	Priority analysis, and initiate repair action	Yes	Parts	Yes	Record RR readings	A little bit	Sign library	Yes
6	SIGNMASTER™	Implicit	Priority analysis, and initiate worker orders and inspections	Yes	No	Yes	Record RR readings	A little bit	Sign library	Yes
9	TOSSSI	Implicit	Queries	Yes	No	Yes	No	A little bit	No sign library	Yes
15	FHWA Sign Management System	Explicit. Built-in forecast model, and deterioration equations.	Replacement predicate, inspection/maintenance schedule	Yes	No	Yes	Yes, built-in FHWA minimal RR standards	A little bit	Sign library	Yes

System functionality is very important in evaluating software packages. For the evaluated software packages, the observations from the system functionality point of view are listed as bellow.
(1) All software packages support replacement forecasting analysis. Only VIMMS and FHWA SMS have developed built-in default forecasting models, while still allowing for customization. Others support replacement forecasting in the way of letting users specify replacement conditions in the format of customized queries.
(2) Similar to replacement forecasting and data analysis, all software packages support scheduling replacement and maintenance.
(3) All software packages focus on on-road sign inventory. In-warehouse inventory is kind of a bonus to SIGN*view*.
(4) TOSSSI (No. 9) has no built-in sign libraries. Also, it is not potential for real-time checking because it has no store place for retro reflectivity readings (it only stores condition). Other packages have built-in sign libraries to allow users click and select instead of typing everything into the system.
(5) All packages allow for limited customization. All packages support recording work histories.
(6) It is concluded that except TOSSSI, all other software packages shows close system functionality.

Evaluation Result Based on Quality Parameter Set 4 ---- System Requirements

Table K-6 summarizes the evaluation result based on quality parameter set 4, which concentrates on system requirements of SIMS. This set of quality parameter tells what computer system the user must have in order to support SIMS. This set is important because the user would like to get SIMS that can work with its currently available computer system instead of buying new computer hardware or software.

Table K-6: Evaluation Result Based on Quality Parameter Set 4 ---- System Requirements

No.	Software	CPU	RAM	Hard Disk	Operating System	Supporting Software	Accessories
1	SIGN*view*	Pentium Processor	32MB	N/A	Win95 or higher, WinNT 4.0 or higher	Microsoft SQL Server 7.x, or Microsoft Jet 4.0, or Oracle 8.x	Graphics card and monitor with 640*480 resolution and 256 colors
3	VIMMS	Pentium III 433 MHz or higher	128MB	50MB	Win95, Win98, 2000, NT, or XP	System Manager™ Module of VIMMS	1.44" floppy drive, CD ROM
4	Sign Inventory and Replacement	450 Mhz	64MB	Huge	Win98 or higher	No	Depends
5	SIMS99	486 or higher	4MB	0.7MB (software only)	Win3.1, 95, NT	No	3.5" floppy drive
6	SIGNMASTER™	N/A	N/A	N/A	Windows	N/A	N/A
9	TOSSSI	Pentium II or higher	N/A	300MB	Win95, 98, 2000, XP, NT	No	CD Rom, VGA Graphics Card (1024*768)
15	FHWA Sign Management System	N/A	N/A	N/A	N/A	N/A	N/A

Observations based this quality parameter set are listed as bellow.
(1) All software packages are developed for Windows operating system.

(2) SIMS99 has the lowest requirement in processor (486 is good enough). VIMMS has the highest CPU requirements (Pentium III 433 MHz or higher). Others fall between these two.
(3) CD-ROM would be a necessity to install software.
(4) Free space requirements are demanding because of the amount of sign information need to be stored.
(5) SIGN*view* and VIMMS require supporting software. SIGN*view* requires supporting database management system. VIMMS requires a system module that is developed by the same vendor as VIMMS.

Evaluation Result Based on Quality Parameter Set 5 ---- Costs and Technical Support

Table K-7 summarizes the evaluation results based on quality parameter set 5, which concentrates on the costs and technical support information. Using this set of quality parameter, the user will at least have an idea of how much the SIMS will cost in the long run. Also, if the user needs strong technical support, these quality parameters provide a reference.

Table K-7: Evaluation Result Based on Quality Parameter Set 5 - Costs and Technical Support

No.	Software	License Cost	Updating/Maintenance Cost	Training	Technical Support
1	SIGN*view*	$4000.00	$800.00	$1000.00 (Web training), $1450.00/day (on-site)	12 months
3	VIMMS	$1995.00+$495.00*	$595.00+$100.00**	N/A	N/A
4***	Sign Inventory and Replacement	$895.00 to $2895.00	N/A	N/A	Help desk through development
5	SIMS99	Free	Free	Not available	Designated Person
6	SIGNMASTER™	N/A	N/A	N/A	N/A
9	TOSSSI	$295.00	N/A	N/A	6 months
15	FHWA Sign Management System	N/A	N/A	N/A	N/A

* This price is for one copy. If network version is used, additional license fee is $450.00/person.
** Each additional user license $100.00.
*** 3M is offering a one-pass program for full sign treatment at the cost of $11-12/sign.

Observation include:
(1) Price for licensing ranges from free to $4000.00. SIGN*view* has the most expensive licensing cost ($4000.00) while SIMS99 is free for use.
(2) Only SIGN*view* and VIMMS have specified costs for updating. Sign Inventory and Replacement has update available, but no cost information is available yet. However, it is offering a one-pass program to take care of sign inventory and maintenance at the price of $11-12/sign. SIMS99 has free updates. All others don't have updates.
(3) Only SIGN*view* provides training with a cost.
(4) For technical, situations vary widely. It is obvious though, expensive commercial software packages have higher level of technical support.

Evaluation Result Based on Quality Parameter Set 6 ---- Ease of Use

This set of quality parameters summarizes the user-friendliness of the user interface design of SIMS. The users of SIMS are usually computer professional. A well-designed graphical user interface is very important. Table 7 summarizes the evaluation results based on this set of quality parameters.

Table K-8. Evaluation Result Based on Quality Parameter Set 6 ---- Ease for Use

No.	Software	Graphical Interface Design	Menu Design
1	SIGN*view*	Good, complicated	Good, complicated
3	VIMMS	Professional, basic	Professional, basic
4	Sign Inventory and Replacement	Professional, easy to use	Professional, easy to use
5	SIMS99	Good, basic	Good, basic
6	SIGNMASTER™	Good, basic	N/A
9	TOSSSI	Good, basic	Good, basic
15	FHWA Sign Management System	N/A	N/A

Observations based on this set of quality parameter include (no sample user interface is available for FHWA SMS, this is the reason that two N/As are filled in the table):
(1) All software packages have graphical user interface. SIGNview has a relatively complicated one while all others have relatively basic design. However, from the evaluator's point of view, all packages have easy to use interfaces. These interfaces are user friendly.
(2) There is no functional difference in user graphical interface design.

References

[McGee and Paniati 1998] McGee, W. H. and Paniati, A. J., "An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs [microfiche]," Publication no. FHWA-RD-97-052, Washing, D.C., April 1998.

CarteGraph Systems, Inc. http://www.cartegraph.com/signview2.html, Copyright 2002, Accessed March 26, 2002.

Advanced Data Technologies http://www.adtcorp.com, Accessed March 26, 2002.

Vulcan, Inc. http://www.vulcaninc.com/plt8p01.htm, Copyright 1997-2001, Accessed March 26, 2002.

3M http://www.3m.com/us/safety/tcm/solutions/prg_sms.jhtml, Copyright 1995-2002, Accessed March 26, 2002.

UNH T2 Center http://www.t2.unh.edu/pwms/sims.html, Accessed March 26, 2002.

MasterMind Systems, Inc. http://www.mastermindsystems.com/signmstr.html, Copyright 1998-2002, Accessed March 26, 2002.

GeoDecision http://www.geodecisions.com/framesservices.htm, Copyright 2002, Accessed March 26, 2002.

No.	Software Name	Source Company/Organization	Homepage	Contact Information		
				Name	Phone	Email
1	SIGN*view*	CarteGraph Systems, Inc.	http://www.cartegraph.com	Tom Barton/Dave Samson	(319) 556-8120 (800) 688-2656-6118	tombarton@cartegraph.com davesamson@cartegraph.com
2	SIMS 3.0 Professional; SIMS 3.0 Express	Advanced Data Technologies	http://www.adtcorp.com	N/A	(330) 723-8212	adtinfo@adtcorp.com
3	VIMMS	Vulcan, Inc.	http://www.vulcaninc.com	N/A	(888) 846-2801 (251) 943-7477	vimms@vulcaninc.com
4	Sign Inventory and Replacement	3M	http://www.3m.com/us/safety/tcm/solutions/prg_sms.jhtml	???	???	Online form feedback
5	SIMS99	UNH T2 Center	http://www.t2.unh.edu/pwms/	David Fluharty (UNH) Ed Lagergren (WSDOT)	(603) 862-4348 (360) 705-7986	orlagerge@wsdot.wa.gov
6	SIGNMASTER™	MasterMind Systems, Inc.	http://www.mastermindsystems.com		(419) 862-3625	sales@mastermindsystems.com
7	Sign Management System*	GeoDecision	http://www.geodecisions.com/	Mark Alexander (PennDOT), Robert Marsters (GeoDecisions)	(717) 783-6261 (717) 763-7211	info@geodecisions.com
8	SIMS	MCTRANS, 99-00 Catalog, p 22				
9	TOSSSI	MCTRANS, 99-00 Catalog, p 23				
10	North Dakota Sign Management System, Version. 4.0	MCTRANS, 99-00 Catalog, p 29				
11	Sign Inventory System	MCTRANS, 99-00 Catalog, p 29				

12	SIGN^3	MCTRANS, 99-00 Catalog, p 29				
13	SIS	PCTRANS, 01 Catalog, p6				
14	WIN-SIGN	PCTRANS, 01 Catalog, p10				
15	FHWA Sign Management System	FHWA				

* This is a customized software being developed for the Port Authority of New York and New Jersey.

No.	Software Name	Status
1	SIGN*view*	Done
2	SIMS 3.0 Professional; SIMS 3.0 Express	No longer available. Done
3	VIMMS	Done
4	Sign Inventory and Replacement	Underworking
5	SIMS99	Done
6	SIGNMASTER™	Done, vendor doesn't want to provide info.
7	Sign Management System*	Emailed. Waiting for reply.
8	SIMS	Emailed
9	TOSSSI	Emailed
10	North Dakota Sign Management System, Version. 4.0	Emailed
11	Sign Inventory System	Emailed
12	SIGN^3	Emailed
13	SIS	Emailed
14	WIN-SIGN	Emailed
15	SIMS	Emailed
16	FHWA Sign Management System	Appendix got from library. Done.

APPENDIX J

GPS SIGN INVENTORY REPORT

The North Carolina Department of Civil Engineering performed an independent study to evaluate the use of GPS as an inventory data collection tool. Through the use of the sign density data collected in the sign count approximation studies by the NCSU Department of Civil Engineering and the time involved in the collection of sign locations and attributes using GPS equipment in this study, reasonable projections were made as to the cost and time involved in developing such an inventory.

Introduction

Background

The North Carolina Department of Transportation (NCDOT) is responsible for the proper signing of its roadways. This responsibility includes not only assuring that the correct signs are located in the correct places, but that these signs are maintained such that they can serve their purpose of communicating information to drivers under all conditions.

The Federal Highway Administration (FHWA) is expected to enact a new standard for the maintenance of roadway signs sometime in the near future. This new standard is to address the issue of retroreflectivity of signs during the low light hours of a day. The NCDOT will likely become legally accountable for the retroreflectivity of its signs and therefore is interested in studying retroreflectivity and methods for dealing with this possible new standard.

Retroreflectivity is the measure of how well a sign reflects light back to its source. Retroreflectivity is affected by the paint and/or the type of reflective sheeting that is present on a sign. The ability of a sign to reflect light is greatly affected by the elements of nature and the age of the sign. The direction that a sign faces, the geographic region of the state, the amount of shade present, and the quality of sheeting all play a major role in how long a sign will sufficiently reflect light in the field.

As a result of the possibility of increasing legal liability for the condition of its signs, the NCDOT is considering alternatives for how to address this possible new standard. Currently, the NCDOT does not know how many signs it owns and maintains. Sign count approximation studies have been completed by the NCSU Department of Civil Engineering for primary and secondary NC routes. These studies estimated the number of signs that are owned and maintained by the NCDOT by using sign densities for different types of roadways.

Knowing the approximate number and type of signs that are present in the field is helpful in estimating maintenance needs and feasibility of further studies, but it falls short in providing adequate information for maintenance budgeting, scheduling, and other management functions. The development of an adequate and expandable sign inventory system to help with those management functions would likely benefit NCDOT greatly. NCDOT currently relies on the drivers in an area informing the department about missing/damaged signs and sign crews determining when and how a sign is to be replaced. A current inventory with the proper attributes, for example, could help with maintenance procedures by calculating replacement dates for signs based on the manufacture date, sheeting type, and local weather conditions.

The NCDOT does not have any sort of sign inventory in place at this time and the development of such an inventory could be worthwhile. An accurate and effective sign inventory could not only address the issue of retroreflectivity, which has inspired this research, but would also allow for improved maintenance procedures and more thrifty budgeting to take place in the future.

One method of addressing the issue of a sign inventory is through the use of both Geographic Information Systems (GIS) and Global Positioning System (GPS) technology as a means for determining accurate location, type, and condition information for individual signs. GPS and GIS are rapidly advancing technologies that allow for very effective infrastructure management to take place when used properly. The implementation of an accurate and expandable sign inventory system using GIS and GPS could greatly assist the NCDOT in meeting the FHWA's possible retroreflectivity standard. However, other methods should be considered as well.

There are several sign management systems commercially available that address many of the needs of a sign inventory system. These systems are available as stand alone software packages that the customer must supply the data for and as inventory collection services provided with software applications. The Civil Engineering Department at NCSU has conducted a study of such off-the-shelf sign management systems to determine the benefits and capabilities of each. These sign management systems are also a possible means of helping NCDOT handle the issues of retroreflectivity and liability via an inventory.

The development of a complete sign inventory for the NCDOT is clearly out of the scope for this project. However, through the use of the sign density data collected in the sign count approximation studies by the NCSU Department of Civil Engineering and the time involved in the collection of sign locations and attributes using GPS equipment in this study, reasonable projections can be made as to the cost and time involved in developing such an inventory.

Objective

The goal of this project is to determine the feasibility of a sign inventory performed using GPS that would also help address the issue of retroreflectivity. This project will help discern the time and costs related to an undertaking of sign inventory via GPS. Upon the conclusion of this investigation, NCDOT should be able to make an informed decision as to whether or not this would be a desired method for dealing with the issue of retroreflectivity and sign inventory.

Approach and Scope

Using the proposed system, the locations and attributes of signs are collected from a vehicle using a Trimble Pro XR GPS Unit and an Advantage laser range finder from Laser Atlanta Optics. These pieces of equipment are owned throughout NCDOT, which is why they were chosen. A statistically significant number of signs (approximately 50) are surveyed along each road type using the same parameters for road type as defined in the sign count studies, allowing a projection to be made for the overall labor needed to do a complete GPS sign inventory survey.

The attributes collected for each individual sign were determined by surveying six NCDOT employees, including advisory committee chair Ron King and advisory committee co-chair Dean Ledbetter, to establish the attributes that would best meet the needs of the NCDOT in managing the roadway signs throughout the state. Bradley Hibbs of the FHWA was also surveyed for this purpose. These attributes were then broken into two sets, referred to as data dictionaries. One data dictionary was comprised of all of the attributes that could be collected from within the vehicle and the second data dictionary contains all of the attributes recommended for collection including those that require exiting the survey vehicle.

Once the data dictionaries were defined, the field survey was undertaken using segments of the same roadways surveyed in the sign count surveys. Just enough signs were surveyed to determine a reasonable estimate of the time involved in collecting data of each sign type. The time taken for collection and the distance covered on a particular segment was recorded so that a time and/or cost prediction for the implementation of a statewide GPS inventory could be undertaken.

The times and costs associated with the maintenance of such an inventory will not be addressed in this investigation. Although substantial maintenance is necessary for any inventory to remain useful, it is not expected that the maintenance of a GIS/GPS inventory would be notably more involved than other inventory methods and it would certainly be less time and cost than required to assemble the inventory originally. Field surveys must continue regardless of the inventory system chosen and the database must be kept current as well.

Development of Sign Inventory

This GPS sign inventory study was performed in part according to the steps listed in the "Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs" by Hugh W. McGee.

Involvement of Key Personnel

The first and most critical step in the development of any type of inventory system is the involvement of the key personnel who will be using the inventory being developed. Without the participation of several NCDOT personnel, this project would not be possible and without a unified effort throughout NCDOT, no sign inventory system will be effective no matter how well it is designed. It is for this reason that a majority of the time spent on any sign inventory study is spent communicating with key participants and stakeholders.

Selection of a Location Reference System

The location reference system for this sign inventory study is latitude/longitude based on GPS coordinate information collected in the field. This location reference system will allow maps to be easily generated to help locate the signs and in addition will allow for easy relation to other reference systems already in place through the use of a GIS. This location reference system is also highly feasible using the technology and skills currently employed by NCDOT.

Determination of Attributes to be Collected

The determination of what attributes or data elements will be necessary to have in a functional inventory system is another crucial step in its development. The number and type of attributes collected determines the resulting complexity of applications that the inventory can be used for. Thus the key personnel involved in the development must define the goals for the inventory system so that the attributes collected are adequate to meet those goals.

The primary goal for the development of this sign inventory is to allow NCDOT to be able to effectively document whether or not the upcoming FHWA retroreflectivity standards are being met on its roadway signs. Other goals for an NCDOT sign inventory are not yet as well defined, but sign replacement/maintenance scheduling is certainly of some interest.

There are several fundamental attributes that must be collected in order for a sign inventory to be useful, including sign location, inspection date, sign condition, and type of sign. All parties questioned regarding this matter agreed upon these core attributes and an attribute for retroreflectivity. However, there were several additional attributes that were not completely agreed upon. These additional attributes were included in the complex data dictionary that is described later.

Data Collection Options

The attributes requested by the key personnel questioned regarding this study can be divided into two simple classifications by the method required for obtaining them. The GPS sign inventory will obviously require the use of a motor vehicle to travel the roadways and have access to the signs along the roadway as well as a crew of two persons, one to drive and one to operate the GPS equipment. The core attributes can be collected from inside the vehicle and a laser rangefinder can be used to offset the GPS coordinates from the vehicle to the sign. However, some of the attributes in the complex data dictionary require one person to exit the vehicle to collect the data. One such attribute is the sign installation date, which can be found on a sticker on the back of each sign.

Data Dictionaries

A data dictionary is the term used to describe the list of attributes to be collected and the file that is created using Trimble Pathfinder Office software that contains this list. This data dictionary is comprised of an electronic file structure that aids in the collection of the field data through the use of menus and required entry fields that tend to reduce collection time and data entry error. It is also important to note that the data dictionaries used for this study are in no way the final data dictionary that NCDOT must use. Additional fields may be added and some fields may be removed. Minor adjustment to these formats will not result in significantly different results.

Simple Data Dictionary

The simple data dictionary, shown in Table 1, is comprised of only the core attributes and several additional attributes that were deemed necessary or would be simple to collect. This set of data can be collected entirely from inside the survey vehicle, maximizing safety and efficiency of collection.

Table 1. Simple Data Dictionary

Field	Type	Menu	Entry Options	Description
Survey Date	Date	No	Automatic Generation	Date of collection.
Road Name	Text	No	User defined. Manual Entry.	Name of road on which sign is located.
Direction Faced	Text	Yes	North, South, East, West, Northeast, Northwest, Southeast, Southwest	Direction sign is facing.
Sign Type	Text	Yes	A, B, D, E (Default), F	*See sign type list below
Sign Sub-Type 1	Text	Yes	Warning, Regulatory, Guide, Motorist Info	Category of Sign
Sign Sub-Type 2	Text	Yes	Red, Yellow, Fl Yellow-Green, White, Green, Blue, Brown	Sign background color.
Stop	Text	Yes	Yes, No (Default)	Specifies whether or not sign is a stop sign.
Retro-Reflectivity	Text	Yes	Pass, Fail	This is a required entry field.
Multi-Sign Assembly	Text	Yes	Yes, No (Default)	Specifies whether or not this sign is part of an assembly.

Num Signs Assembly	Numeric	No	1 to 20, User defined. 1 (Default)	Total number of signs in the assembly.
Sign Panel	Numeric	No	1 to 20, User defined. 1 (Default)	Signs are identified left to right, top to bottom on the assembly from 0 to 20.
Overhead Assembly	Text	Yes	Yes, No (Default)	Specifies whether or not this sign is part of an overhead assembly.
Line of Sight	Text	Yes	Adequate (Default), Obstructed	Specifies whether or not this sign has sufficient sight distance available.

Sign Type Field List

- Type A – Advance Guide Signs, Exit Direction Signs, Exit Gore Signs, Logo Signs, General Service Signs, Mileage Destination Signs, Exit Number Panels, and Supplemental Guide Signs.
  Dimensions: Width > 144", Height > 48"

- Type B – Advance Guide Signs, Exit Direction Signs, Exit Gore Signs, Logo Signs, General Service Signs, Mileage Destination Signs, Exit Number Panels, and Supplemental Guide Signs.
  Dimensions: Width <= 144", Height <= 48"

- Type D – Destination Signs and Mileage Destination Signs (The maximum size without "Z" bar stringers is 108" by 48". If this type of sign must be larger, it is built with stringers and is then an "A" or "B" type).

- Type E – Regulatory and Warning Signs, such as one-way signs, stop signs, yield signs, speed limit, signs, merging traffic signs, etc.

- Type F – Route marker assemblies

Complex Data Dictionary

The complex data dictionary, shown in Table 2, consists of the same entry fields as in the simple data dictionary and adds five more fields. At least two of the additional fields, installation date and sign dimensions, will require one of the survey personnel to get out of the survey vehicle to determine these attributes. This will add a significant amount of time to the collection of data, but will provide a more complete and useful inventory immediately. In addition to lost time, safety will also be adversely affected since personnel will have to exit the survey vehicle for data collection. The collection of attributes for signs located in the median of divided highways and signs located on overhead assemblies will also prove to be more difficult and time consuming.

Table 2. Complex Data Dictionary

** Denotes Field also Included in Simple Data Dictionary*

Field	Type	Menu	Entry Options	Description
Survey Date *	Date	No	Automatic Generation	Date of collection.
Road Name *	Text	No	User defined.	Name of road on which sign is located.
Direction	Text	Yes	North, South, East, West,	Direction sign is facing.

Faced *			Northeast, Northwest, Southeast, Southwest	
Sign Type *	Text	Yes	A, B, D, E (Default), F	See sign type list following Table 1.
Sign Sub-Type 1 *	Text	Yes	Warning, Regulatory, Guide, Motorist Info	Category of Sign
Sign Sub-Type 2 *	Text	Yes	Red, Yellow, Fl Yellow-Green, White, Green, Blue, Brown	Sign background color.
Stop *	Text	Yes	Yes, No (Default)	Specifies whether or not sign is a stop sign.
Installation Date	Date	No	User defined. Manual entry.	Corresponds to installation sticker found on back of sign.
Sign Dimensions	Numeric	No	User defined. Manual entry.	Dimensions of sign panel
Sheeting Type 1	Text	Yes	Type 1, Type 2, Type 3	Distinguishes between grades of sheeting.
Sheeting Type 2	Text	Yes	Glass Bean, Prismatic, Null	To better describe the previous sheeting type.
Post Type	Text	Yes	Steel, Wood, Channel	Type of post sign is mounted on.
Retro-Reflectivity *	Text	Yes	Pass, Fail	This is a required entry field.
Multi-Sign Assembly *	Text	Yes	Yes, No (Default)	Specifies whether or not this sign is part of an assembly.
Num Signs Assembly *	Numeric	No	1 to 20, User defined. 1 (Default)	Total number of signs in the assembly.
Sign Panel *	Numeric	No	1 to 20, User defined. 1 (Default)	Signs are identified left to right, top to bottom on the assembly from 0 to 20.
Overhead Assembly *	Text	Yes	Yes, No (Default)	Specifies whether or not this sign is part of an overhead assembly.
Line of Sight *	Text	Yes	Adequate (Default), Obstructed	Specifies whether or not this sign has sufficient sight distance available.

Equipment Used

Data Collection Software

The data collection software used in this study was Pathfinder Office version 2.70 developed by Trimble Navigation. Pathfinder Office runs on Microsoft Windows 95 and newer operating systems. This software was used because it comes packaged with the Trimble GPS equipment that NCDOT already owns and operates.

GPS Equipment

The GPS equipment used in this study was the Trimble Pro XR GPS receiver and the Trimble TSC1 datalogger. This GPS equipment was chosen because NCDOT owns several such units per division and this would allow the opportunity for the proposed sign inventory to be conducted in house. The data collected with this equipment are considered map grade data, meaning that the location data are not an exact measurement, but rather an approximation with sub-meter accuracy.

Laser Rangefinder

The Laser Atlanta Advantage laser rangefinder used in this study allowed for the transfer of the GPS coordinates collected from the vehicle to the actual location of the sign on the ground when used as an external sensor to the GPS unit. This piece of equipment was chosen because NCDOT owns one of these laser rangefinders for each GPS unit owned and it allows for the location of signs to be determined from inside the survey vehicle. The laser does, however, add additional error to the location measurements collected by the GPS receiver. This error varies, but provided the laser rangefinder is calibrated properly, the additional error added should not be significant for close range offsets. The error induced by the laser rangefinder will, however, increase noticeably when offsets are taken for signs located across divided highways or similar situations that require a longer offset from the initial GPS coordinates. The error incurred from using the laser cannot be ignored, but it is certainly better than eyeballing distance or having to stand at each sign when collecting the GPS coordinates.

Study Routes

The routes surveyed for this study, shown in Tables 3 and 4, were also surveyed in the two sign count approximation studies that were conducted by the Civil Engineering Department at NCSU. The routes were chosen based on their respective classifications; for instance, two interstate routes were chosen, one rural and one urban, as they were classified in the sign count surveys. These routes also had approximately 50 or more signs as measured in the sign count studies and were considered representative of routes statewide. This process was used for US routes, NC routes, interchanges, and secondary routes as well.

All of the routes used in this study were chosen so that the results could be used in conjunction with the sign count study results to develop projections for time and cost involved with a statewide GPS sign inventory. All of the secondary routes used in this study were located in Durham County which had a slightly higher sign density than most counties included in the sign count approximation study for secondary routes, with the exception of Wake County.

Table 3. Primary Study Routes

Segment	Type	Distance (Miles)	# of Signs
US 64 West -- US 1 to Laura Duncan Rd	Urban	2.4	58
I 40 East -- Mile 295 to Mile 301	Urban	6.0	110
NC 157 North -- I 85 to Rose of Sharon	Urban	2.5	40
US 64 West -- NC 751 to Jordan Lake	Rural	5.2	52
I 40 East -- Mile 307 to Mile 317	Rural	10.0	52
NC 27 -- NC 50 to NC 55	Rural	6.8	74
Interchanges			
I 40 West Exit 284	Urban	N/A	5
I 40 West Exit 285	Urban	N/A	9

I 40 West Exit 287	Urban	N/A	8
I 40 East Exit 285	Urban	N/A	6
I 40 East Exit 287	Urban	N/A	9
I 40 East Exit 303	Rural	N/A	5
I 40 East Exit 312	Rural	N/A	11
I 40 East Exit 319	Rural	N/A	6
I 40 West Exit 303	Rural	N/A	4
I 40 West Exit 312	Rural	N/A	10
I 40 West Exit 319	Rural	N/A	8

Table 4. Secondary Study Routes (Durham County)

Segment	Type	Distance (Miles)	# of Signs
SR 1171 -- SR 1118 to SR 1926	Urban	3.0	22
SR 1800 -- SR 1670 to SR 1675	Urban	1.9	8
SR 1671 -- NC 55 to SR 1669	Urban	2.0	21
SR 1669 -- SR 1671 to BUS 501	Urban	2.1	13
SR 1634 -- SR 1632 to SR 1004	Rural	3.4	21
SR 1004 -- SR 1634 to SR 1615	Rural	5.9	31
SR 1615 -- SR 1004 to US 501	Rural	6.2	33

Field Procedures

Procedures

The procedures involved in the GPS surveying of signs are quite simple. A crew of two persons, a driver and a surveyor, conduct the survey while traveling along a roadway. The driver must stop at every sign that faces the survey crew, in the case of the complex data dictionary, or stop in a location that allows for many signs to be collected at once in the case of a location with high sign density and when using the simple data dictionary. Once the vehicle has come to a complete stop and is located in a safe place, preferably out of the travel way, the surveyor then takes the GPS coordinates of the location. After the coordinates have been taken using the GPS receiver, the laser rangefinder is then aimed and fired at the sign being surveyed, determining the offset from the GPS coordinates to the actual location of the sign. Once the location has been acquired, the surveyor then begins the collection of the remainder of the sign attributes. After all the attributes of the sign are collected the data are saved and the crew moves on to the next sign.

The time taken for surveying the signs on each segment was recorded to help develop time projections for the undertaking of such an inventory. The time was recorded starting at the beginning of the each segment and at the intersection or milepost of the ending the segment as noted in the study route section. This time does not include travel time to and from the study location, only time on the segments being surveyed.

Issues or Problems

The following section lists the issues and problems faced when conducting this study in the field. Each heading represents an issue or problem faced and how it was routinely handled throughout this study.

Perpendicular Signs

All signs perpendicular to the roadway and facing the direction of travel were surveyed with the exception of excluded signs as noted in the excluded sign section that follows.

Parallel Signs

Signs that were oriented parallel to the roadway were only surveyed if they would not otherwise be surveyed from an intersecting roadway. That is, most of the signs oriented parallel to one roadway will be oriented perpendicular to an intersecting roadway. Since this is not always the case, signs that did not meet these criteria were surveyed from the parallel roadway.

Composite Signs

Composite signs were a very significant issue to this GIS sign inventory study. Many signs at one point can be a challenging problem to resolve in a GIS. For the purpose of this study each sign was treated as having its own individual location, even composite signs.

There are three fields, common to both data dictionaries, that address the issue of composite signs. The first field, "Multi-Sign Assembly", is a simple yes/no field indicating whether or not the sign is a part of a composite assembly. The second field, "Num Signs Assembly", represents the total number of signs on a particular assembly. The third field, "Sign Panel", represents the location of the sign panel on the assembly by numbering the sign panels right to left, top to bottom. If it is determined that these composite signs should be recognized as only occupying one point in space, GIS software can handle such a conversion based on the previously mentioned sign attributes.

Overhead Assemblies

Signs mounted on overhead assemblies presented a problem as well and were defined as signs that were mounted onto a structure located over the roadway. It is obviously too difficult to determine the dimensions or installation dates of these signs and it would be very dangerous to obtain the GPS coordinates of such signs without the use of a laser rangefinder to determine an offset.

The problem of obtaining dimensions and installation dates is only a issue when using the complex data dictionary. No such assemblies were encountered during the use of the complex data dictionary since only one segment was surveyed using the complex data dictionary. This is an issue that needs addressing if NCDOT was to choose to use such an inventory method.

Rear-Facing Signs

There are occasionally signs that are located perpendicular and adjacent to roadway segments that face opposite the direction of travel. These signs were noted on interstate ramps and divided highways and were limited to 'Do Not Enter' and 'Wrong Way' signs.

In the case of divided highways, only the signs facing the direction of travel were surveyed. Therefore, long shots across the roadway had to be taken with the laser rangefinder in order to offset the GPS coordinates from the GPS receiver to the sign. This did result in the largest amount of spatial error encountered, but is easily corrected using GIS software.

In the case of interstate ramps, all of the signs were surveyed, including those facing opposite the direction of travel.

Excluded Signs

Signs excluded from this sign inventory study were any signs not the property of nor maintained by NCDOT. Therefore, it was assumed that NCDOT does not have the potential to incur any liability for such signs. Examples of such excluded signs include secondary route markers, county street signs, city bus stops, and signs associated with businesses and schools other than the blue guide signs supplied by NCDOT. The signs excluded from this study are identical to the signs that were excluded from both sign count studies as well.

Results

The results of this GPS sign inventory study are listed in the following tables. The study was divided into three parts, which were primary routes, secondary routes, and the complex data dictionary, which required one of the surveyors to exit the vehicle at each sign. The division of the study into primary and secondary routes allowed compatibility with the sign count approximation studies, which were used in conjunction with the results of this study to develop time projections for statewide implementation. The third part of the study, using the complex data dictionary, was conducted to develop a time relationship between the simple and complex data dictionaries. The complete tables of the results can be found in Appendix A.

Primary Routes

The results from the primary routes can be seen in Tables 5a, 5b, and 6. The results of the primary routes survey are all quite reasonable with the exception of the urban US 64 segment. That particular segment was removed from the overall calculations due to the fact that its time per sign was almost twice that of all the other segments. The considerably higher time was a result of that being the very first segment surveyed and the driver and surveyor becoming acquainted with the procedures while addressing any issues that developed.

Table 5a. Primary Route Results

Segment	Type	Distance (Miles)	Time (Minutes)	# Signs	Time per Sign (Minutes)
US 64 West -- US 1 to Laura Duncan Rd	Urban	2.4	79	58	1.36
I 40 East -- Mile 295 to Mile 301	Urban	6.0	61	110	0.55
NC 157 North -- I 85 to Rose of Sharon	Urban	2.5	25	40	0.63
US 64 West -- NC 751 to Jordan Lake	Rural	5.2	37	52	0.71
I 40 East -- Mile 307 to Mile 317	Rural	10.0	36	52	0.69
NC 27 -- NC 50 to NC 55	Rural	6.8	43	74	0.58

Table 5b. Primary Route Results -- Interchanges

Interchange	Type	Time (Minutes)	# Signs	Time per Sign (Minutes)
I 40 West Exit 284	Urban	5	10	0.50
I 40 West Exit 285	Urban	9	13	0.69

I 40 West Exit 287	Urban	8	15	0.53
I 40 East Exit 285	Urban	6	13	0.46
I 40 East Exit 287	Urban	9	13	0.69
I 40 East Exit 303	Rural	5	12	0.42
I 40 East Exit 312	Rural	11	17	0.65
I 40 East Exit 319	Rural	6	16	0.38
I 40 West Exit 303	Rural	4	9	0.44
I 40 West Exit 312	Rural	10	17	0.59
I 40 West Exit 319	Rural	8	17	0.47

After removing the urban US 64 segment, the times per sign were consistent. The final results for the primary routes had primary urban routes averaging 0.57 minutes or 34 seconds per sign and rural routes averaging 0.60 minutes or 36 seconds per sign. The overall average time per sign on primary routes is 0.59 minutes or 35 seconds with a standard deviation of 0.11 minutes or 7 seconds per sign. There was not an important difference in time per sign between the urban and rural primary routes.

Table 6. Primary Route Totals --- Includes Interchanges

Type	Time (Minutes)	# Signs	Time per Sign (Minutes)	Standard Deviation
Urban	123	214	0.57	0.09
Rural	160	266	0.60	0.12
Combined	283	480	0.59	0.11

* Does Not Include Urban US 64 segment.

Secondary Routes

Secondary route results showed more variability than did the primary routes. This is due to many factors that the primary routes were not exposed to such as only having a two-lane cross section with one lane in each direction. The presence of only one lane to travel in, especially on higher traffic roads, can prevent the survey crew from re-entering the traffic flow immediately after surveying a sign. Sign locations and densities on the secondary routes also tended to exhibit more variability than on the primary routes, occasionally resulting in the inability to survey several signs from the same point

The segment of SR 1800 was not considered in the determination of the results for the secondary routes due to many of the same reasons as the urban US 64 route that was excluded from the primary route results. SR 1800 was surveyed with a new driver not familiar with the survey process and there was a significant amount of construction being carried out on and around the road at that time. The time per sign for the SR 1800 segment, as a result of those reasons and due to the considerably higher value, was not considered in the overall calculations for the secondary route results.

Table 7. Secondary Route Results (Durham County)

Segment	Type	Distance (Miles)	Time (Minutes)	# Signs	Time per Sign (Minutes)
SR 1171 -- SR 1118 to SR 1926	Urban	3.0	15	22	0.68

SR 1800 -- SR 1670 to SR 1675	Urban	1.9	14	8	1.75
SR 1671 -- NC 55 to SR 1669	Urban	2.0	14	21	0.67
SR 1669 -- SR 1671 to BUS 501	Urban	2.1	14	13	1.08
SR 1634 -- SR 1632 to SR 1004	Rural	3.4	14	21	0.67
SR 1004 -- SR 1634 to SR 1615	Rural	5.9	22	31	0.71
SR 1615 -- SR 1004 to US 501	Rural	6.2	27	33	0.82

The secondary route results, listed in Table 8, were somewhat more variable than were the primary route results, with the standard deviation being a little higher. However, with the SR 1800 segment removed from the calculations, the final results for the secondary routes are rather precise. The average time per sign for secondary urban routes was determined to be 0.77 minutes or 46 seconds and the average time per sign for rural secondary routes was determined to be 0.74 minutes or 44 seconds. The overall average time per sign for the secondary routes surveyed is 0.75 minutes or 45 seconds with a standard deviation of 0.16 minutes or 10 seconds per sign. There was not an important difference in time per sign between the urban and rural secondary routes.

Table 8. Secondary Route Totals

Type	Distance (Miles)	Time (Minutes)	# Signs	Time per Sign (Minutes)	Standard Deviation
Urban	7.1	43	56	0.77	0.23
Rural	15.5	63	85	0.74	0.08
Combined	22.6	106	141	0.75	0.16

* Does Not Include Urban SR 1800 segment.

Complex Data Dictionary

The third part of the study was completed using the complex data dictionary. The use of this dictionary requires the surveyor to exit the vehicle to obtain specific information from each sign such as installation date. The segment used for this part of the study is a segment that was also used in the primary route part of this study to help with the comparison of the two data dictionaries. The results of the complex data dictionary portion of this study are listed in Table 9 along with the results from the same segment obtained when surveying the primary routes.

The complex data dictionary took almost twice as long to survey one sign than did the simple data dictionary. Getting in and out of the vehicle with a GPS unit proved to be a very cumbersome and difficult task, but once out of the vehicle the additional information required by the complex data dictionary was easily obtained. Survey time per sign, however, proved to be much less in areas of higher sign densities since the surveyor could walk from sign to sign and did not have to enter and exit the vehicle as frequently.

Table 9. Complex Data Dictionary Results

Segment	Data Dictionary	Type	Distance (Miles)	Time (Minutes)	# Signs	Time per Sign (Minutes)
NC 27 -- NC 50 to NC 55	**Complex**	Rural	6.8	82	74	1.11
NC 27 -- NC 50 to NC 55	**Simple**	Rural	6.8	43	74	0.58

GPS Sign Inventory Time Projections

As previously mentioned, the time per sign values determined for the primary and secondary routes are based on the time it takes to completely survey one segment of roadway in one direction of travel. This is a very important fact that should not be overlooked. Travel time to and from the survey locations are not included in the time per sign values, nor is it included anywhere else in the calculations to determine the projected collection time. No conclusive information was obtained during this study to make any reasonable predictions on the additional time incurred due to travel. This travel time will obviously vary on a daily basis depending on the Division the crew is based in, the location of the survey area, weather conditions, and other factors.

In addition to the absence of travel time, the data obtained via GPS must be downloaded and post-processed in the office at the end of each day or week. The time associated with this aspect of GPS data collection is nominal; one week's worth of work can be easily downloaded and post processed in approximately 30 minutes.

The projected collection time was determined by using the estimated number of primary and secondary signs maintained by NCDOT as determined by the Sign Count Approximation Studies and multiplying this value times the time per sign values determined in this study. Although the additional time incurred from travel is not known within a reasonable doubt, NCDOT may want to modify the projected collection time by using travel times from their own projects or experiences in which the travel times are known.

Table 10. Projected Time for Collection

	Time per Sign (Minutes)*	Estimated Number of Signs**	Projected Collection Time (Minutes)	Projected Collection Time (Hours)
Primary Routes	0.59	386,770	228,194.30	3,803.24
Secondary Routes	0.75	616,436	462,327.00	7,705.45
Statewide Total	0.69***	1,003,206	690,521.30	11,508.69

*Average Time Per Sign From Tables
**Estimated Number of Signs from Sign Count Approximation Studies
***Weighted Average

Conclusions and Recommendations

There are several different options available to the NCDOT for addressing the expected FHWA standards for retroreflectivity of road signs. Among these options are sign inventory systems. Such systems, in addition to providing NCDOT with a means of addressing the expected retroreflectivity standards, can provide the opportunity to have a system that assists with the many facets of sign maintenance.

This study examined the method of developing a sign inventory using GPS and GIS technology. The use of GPS and GIS for the purpose of a sign inventory is an excellent application of the technology and this powerful technology is owned and operated throughout NCDOT, increasing the feasibility of implementation. Such technology solves one of the key problems in developing and maintaining a sign inventory system and that problem is the location reference system. GPS collects latitude and longitude measurements for the location of each sign so that mile markers and landmarks are not used for location identification. This makes it much easier to locate signs in the field for future inventories or updates and is especially helpful in determining if a sign is missing or not.

The benefits of using GPS and GIS in a sign inventory system are quite impressive, although this study did not address these benefits. This study simply addresses the feasibility of using GPS as a means for inventory. The results are consistent for survey times using GPS and the time involved in collection of the desired attributes of signs does not seem to be prohibitive when using the simple data dictionary. However, the complex data dictionary requires one member of the survey team to exit the vehicle to obtain some of the sign attributes, which makes the complex data dictionary take about twice as long to obtain per sign.

It is very important to note that the attributes that require a member of the survey team to exit the vehicle in order to obtain can be collected in another way. Every sign must be replaced eventually and whenever a sign is installed or replaced there is an opportunity to obtain the installation date, dimensions, and other such sign attributes that require exiting of the vehicle. It will take some time for all of this information to be collected and entered into the sign inventory database, but it is a much more efficient means of collecting the desired attributes.

In addition to efficiency, inventories should evolve over time to reflect the needs of the users. It is very likely that more sign attributes will be desired over time and will require additional inventories to collect such information. Therefore, NCDOT should consider implementing some attributes over time and not all at once, regardless of the inventory method chosen.

This study estimates the level of effort required to use GPS and GIS for a sign inventory, but not completely. The results of this study should give NCDOT a better idea of what can be accomplished using this technology and at what level of effort when combined with additional data concerning travel times. More signs should be surveyed to reinforce or rebut the findings of this study or a trial version of this method of inventory could be implemented at the Division level or lower to better determine the feasibility of such an inventory system. The implementation of a complete inventory system at a lower level will allow for much more accurate predictions to be made for the time involved in the total process.

The use of GPS and GIS in a sign inventory system can be a very beneficial and effective means of addressing retroreflectivity issues as well as other maintenance and scheduling tasks. NCDOT should definitely consider this method when deciding what inventory method to use, if any.

References

McGee, Hugh W. and Paniati, Jeffrey A., An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs, USDOT, FHWA Research and Development. McLean, VA. 1998.

Manual on Uniform Traffic Control Devices, *Millennium Edition*, US Dept. of Transportation, Federal Highway Administration, American Traffic Safety Services Association, Fredericksburg, VA. 2000.

Vereen, Stephanie. "A Sign Inventory Study to Assess and Control Liability and Cost." Department of Civil Engineering, North Carolina State University, Raleigh, NC, May 2002.

Palmquist, Mark. "Sign Count Approximation Using Field Inventory Sampling and Calculated Sign Densities for Secondary Roads: Analysis, Improvements, and Methods." Department of Civil Engineering, North Carolina State University, Raleigh, NC, May 2002.

Kirtley, Nathan. "Sign Count Approximation Using Field Inventory Sampling and Calculated Sign Densities for Primary Routes." Department of Civil Engineering, North Carolina State University, Raleigh, NC, May 2002.

APPENDIX K

VISUAL EVALUATION MEASUREMENT SPREADSHEET EXAMPLE

Several spreadsheets were created to evaluate the accuracy of the visual evaluation method on North Carolina and to assess how many signs would potentially not be in compliance at various accuracy percentages. This appendix includes a complete explanation of each spreadsheet column followed by a complete example. The example is for warning signs on Interstates.

A spreadsheet was created to simulate the number of signs that are evaluated and replaced each year. The goal of the spreadsheet was to try and determine the percent of signs potentially not in compliance after performing visual evaluations. A spreadsheet was created for each combination of warning and stop signs on Interstate, primary, and secondary roads to yield the following spreadsheets:

- warning signs on Interstate,
- warning signs on primary,
- Stop signs on primary,
- warnings signs on secondary, and
- Stop signs on secondary.

The frequencies as outlined in the North Carolina Sign Condition Survey Guidelines were used. The spreadsheets were also used to evaluate the percentage of signs potentially not compliance at different inspection frequencies (Interstates and secondary roads were evaluated at an interval of every other year). And they were used to evaluate the nighttime visual evaluation at different percent accuracies to reflect better trained and more-highly skilled workers.

The spreadsheets were set up to calculate for three seven-year cycles. In the first cycle, the number of signs replaced in each of the previous seven years (years –1 through –7) was assumed to be equal each year. This cycle was not evaluated because this assumed scenario is not realistic. Beginning in the second cycle, the numbers are those generated completely by the spreadsheet. The results of the second and third cycle are used as comparison in Section 10.0

The first column indicates which year is being evaluated. These years are represented by the variable n. A cycle consists of seven years, which is equal to the anticipated life of a sign manufactured with engineer sheeting grade. The cycle begins in year 0 so that year 1 represents the passing of one year over the course of which signs are being evaluated. So the data in Year 1 represent data for inspections occurring between year 0 and year 1.

Column A indicates the total number of the specified sign on the specified road type. Column B indicates how many of the signs in column A are scheduled for evaluation in the current year n. For example, primary roads are evaluated every other year and there are 98,764 warning (yellow and orange) signs on primary roads, so column A indicates 98,764, the total number of signs, and column B, represents 49,382, or half of the total being evaluated each year.

Column C indicates the previous 7 years in the cycle. Activity associated with signs installed in these years will be tracked by these rows. These years are represented by the variable X. Column D says how old the signs replaced in the year in Column C are in the current year, n.

The next column, E, lists the number of signs that have been installed in previous years n-1 through n-7. At any given point, all in-place signs represent a distribution of ages and conditions. In order to begin the cycle, it is estimated that prior to year 0, in years n minus 1 through n minus 7, that the same number of signs were replaced in each of those years. As the spreadsheet continues, the numbers generated by the calculations will replace these estimates. (An alternate method would have been to begin the first cycle by skipping the years in which signs would not have been evaluated, however, there was no significant difference between the two methods.)

Column F contains the total number of signs that were replaced in years X prior to the current year, n. The numbers in column F are equal to the numbers in column Y from the previous years.

Column G subtracts the number of signs replaced in previous years (column F) from the total number of signs installed in those previous years (column E). The subtracted signs are now accounted for in the signs replaced in the previous year (n-1). For example, in year 0, no signs had been replaced in previous years. However, in Year 1, some of the signs installed in years –6 through –1 were replaced in Year 0. These signs that were replaced are now included in the signs that were newly installed in Year 0 (column Y), so they must be subtracted so that they are no longer considered in the number of signs that were actually installed in previous years.

Next, column H indicates the number of signs that should have been replaced in previous years that were not. This number is extracted from column Z from the previous year n-1. This number is then added back because these are signs that are still no longer compliant and will be evaluated again in the current year (or in the next year the same set of signs is designated for evaluation according to schedule). The number is added back to the signs in the row that are 7 years old in year n because these signs are no longer compliant as well and will be considered with these. Column H is added to column G to generate a sign total. The 'total signs being evaluated in the current year' column, I, should be equal to the total number of signs scheduled for evaluation this year (column B). The number may fluctuate due to rounding in the calculations.

Columns J, K, and L include information related to Figures 10-5 and 10-6. Column J indicates the current SIA value of the signs replaced in year X should now be in year n. Column K indicates the rating the sign should receive from an observer during a nighttime visual inspection and column L simply indicates whether the signs should be replaced based on the SIA value with either a 'y' for yes or an 'n' for no.

Columns M, N, O, and P indicate the percentage of signs needing replacement correctly identified (correct positive), needing replacement incorrectly identified (false negative), needing replacement correctly identified (correct negative), and needing replacement incorrectly identified (false positive) respectively. The percentages are based on Figures 10-1 and 10-2. Columns L and M should be used for signs that are no longer meeting the minimum proposed numerical values and columns N and O are for signs that are (based on columns I, J, and K).

Then, columns P, Q, R, and S correspond to L, M, N, and O by calculating the actual number of signs represented by the percentages using the sign total column H. Whether columns M and N or O and P are used to calculate the figures in columns Q, R, S, and T, is determined by column F. Signs in a row with a 'y' or yes need replacing indication are calculated using columns M and N, the accuracy percentages for signs needing replacement. And signs in a row with a 'n' or no does not need replacing indication are calculated using columns O and P, the accuracy percentage for signs not needing replacement. The resulting numbers are displayed in columns Q, R, S, and T.

Columns U and V are sums of the number of signs installed in years X that are no compliant in the current year n and the number of signs that are compliant, respectively. The sum of these two columns can be totaled to verify that they equal sign total column I as a quality control check.

Columns W, X, and Y are various totals based on the accuracy percentage calculations. Column W is the total number of signs that were replaced correctly (equal to column Q). Column X is the total number of signs replaced incorrectly (equal to column T). Column Y is the total number of signs replaced correctly and incorrectly (W plus X).

Column Z indicates the total number of signs that should have been replaced and were not (equal to column R). Column AA, 'total signs that should have been replaced in previous years and were not that are NOT EVALUATED IN CURRENT YEAR' is included to take into account the signs that were not replaced in the fraction of signs that is not evaluated in the current year, n. It is equal to column Z for the previous year (or previous two years for secondary roads with every third year frequency). This column allows a percentage of total signs potentially not in compliance to be formulated for all signs regardless if they were evaluated in the current year. Column BB is a total of signs that are potentially not in compliance, a total of columns Z and AA.

Column CC is the total number of signs evaluated incorrectly (either replace or not replace). Column DD is the percent of signs evaluated incorrectly. This column is calculated by dividing the total signs evaluated incorrectly (column CC) by the total number of signs scheduled for evaluation in the current year n (column B). Column EE represents the percent accuracy, or percentage of signs evaluated correctly; it is formulated by subtracting the percent evaluated incorrectly from 100% (100% minus column DD).

It is important to note that column DD, the percent of signs evaluated incorrectly is calculated using only half (or all, or one-third, depending on the appropriate frequency) of signs the total number of signs. But column FF, the percent of signs potentially not meeting the standard after evaluation is based on all signs, regardless if they were evaluated the current year, n, or not. This is because the signs not replaced the year before that needed replacing (column AA), is considered.

Finally, column FF indicates what percent of signs are not meeting the standards after the evaluation in year n. This number is calculated by dividing the number of signs potentially not in compliance in year n (column BB), by the total number of signs (column A).

The table that evaluates warning signs on Interstates differs slightly from the previous description. Because Interstate roads are evaluated every year, the columns that take into account signs on road sections not being evaluated during the current year are omitted (columns A, Z, AA, and BB). The remaining columns are the exactly the same.

The following information is only relevant to the spreadsheets for every other year frequencies. The same principal applies to signs evaluate every third year as well. Beginning in the second cycle, the spreadsheet represents one-half of signs being evaluated. However, in year 0, none of the signs that are 1, 3, 5, or 7 old are evaluated. (In reality, there would be signs that are odd-intervals old because of sign replaced randomly die to accidents and vandalism, however, these signs represent a small percentage and are not take into consideration in this evaluation.)

All signs that are 7 years old and not evaluated are potentially not in compliance because of their age. So, although not evaluated in the current year, seven-year-old signs are included in columns E, F, and G. The signs from year 7 are not included in the total signs evaluated this year (column I) or in the evaluation columns (J through X).

The total number of seven-year old signs still in place (column G) is added to the total number of signs evaluated in the current year that should have been replaced and were not (column Z).

Column AA, totals the signs that should have been replaced in the previous year and were not (also not evaluated this year, yet still in place and deficient) and the number of seven-year-old signs still in place. Column BB is a total of column Z and column AA. This column represents the total number of signs potentially not in compliance after visual signs inspection, whether inspected in the current year or not. The column BB total is then divided by the total number of signs to formulate a percentage of signs potentially not in compliance, which is displayed in column FF.

PRIMARY - WARNING	(A) Total Number of Warning Signs on Primary	(B) Number of Signs **Scheduled** for Evaluation in Year n	(C) Year X	(D) Signs replaced in this year are ___ years old	(E) Number of signs newly installed in year X	(F) Total installed in Year X that were replaced before year n	(G) Number of signs from year X still in place in year n	(H) Number of signs that should have been replaced and were not prior to year n EVALUATED THIS YEAR	(I) Total Signs Being Evaluated in Current Year	(J) Estimated SIA value of signs replaced in year X according to Figure 9-xx
			-8	8	7,054	0	7,054		7,054	0
			-7	7	7,054	0	7,054		7,054	10
			-6	6	7,054	0	7,054		7,054	20
			-5	5	7,055	0	7,055		7,055	30
			-4	4	7,055	0	7,055		7,055	40
			-3	3	7,055	0	7,055		7,055	50
			-2	2	7,055	0	7,055		7,055	60
			-1	1	0	0	0		0	70
Year n= 0	98,764	49,382	-						**49,382**	
			-7	8	7,054	0	7,054		7,054	0
			-6	7	7,054	0	7,054		7,054	10
			-5	6	7,054	0	7,054		7,054	20
			-4	5	7,055	0	7,055		7,055	30
			-3	4	7,055	0	7,055		7,055	40
			-2	3	7,055	0	7,055		7,055	50
			-1	2	7,055	0	7,055		7,055	60
			0	1	0	0	0		0	70
Year n=1	98,764	49,382	-						**49,382**	
			-6	8	7,054	1,834	5,220	2,116	7,336	0
			-5	7	7,055	1,834	5,221		5,221	10
			-4	6	7,055	1,199	5,856		5,856	20
			-3	5	7,055	1,199	5,856		5,856	30

			-2	4	7,055	1,199	5,856		5,856	40
			-1	3	0	0	0		0	50
			0	2	19,258	0	19,258		19,258	60
			1	1	0	0	0		0	70
Year n=2	98,764	49,382	-						**49,382**	
			-5	8	7,054	1,834	5,220	2,116	7,336	0
			-4	7	7,055	1,834	5,221		5,221	10
			-3	6	7,055	1,199	5,856		5,856	20
			-2	5	7,055	1,199	5,856		5,856	30
			-1	4	7,055	1,199	5,856		5,856	40
			0	3	0	0	0		0	50
			1	2	19,258	0	19,258		19,258	60
			2	1	0	0	0		0	70
Year n=3	98,764	49,382	-						**49,382**	
			-4	8	7,055	2,722	4,333	1,672	6,005	0
			-3	7	7,055	2,722	4,333		4,333	10
			-2	6	7,055	2,195	4,860		4,860	20
			-1	5	0	0	0		0	30
			0	4	19,258	3,274	15,984		15,984	40
			1	3	0	0	0		0	50
			2	2	18,199	0	18,199		18,199	60
			3	1	0	0	0		0	70
Year n=4	98,764	49,382	-						**49,382**	
			-3	8	7,055	2,722	4,333	1,672	6,005	0
			-2	7	7,055	2,722	4,333		4,333	10
			-1	6	7,055	2,195	4,860		4,860	20
			0	5	0	0	0		0	30
			1	4	19,258	3,274	15,984		15,984	40
			2	3	0	0	0		0	50
			3	2	18,199	0	18,199		18,199	60
			4	1	0	0	0		0	70
Year n=5	98,764	49,382	-						**49,382**	
			-2	8	7,055	3,458	3,597	1,384	4,980	0
			-1	7	7,055	3,458	3,597		0	10

			0	6	19,258	5,991	13,267		13,267	20
			1	5	0	0	0		0	30
			2	4	18,199	3,094	15,105		15,105	40
			3	3	0	0	0		0	50
			4	2	16,030	0	16,030		16,030	60
			5	1	0	0	0		0	70
Year n=6	98,764	49,382	-						**49,382**	
			-1	8	7,055	3,458	3,597	1,384	4,980	0
			0	7	19,258	9,441	9,818	0	0	10
			1	6	19,258	5,991	13,267		13,267	20
			2	5	0	0	0		0	30
			3	4	18,199	3,094	15,105		15,105	40
			4	3	0	0	0		0	50
			5	2	16,030	0	16,030		16,030	60
			6	1	0	0	0		0	70
Year n=7	98,764	49,382	-						**49,382**	
			0	8	19,258	9,441	9,818	249	10,067	0
			1	7	19,258	9,441	9,818	0	0	10
			2	6	18,199	5,662	12,537		12,537	20
			3	5	0	0	0		0	30
			4	4	16,030	2,725	13,305		13,305	40
			5	3	0	0	0		0	50
			6	2	13,473	0	13,473		13,473	60
			7	1	0	0	0		0	70
Year n=0	98,764	49,382	-						**49,382**	
			1	8	19,258	9,441	9,818	249	10,067	0
			0	7	18,199	8,921	9,278	0	0	10
			3	6	18,199	5,662	12,537		12,537	20
			4	5	0	0	0		0	30
			5	4	16,030	2,725	13,305		13,305	40
			6	3	0	0	0		0	50
			7	2	13,473	0	13,473		13,473	60
			0	1	0	0	0		0	70
Year n=1	98,764	49,382	-						**49,382**	

			2	8	18,199	8,921	9,278	503	9,781	0
			0	7	18,199	8,921	9,278	0	0	10
			4	6	16,030	4,987	11,043		11,043	20
			5	5	0	0	0		0	30
			6	4	13,473	2,290	11,183		11,183	40
			7	3	0	0	0		0	50
			0	2	17,375	0	17,375		17,375	60
			1	1	0	0	0		0	70
Year n=2	98,764	49,382	-						**49,382**	
			3	8	18,199	8,921	9,278	503	9,781	0
			0	7	16,030	7,858	8,172	0	0	10
			5	6	16,030	4,987	11,043		11,043	20
			6	5	0	0	0		0	30
			7	4	13,473	2,290	11,183		11,183	40
			0	3	0	0	0		0	50
			1	2	17,375	0	17,375		17,375	60
			2	1	0	0	0		0	70
Year n=3	98,764	49,382	-						**49,382**	
			4	8	16,030	7,858	8,172	489	8,661	0
			0	7	16,030	7,858	8,172	0	0	10
			6	6	13,473	4,192	9,282		9,282	20
			7	5	0	0	0		0	30
			0	4	17,375	2,954	14,421		14,421	40
			1	3	0	0	0		0	50
			2	2	17,018	0	17,018		17,018	60
			3	1	0	0	0		0	70
Year n=4	98,764	49,382	-						**49,382**	
			5	8	16,030	7,858	8,172	489	8,661	0
			6	7	13,473	6,605	6,869	0	0	10
			7	6	13,473	4,192	9,282		9,282	20
			0	5	0	0	0		0	30
			1	4	17,375	2,954	14,421		14,421	40
			2	3	0	0	0		0	50
			3	2	17,018	0	17,018		17,018	60

			4	1	0	0	0		0	70
Year n=5	98,764	49,382	-						**49,382**	
			6	8	13,473	6,605	6,869	433	7,302	0
			7	7	13,473	6,605	6,869	0	0	10
			0	6	17,375	5,405	11,970		11,970	20
			1	5	0	0	0		0	30
			2	4	17,018	2,893	14,125		14,125	40
			3	3	0	0	0		0	50
			4	2	15,986	0	15,986		15,986	60
			5	1	0	0	0		0	70
Year n=6	98,764	49,382	-						**49,382**	
			7	8	13,473	6,605	6,869	433	7,302	0
			0	7	17,375	8,518	8,858	0	0	10
			1	6	17,375	5,405	11,970		11,970	20
			2	5	0	0	0		0	30
			3	4	17,018	2,893	14,125		14,125	40
			4	3	0	0	0		0	50
			5	2	15,986	0	15,986		15,986	60
			6	1	0	0	0		0	70
Year n=7	98,764	49,382	-						**49,382**	
			0	8	17,375	8,518	8,858	365	9,223	0
			1	7	17,375	8,518	8,858	0	0	10
			2	6	17,018	5,294	11,724		11,724	20
			3	5	0	0	0		0	30
			4	4	15,986	2,718	13,268		13,268	40
			5	3	0	0	0		0	50
			6	2	15,167	0	15,167		15,167	60
			7	1	0	0	0		0	70
Year n=0	98,764	49,382	-						**49,382**	
			1	8	17,375	8,518	8,858	365	9,223	0
			2	7	17,018	8,342	8,676	0	0	10
			3	6	17,018	5,294	11,724		11,724	20
			4	5	0	0	0		0	30
			5	4	15,986	2,718	13,268		13,268	40

			6	3	0	0	0		0	50
			7	2	15,167	0	15,167		15,167	60
			0	1	0	0	0		0	70
Year n=1	98,764	49,382	-						**49,382**	
			2	8	17,018	8,342	8,676	461	9,137	0
			3	7	17,018	8,342	8,676	0	0	10
			4	6	15,986	4,973	11,013		11,013	20
			5	5	0	0	0		0	30
			6	4	15,167	2,578	12,589		12,589	40
			7	3	0	0	0		0	50
			0	2	16,644	0	16,644		16,644	60
			1	1	0	0	0		0	70
Year n=2	98,764	49,382	-						**49,382**	
			3	8	17,018	8,342	8,676	461	9,137	0
			4	7	15,986	7,836	8,149	0	0	10
			5	6	15,986	4,973	11,013		11,013	20
			6	5	0	0	0		0	30
			7	4	15,167	2,578	12,589		12,589	40
			0	3	0	0	0		0	50
			1	2	16,644	0	16,644		16,644	60
			2	1	0	0	0		0	70
Year n=3	98,764	49,382	-						**49,382**	
			4	8	15,986	7,836	8,149	457	8,606	0
			5	7	15,986	7,836	8,149	0	0	10
			6	6	15,167	4,719	10,449		10,449	20
			7	5	0	0	0		0	30
			0	4	16,644	2,829	13,814		13,814	40
			1	3	0	0	0		0	50
			2	2	16,513	0	16,513		16,513	60
			3	1	0	0	0		0	70
Year n=4	98,764	49,382	-						**49,382**	
			5	8	15,986	7,836	8,149	457	8,606	0
			6	7	15,167	7,435	7,732	0	0	10
			7	6	15,167	4,719	10,449		10,449	20

			0	5	0	0	0		0	30
			1	4	16,644	2,829	13,814		13,814	40
			2	3	0	0	0		0	50
			3	2	16,513	0	16,513		16,513	60
			4	1	0	0	0		0	70
Year n=5	98,764	49,382	-						**49,382**	
			6	8	15,167	7,435	7,732	430	8,162	0
			7	7	15,167	7,435	7,732	0	0	10
			0	6	16,644	5,178	11,466		11,466	20
			1	5	0	0	0		0	30
			2	4	16,513	2,807	13,706		13,706	40
			3	3	0	0	0		0	50
			4	2	16,048	0	16,048		16,048	60
			5	1	0	0	0		0	70
Year n=6	98,764	49,382	-						**49,382**	
			7	8	15,167	7,435	7,732	430	8,162	0
			0	7	16,644	8,159	8,485	0	0	10
			1	6	16,644	5,178	11,466		11,466	20
			2	5	0	0	0		0	30
			3	4	16,513	2,807	13,706		13,706	40
			4	3	0	0	0		0	50
			5	2	16,048	0	16,048		16,048	60
			6	1	0	0	0		0	70
Year n=7	98,764	49,382	-						**49,382**	

(K) Rating a sign replaced in Year X should receive from an observer's evaluation	(L) signs installed in this year need replacing??	(M) % of signs needing replacement correctly identified (CP)	(N) % of signs needing replacement incorrectly identified (FN)	(O) % of signs NOT needing replacement correctly identified (CN)	(P) % of signs NOT needing replacement incorrectly identified (FP)	(Q) Number of signs NEEDING REPLACEMENT that WERE REPLACED (CP)	(R) Number of signs NEEDING REPLACEMENT that WERE NOT replaced (FN)	(S) Number of signs NOT NEEDING REPLACEMENT that WERE NOT REPLACED (CN)	(T) Number of signs NOT NEEDING REPLACEMENT that WERE REPLACED (FP)
0	y	95%	5%	-	-	6,701	353		
1	y	75%	25%	-	-	5,291	1,764		
2	n	-	-	74%	26%			5,220	1,834
2	n	-	-	74%	26%			5,221	1,834
3	n	-	-	83%	17%			5,856	1,199
3	n	-	-	83%	17%			5,856	1,199
3	n	-	-	83%	17%			5,856	1,199
4	n	-	-	96%	4%			0	0
						11,992	2,116	28,008	7,266
0	y	95%	5%			6,701	353		
1	y	75%	25%	-	-	5,291	1,764		
2	n	-	-	74%	26%			5,220	1,834
2	n	-	-	74%	26%			5,221	1,834
3	n	-	-	83%	17%			5,856	1,199
3	n	-	-	83%	17%			5,856	1,199
3	n	-	-	83%	17%			5,856	1,199
4	n	-	-	96%	4%			0	0
						11,992	2,116	28,008	7,266
0	y	95%	5%			6,969	367		
1	y	75%	25%	-	-	3,916	1,305		
2	n	-	-	74%	26%			4,333	1,522
2	n	-	-	74%	26%			4,333	1,522

3	n	-	-	83%	17%			4,860	995
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			15,984	3,274
4	n	-	-	96%	4%			0	0
						10,885	1,672	29,511	7,314
0	y	95%	5%	-	-	6,969	367		
1	y	75%	25%			3,916	1,305		
2	n	-	-	74%	26%			4,333	1,522
2	n	-	-	74%	26%			4,333	1,522
3	n	-	-	83%	17%			4,860	995
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			15,984	3,274
4	n			96%	4%			0	0
						10,885	1,672	29,511	7,314
0	y	95%	5%			5,705	300		
1	y	75%	25%	-	-	3,250	1,083		
2	n	-	-	74%	26%			3,597	1,264
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			13,267	2,717
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			15,105	3,094
4	n	-	-	96%	4%			0	0
						8,955	1,384	31,969	7,075
0	y	95%	5%	-	-	5,705	300		
1	y	75%	25%			3,250	1,083		
2	n	-	-	74%	26%			3,597	1,264
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			13,267	2,717
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			15,105	3,094
4	n			96%	4%			0	0
						8,955	1,384	31,969	7,075
0	y	95%	5%			4,731	249		
1	y	75%	25%	-	-	0	0		

2	n	-	-	74%	26%			9,818	3,449
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			12,537	2,568
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,305	2,725
4	n	-	-	96%	4%			0	0
						4,731	249	35,660	8,742
0	y	95%	5%	-	-	4,731	249		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			9,818	3,449
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			12,537	2,568
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,305	2,725
4	n			96%	4%			0	0
						4,731	249	35,660	8,742
0	y	95%	5%			9,563	503		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			9,278	3,260
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,043	2,262
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			11,183	2,290
4	n	-	-	96%	4%			0	0
						9,563	503	31,503	7,812
0	y	95%	5%	-	-	9,563	503		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			9,278	3,260
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,043	2,262
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			11,183	2,290
4	n			96%	4%			0	0
						9,563	503	31,503	7,812

0	y	95%	5%	-	-	9,292	489		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,172	2,871
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			9,282	1,901
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			14,421	2,954
4	n			96%	4%			0	0
						9,292	489	31,875	7,726
0	y	95%	5%	-	-	9,292	489		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,172	2,871
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			9,282	1,901
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			14,421	2,954
4	n			96%	4%			0	0
						9,292	489	31,875	7,726
0	y	95%	5%	-	-	8,228	433		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			6,869	2,413
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,970	2,452
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			14,125	2,893
4	n			96%	4%			0	0
						8,228	433	32,963	7,758
0	y	95%	5%	-	-	8,228	433		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			6,869	2,413
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,970	2,452
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			14,125	2,893

4	n			96%	4%			0	0
						8,228	433	32,963	7,758
0	y	95%	5%	-	-	6,937	365		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,858	3,112
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,724	2,401
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,268	2,718
4	n			96%	4%			0	0
						6,937	365	33,849	8,231
0	y	95%	5%	-	-	6,937	365		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,858	3,112
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,724	2,401
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,268	2,718
4	n			96%	4%			0	0
						6,937	365	33,849	8,231
0	y	95%	5%	-	-	8,762	461		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,676	3,048
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,013	2,256
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			12,589	2,578
4	n			96%	4%			0	0
						8,762	461	32,277	7,882
0	y	95%	5%	-	-	8,762	461		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,676	3,048
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,013	2,256

3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			12,589	2,578
4	n			96%	4%			0	0
						8,762	461	32,277	7,882
0	y	95%	5%	-	-	8,680	457		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,149	2,863
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			10,449	2,140
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,814	2,829
4	n			96%	4%			0	0
						8,680	457	32,413	7,833
0	y	95%	5%	-	-	8,680	457		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,149	2,863
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			10,449	2,140
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,814	2,829
4	n			96%	4%			0	0
						8,680	457	32,413	7,833
0	y	95%	5%	-	-	8,176	430		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			7,732	2,717
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,466	2,348
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,706	2,807
4	n			96%	4%			0	0
						8,176	430	32,904	7,872
0	y	95%	5%	-	-	8,176	430		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			7,732	2,717

2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,466	2,348
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,706	2,807
4	n			96%	4%			0	0
						8,176	430	32,904	7,872
0	y	95%	5%	-	-	7,754	408		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,485	2,981
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,376	2,330
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,320	2,728
4	n			96%	4%			0	0
						7,754	408	33,180	8,039
0	y	95%	5%	-	-	7,754	408		
1	y	75%	25%			0	0		
2	n	-	-	74%	26%			8,485	2,981
2	n	-	-	74%	26%			0	0
3	n	-	-	83%	17%			11,376	2,330
3	n	-	-	83%	17%			0	0
3	n	-	-	83%	17%			13,320	2,728
4	n			96%	4%			0	0
						7,754	408	33,180	8,039

(U) Total number of signs installed in year X that are not compliant in year N **(Should be replaced)**	(V) Total number of signs installed in year X that are compliant in year N **(should NOT be replaced)**	(W) Total Signs Replaced Correctly	(X) Total Signs Replaced Incorrectly	(Y) Total Signs Replaced	(Z) Total that should have been replaced and were not	(AA) Total signs that should have been replaced in previous years and were not that were NOT EVALUATED IN CURRENT YEAR	(BB) Total signs potentially not in compliance in Year n	(CC) Total signs evaluated incorrectly	(DD) % evaluated incorrectly	(EE) % accuracy (% evaluated correctly)	(FF) % of signs potentially not meeting standard after evaluation
7,054	0	6,701	0	6,701	353			353			
7,054	0	5,291	0	5,291	1,764			1,764			
0	7,054	0	1,834	1,834	0			1,834			
0	7,055	0	1,834	1,834	0			1,834			
0	7,055	0	1,199	1,199	0			1,199			
0	7,055	0	1,199	1,199	0			1,199			
0	7,055	0	1,199	1,199	0			1,199			
0	0	0	0	0	0			0			
14,108	35,274	11,992	7,266	19,258	**2,116**	**0**	**2,116**	9,383	19.0%	81.0%	2.14%
7,054	0	6,701	0	6,701	353			353			
7,054	0	5,291	0	5,291	1,764			1,764			
0	7,054	0	1,834	1,834	0			1,834			
0	7,055	0	1,834	1,834	0			1,834			
0	7,055	0	1,199	1,199	0			1,199			
0	7,055	0	1,199	1,199	0			1,199			
0	7,055	0	1,199	1,199	0			1,199			
0	0	0	0	0	0	2,116		0			
14,108	35,274	11,992	7,266	19,258	**2,116**	**2,116**	**4,232**	9,383	19.0%	81.0%	4.29%
7,336	0	6,969	0	6,969	367			367			
5,221	0	3,916	0	3,916	1,305			1,305			
0	5,856	0	1,522	1,522	0			1,522			
0	5,856	0	1,522	1,522	0			1,522			

0	5,856	0	995	995	0			995			
0	0	0	0	0	0			0			
0	19,258	0	3,274	3,274	0			3,274			
0	0	0	0	0	0	2,116		0			
12,557	36,825	10,885	7,314	18,199	**1,672**	**2,116**	**3,788**	8,986	18.2%	81.8%	3.84%
7,336	0	6,969	0	6,969	367			367			
5,221	0	3,916	0	3,916	1,305			1,305			
0	5,856	0	1,522	1,522	0			1,522			
0	5,856	0	1,522	1,522	0			1,522			
0	5,856	0	995	995	0			995			
0	0	0	0	0	0			0			
0	19,258	0	3,274	3,274	0			3,274			
	0		0		0	1,672					
12,557	36,825	10,885	7,314	18,199	**1,672**	**1,672**	**3,344**	8,986	18.2%	81.8%	3.39%
6,005	0	5,705	0	5,705	300			300			
4,333	0	3,250	0	3,250	1,083			1,083			
0	4,860	0	1,264	1,264	0			1,264			
0	0	0	0	0	0			0			
0	15,984	0	2,717	2,717	0			2,717			
0	0	0	0	0	0			0			
0	18,199	0	3,094	3,094	0			3,094			
0	0	0	0	0	0	1,672		0			
10,338	39,044	8,955	7,075	16,030	**1,384**	**1,672**	**3,056**	8,458	17.1%	82.9%	3.09%
6,005	0	5,705	0	5,705	300			300			
4,333	0	3,250	0	3,250	1,083			1,083			
0	4,860	0	1,264	1,264	0			1,264			
0	0	0	0	0	0			0			
0	15,984	0	2,717	2,717	0			2,717			
0	0	0	0	0	0			0			
0	18,199	0	3,094	3,094	0			3,094			
	0		0		0	1,384					
10,338	39,044	8,955	7,075	16,030	**1,384**	**1,384**	**2,767**	8,458	17.1%	82.9%	2.80%
4,980	0	4,731	0	4,731	249			249			
0	0	0	0	0	0	3,597		0			

0	13,267	0	3,449	3,449	0			3,449			
0	0	0	0	0	0			0			
0	15,105	0	2,568	2,568	0			2,568			
0	0	0	0	0	0			0			
0	16,030	0	2,725	2,725	0			2,725			
0	0	0	0	0	0	1,384		0			
4,980	44,402	4,731	8,742	13,473	**249**	**4,980**	**5,229**	8,991	18.2%	81.8%	5.29%
4,980	0	4,731	0	4,731	249			249			
0	0	0	0	0		9,818		0			
0	13,267	0	3,449	3,449	0			3,449			
0	0	0	0	0	0			0			
0	15,105	0	2,568	2,568	0			2,568			
0	0	0	0	0	0			0			
0	16,030	0	2,725	2,725	0			2,725			
	0		0		0	249					
4,980	44,402	4,731	8,742	13,473	**249**	**10,067**	**10,316**	8,991	18.2%	81.8%	10.44%
10,067	0	9,563	0	9,563	503			503			
0	0	0	0	0	0	9,818		0			
0	12,537	0	3,260	3,260	0			3,260			
0	0	0	0	0	0			0			
0	13,305	0	2,262	2,262	0			2,262			
0	0	0	0	0	0			0			
0	13,473	0	2,290	2,290	0			2,290			
0	0	0	0	0	0	503		0			
10,067	39,315	9,563	7,812	17,375	**503**	**10,321**	**10,824**	8,315	16.8%	83.2%	10.96%
10,067	0	9,563	0	9,563	503			503			
0	0	0	0	0	0	9,278		0			
0	12,537	0	3,260	3,260	0			3,260			
0	0	0	0	0	0			0			
0	13,305	0	2,262	2,262	0			2,262			
0	0	0	0	0	0			0			
0	13,473	0	2,290	2,290	0			2,290			
	0		0		0	503					
10,067	39,315	9,563	7,812	17,375	**503**	**9,781**	**10,284**	8,315	16.8%	83.2%	10.41%

9,781	0	9,292	0	9,292	489			489			
0	0	0	0	0	0	9,278		0			
0	11,043	0	2,871	2,871	0			2,871			
0	0	0	0	0	0			0			
0	11,183	0	1,901	1,901	0			1,901			
0	0	0	0	0	0			0			
0	17,375	0	2,954	2,954	0			2,954			
	0		0		0	503					
9,781	39,601	9,292	7,726	17,018	**489**	**9,781**	**10,270**	8,215	16.6%	83.4%	10.40%
9,781	0	9,292	0	9,292	489			489			
0	0	0	0	0	0	8,172		0			
0	11,043	0	2,871	2,871	0			2,871			
0	0	0	0	0	0			0			
0	11,183	0	1,901	1,901	0			1,901			
0	0	0	0	0	0			0			
0	17,375	0	2,954	2,954	0			2,954			
	0		0		0	489					
9,781	39,601	9,292	7,726	17,018	**489**	**8,661**	**9,150**	8,215	16.6%	83.4%	9.26%
8,661	0	8,228	0	8,228	433			433			
0	0	0	0	0	0	8,172		0			
0	9,282	0	2,413	2,413	0			2,413			
0	0	0	0	0	0			0			
0	14,421	0	2,452	2,452	0			2,452			
0	0	0	0	0	0			0			
0	17,018	0	2,893	2,893	0			2,893			
	0		0		0	489					
8,661	40,721	8,228	7,758	15,986	**433**	**8,661**	**9,094**	8,191	16.6%	83.4%	9.21%
8,661	0	8,228	0	8,228	433			433			
0	0	0	0	0	0	6,869		0			
0	9,282	0	2,413	2,413	0			2,413			
0	0	0	0	0	0			0			
0	14,421	0	2,452	2,452	0			2,452			
0	0	0	0	0	0			0			
0	17,018	0	2,893	2,893	0			2,893			

	0		0		0	433					
8,661	40,721	8,228	7,758	15,986	433	7,302	7,735	8,191	16.6%	83.4%	7.83%
7,302	0	6,937	0	6,937	365			365			
0	0	0	0	0	0	6,869		0			
0	11,970	0	3,112	3,112	0			3,112			
0	0	0	0	0	0			0			
0	14,125	0	2,401	2,401	0			2,401			
0	0	0	0	0	0			0			
0	15,986	0	2,718	2,718	0			2,718			
	0		0		0	433					
7,302	42,080	6,937	8,231	15,167	365	7,302	7,667	8,596	17.4%	82.6%	7.76%
7,302	0	6,937	0	6,937	365			365			
0	0	0	0	0	0	8,858		0			
0	11,970	0	3,112	3,112	0			3,112			
0	0	0	0	0	0			0			
0	14,125	0	2,401	2,401	0			2,401			
0	0	0	0	0	0			0			
0	15,986	0	2,718	2,718	0			2,718			
	0		0		0	365					
7,302	42,080	6,937	8,231	15,167	365	9,223	9,588	8,596	17.4%	82.6%	9.71%
9,223	0	8,762	0	8,762	461			461			
0	0	0	0	0	0	8,858		0			
0	11,724	0	3,048	3,048	0			3,048			
0	0	0	0	0	0			0			
0	13,268	0	2,256	2,256	0			2,256			
0	0	0	0	0	0			0			
0	15,167	0	2,578	2,578	0			2,578			
	0		0		0	365					
9,223	40,159	8,762	7,882	16,644	461	9,223	9,684	8,343	16.9%	83.1%	9.81%
9,223	0	8,762	0	8,762	461			461			
0	0	0	0	0	0	8,676		0			
0	11,724	0	3,048	3,048	0			3,048			
0	0	0	0	0	0			0			
0	13,268	0	2,256	2,256	0			2,256			

0	0	0	0	0	0			0			
0	15,167	0	2,578	2,578	0			2,578			
	0		0		0	461					
9,223	40,159	8,762	7,882	16,644	**461**	**9,137**	**9,598**	8,343	16.9%	83.1%	9.72%
9,137	0	8,680	0	8,680	457			457			
0	0	0	0	0	0	8,676		0			
0	11,013	0	2,863	2,863	0			2,863			
0	0	0	0	0	0			0			
0	12,589	0	2,140	2,140	0			2,140			
0	0	0	0	0	0			0			
0	16,644	0	2,829	2,829	0			2,829			
	0		0		0	461					
9,137	40,245	8,680	7,833	16,513	**457**	**9,137**	**9,593**	8,290	16.8%	83.2%	9.71%
9,137	0	8,680	0	8,680	457			457			
0	0	0	0	0	0	8,149		0			
0	11,013	0	2,863	2,863	0			2,863			
0	0	0	0	0	0			0			
0	12,589	0	2,140	2,140	0			2,140			
0	0	0	0	0	0			0			
0	16,644	0	2,829	2,829	0			2,829			
	0		0		0	457					
9,137	40,245	8,680	7,833	16,513	**457**	**8,606**	**9,063**	8,290	16.8%	83.2%	9.18%
8,606	0	8,176	0	8,176	430			430			
0	0	0	0	0	0	8,149		0			
0	10,449	0	2,717	2,717	0			2,717			
0	0	0	0	0	0			0			
0	13,814	0	2,348	2,348	0			2,348			
0	0	0	0	0	0			0			
0	16,513	0	2,807	2,807	0			2,807			
	0		0		0	457					
8,606	40,776	8,176	7,872	16,048	**430**	**8,606**	**9,036**	8,303	16.8%	83.2%	9.15%
8,606	0	8,176	0	8,176	430			430			
0	0	0	0	0	0	7,732		0			
0	10,449	0	2,717	2,717	0			2,717			

0	0	0	0	0	0			0			
0	13,814	0	2,348	2,348	0			2,348			
0	0	0	0	0	0			0			
0	16,513	0	2,807	2,807	0			2,807			
	0		0		0	430					
8,606	40,776	8,176	7,872	16,048	**430**	**8,162**	**8,593**	8,303	16.8%	83.2%	8.70%
8,162	0	7,754	0	7,754	408			408			
0	0	0	0	0	0	7,732		0			
0	11,466	0	2,981	2,981	0			2,981			
0	0	0	0	0	0			0			
0	13,706	0	2,330	2,330	0			2,330			
0	0	0	0	0	0			0			
0	16,048	0	2,728	2,728	0			2,728			
	0		0		0	430					
8,162	41,220	7,754	8,039	15,794	**408**	**8,162**	**8,571**	8,447	17.1%	82.9%	8.68%
8,162	0	7,754	0	7,754	408			408			
0	0	0	0	0	0	8,485		0			
0	11,466	0	2,981	2,981	0			2,981			
0	0	0	0	0	0			0			
0	13,706	0	2,330	2,330	0			2,330			
0	0	0	0	0	0			0			
0	16,048	0	2,728	2,728	0			2,728			
	0		0		0	408					
8,162	41,220	7,754	8,039	15,794	**408**	**8,893**	**9,301**	8,447	17.1%	82.9%	9.42%