A North Carolina Sign Study:

Sign Count Approximation Using Field Inventory Sampling and Calculated Sign Densities for NC Primary Routes

Technical Report

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1. INTRODUCTION

1.1 Background

Road signs play a vital role in the operation of North Carolina's roadway transportation system. It is the North Carolina Department of Transportation (NCDOT) that has the major responsibility for erection and replacement of these signs. Part of the NCDOT sign management responsibility involves the replacement of signs that are damaged, stolen, or have lost the retroreflective properties with which they were initially manufactured and installed.

During nighttime hours, road signs would be nearly impossible for motorists to see if they do not have appropriate retroreflective properties. Retroreflectivity enables light from a vehicle's headlights to be returned along the same path that it came from, thus directing it back to the car and driver. For this reason, all road signs are manufactured with various types of reflective sheeting. Over time, the reflective sheeting of signs deteriorates, leading to reduced visibility. This ultimately poses potential danger to motorists. Signs that have lost their retroreflective properties also lose their value to nighttime drivers and must be replaced by the NCDOT.

In the near future, the Federal Highway Administration (FHWA) is expected to release new requirements for minimum levels of road sign reflectivity. These new requirments will place a certain amount of liability on the NCDOT in the event of an accident that might be caused by inadequate or substandard sign reflectivity. Therefore, it is in the best interest of the NCDOT to perform the duties of sign management in a diligent manner, thus replacing signs with substandard retroreflectivity.

In fact, the NCDOT would like to develop strategies for meeting the FHWA requirements on retroreflectivity before they are actually released. Clearly, the NCDOT has concerns about the cost, particularly with respect to liability and sign replacement, that such a standard might create. The question of liability and cost cannot be fully answered however, without an accurate estimate of the number of signs that line North Carolina's roadways.

Currently, there are only rough estimates of how many signs NCDOT is responsible for maintaining. Other studies in other states yield very limited methodologies for determining the number of signs. The purpose of this study is to obtain an accurate estimate of the number of signs that there are in North Carolina. A more accurate estimate will allow the NCDOT to better understand, determine, and evaluate the amount of liability involved with, and the cost of meeting, the newly created retroreflectivity standards. The extent of liability that the new standards will create is being investigated in another study (Source 4) and will be based on using the results presented herein.

1.2 General Approach

Currently, the NCDOT does not have a sign inventory program, leaving unknown the number, type, location, age, etc. of signs owned and maintained by the NCDOT. Also, any estimates of the number of signs that currently exist are guesses at best and are not highly reliable. Due to the possibility of increased liability and replacement expense created by the anticipated FHWA retroreflectivity requirements, the NCDOT would like to know exactly how many signs it is responsible for.

However, determining an exact number of road signs in North Carolina is a more difficult task than it may at first seem to be. To be a completely accurate would require a flawless sign count of all 78,083 miles of North Carolina roadway. This is a task that would not only be extremely difficult but also very time and resource consuming. Thus, a less exact, yet a more reasonably attainable method of counting and estimating the number of road signs must be devised.

Because of the time and resource limitations mentioned above, the only feasible method for completing a sign count is to perform an estimation of the total number of road signs in North Carolina through the use of sampling. Samples of portions of the overall highway network would be used to obtain average sign densities that can be extrapolated to all segments of roadway. Although such an approach will not produce the exact number of road signs found in North Carolina, it will provide a reasonably accurate estimate that is acceptable for use by the NCDOT for further sign retroreflectivity work.

1.3 Scope

In order to calculate the required sign densities, targeted sign counts were completed for NC Routes, US Routes, and Interstates for both urban and rural settings located within North Carolina's boundaries. Secondary roads are being sampled in a separate study (Source 5). Urban (or municipal) areas are defined as those having a population greater than 5,000 (Source 2). Rural areas are defined as those areas outside of city limits or areas where the population is fewer than 5,000 persons (Source 2).

On the North Carolina State Transportation Map, urban areas are defined by pink shading. This coloring represents areas with a population greater than 10,000. Urban areas are also defined by circles with a solid dot inside which represent areas with a population between 5,000 and 10,000. In this study, all urban driving occurred on roads inside the shaded areas on the state transportation map. All rural driving occurred outside of the shaded areas and outside of the circle/small dot areas as well.

A distinction was also made between divided and undivided highways. Divided highways are those where apposing directions of travel are separated by a physical barrier or by a physical space. Adequate sampling for both divided and undivided highways was included in this study.

Initially, evenly distributing the counts among the three regions of North Carolina (coastal plain, piedmont, mountains) was considered. However, it was more practical to work in a region roughly bounded by Charlotte, Raleigh, and Wilmington, although the driving of interstates included portions of North Carolina's mountain region as well. Finally, it was felt that the relatively large and diverse area that was driven would be sufficiently representative of other areas in the state. As a result, the majority of sign counts were obtained from the coastal plain and piedmont regions.

With few exceptions (refer to Sections 2.2.3.5 and 2.2.3.6), all signs facing perpendicular to oncoming traffic were included in these counts and rules were established for the counting of signs facing parallel to the direction of travel. This ensures that all signs are counted regardless of the path taken by the sign counter during the drive. This unique situation is discussed in Section 2.2.3.5.

Counting city street signs is an extremely difficult task and one that is unnecessary for the inventory defined herein. Cities, rather than the NCDOT, are responsible for the maintenance of their own street signs. It would not be appropriate to include city street signs in this project's sign count since the objective of this project is to provide the NCDOT with an estimation of the number of signs for which the State maintains responsibility. Although the NCDOT does contract out to a few cities for the maintenance of street signs, these were not included in the scope of this project. However, signs located on NC Routes, US Routes, and interstate roads that pass through city limits, were counted, since the NCDOT is responsible for their maintenance.

Sign density is herein defined as the number of signs per mile of highway. These were determined by dividing the sign counts by the total miles traveled to obtain a density. Sign density varies by locale. Generally, there are more signs in urban areas than in rural areas. Thus, in this study, significant samples of roads in both urban and rural areas were included in the sign counts. But no special locations, such as state or national parks, military installations, wildlife refuges, reservations, or the like, were included in the project.

There are hundreds of different signs used by the NCDOT. Currently, these signs all use one of eight background colors: black, blue, brown, green, orange, red, white, and yellow (Source 3). In this study, only signs with one of these dominant background colors were counted. It should be noted, however, that according to the rule for determining a sign's background color (presented in Section 2.3.3 of this paper), signs with black backgrounds were counted as white.

There are four other background colors that are reserved for future use: strong yellow-green, coral, light blue, and purple (Source 3). Signs with strong yellow-green backgrounds are slowly coming into greater use (primarily as school and pedestrian crossing warnings signs) and a few or these were encountered while performing sign counts. In this study, these signs were counted as simply having yellow backgrounds.

Sign density estimates were not generated for individual sign types such as 'yield' signs for two reasons. First, counting by color alone met the needs of another project (Source 4) for which this work was being done. Second, a complete statewide inventory of the number of every sign used by the NCDOT was not possible given the resources available to conduct this study. The exception to this color counting approach was stop signs. These were counted individually because of their large numbers and because of the high level of potential liability that they create for the NCDOT.

The results of the sign counts were used to calculate an average sign density for both urban and rural areas for each chosen background color and for each road type. Using the calculated sign densities, an estimate of the total number of NCDOT signs was generated. Estimates for the individual number of signs of each color were generated in a similar manner.

1.4 Preliminary Strategies

Before the sign counting process could begin, procedures for counting had to be established and tested. The first step in developing a counting procedure was to determine which signs would be counted, or rather, which signs would not be counted. Next, the way in which the signs were counted had to be determined. There were several possibilities for this, which included counting signs by color, by shape, or by both color and shape. A final decision could not be made without valid preliminary data, so each of these counting procedures was tested during a preliminary drive of selected types of roads. Different types of spreadsheets were then developed for each possible counting procedure in order to assist in keeping track of the counting.

During the preliminary test drives it was quickly discovered that it would be extremely difficult to count signs by both color and shape due to the speeds at which the driving had to be done in order to remain safe. It was simply not possible to safely drive slowly enough to count signs in such a detailed and differentiating manner. It was, however, feasible to count signs by either shape or color, and so a final decision had to be made between these two choices. Since the color of signs often corresponds with certain shapes of signs, and is also most closely aligned with safety, it was decided that signs should be counted by color.

During the preliminary drives it was also concluded that it was still extremely difficult to count signs by color using the preliminary drafts of the counting spreadsheets. If spreadsheets were used for keeping track of the sign counts then a counter, as well as the driver, would be needed. Also, the driver would have to drive ten to fifteen miles per hour slower than the posted speed limits. Thus, an alternative method was chosen in which an audio micro-recorder was used to verbally count the signs. This method was quickly found to be the most effective sign count recording procedure. It would allow the driver to do the counting without the need of a passenger. The tape could then later be transcribed.

2. METHODOLOGY

2.1 Overall Approach

The first step in getting started with the estimation of the number of signs located in North Carolina involved the creation of a plan detailing the methods that would be used for counting the road signs. These detailed methods covered everything from how the signs would be accounted for on paper, to the specifics of which signs would and would not be counted.

The next step in the overall approach to this project was the identification of the roads that would be driven during the counting process. This step included making decisions regarding how the various road types, road structures, and road locations would be treated. A decision was also made regarding the number of miles of each road type that would be counted in order to produce reasonable or representative results.

To allow for flexibility and minimization of driving time, the identification of roads to include in the sign counts was completed in a manner in which roads were selected progressively, that is, as we went. The counting process was continued until the desired number of miles of each road type were counted. In summary, we sought to answer the following questions.

- What types of signs are there?
- Of these, which signs do we count?
- What types of roads are of interest?
- Of these, which ones should we drive?
    - Location
    - Distance

The process of counting signs was completed using an audio micro-recorder, commonly referred to as a dictaphone. As signs were passed along the road being driven, they were verbally identified and counted using the dictaphone. Before beginning a sign count, the road structure, type, and location were recorded along with the beginning odometer reading. Also, at random intervals during the sign counts the odometer reading or mileage marker was recorded to act as a safeguard stopping point. During the sign counts it was often difficult to determine when an area changed from rural to urban or vise versa. Also, sudden highway structure changes from undivided to divided or vice versa may not be realized until it is too late. Thus, the mile markers (or odometer readings) were recorded often in order to provide an intermediate stopping point in case of such an incident.

2.1.1 Data Compilation

Following the completion of several sign counts, the audio recordings for them were transcribed onto paper and then entered into a spreadsheet like the one shown in Table 1.

The data from each of these individual spreadsheets were then entered into another spreadsheet such as the ones shown in Tables 2 and 3 below in which sign totals, sign densities, and mileage totals were calculated.

Spreadsheets like the one shown in Table 1 were generated for each segment of roadway that was counted. The information in the left corner of the spreadsheet provides the count number, date the survey was conducted, a description (including road name, type, and location) of the road being surveyed, and the mileage and sign totals for the sign count for that specific portion of highway. The main body of the spreadsheet is simply a tally of the number of signs of each sign color. The numbers in the first column of the main body represent mileposts for interstate counts while representing the odometer readings for all other counts. The numbers in the bottom row represent the totals for the specified road segment.

Tables 2 and 3 summarize and divide each sign count's results and calculations including sign totals, sign densities, and mileage totals into their respective road segment combination. In Table 2, columns 1-3 define the road segment combination for each of the rows to the right of these columns. Column 4 gives the count number that its row represents. Column 5 displays the total number of miles traveled for each respective count number while columns 6-13 display the sign totals of each color for their respective count number. Column 14 shows the total number of signs for each sign count. Each row in Table 2 corresponds to an entire spreadsheet like that shown in Table 1.

In Table 3 columns 1-5 are the same as in Table 2. Column 6 then displays the combined total for all sign colors for each respective count. Column 7 then shows the calculated sign density for each respective count and columns 8 and 9 display the cumulative values for total miles and total signs respectively for all of the counts shown in the entire table. Column 10 shows the calculated value for the overall sign density.

After the completion of the sign count spreadsheets (Tables 2 and 3), the sign densities for the State of North Carolina were then used to estimate the total number of signs on all roads in the State.

Count #	7	Geographic Description:						
Date	July, 2001	The highway segment between						
Road Name	85 North	mileposts 122 and 128						
Road Type	Interstate							
Road Location	Urban							
Total Miles	6							
Total Signs	123							
Begin	Blue	Yellow	Green	White	Orange	Brown	Red	Stop
122-124	11	5	23	9	6	0	0	0
124-125	7	5	7	9	0	0	0	0
125-126	0	3	17	1	0	0	0	0
126-128	3	3	9	5	0	0	0	0
End								
Totals	21	16	56	24	6	0	0	0

Table 1: Sample Sign Count Spreadsheet

Road Type	Road Characteristic	Road Location	Count #	Miles Counted	Signs								Total Signs
					Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Interstate	Divided	Rural											
		Urban											
US Route	Undivided	Rural											
		Urban											
	Divided	Rural											
		Urban											
NC Route	Undivided	Rural											
		Urban											
	Divided	Rural											
		Urban											

Table 2: Sign Count Summarization Sheet for Road Segment Categories and Combinations

Road Type	Road Characteristic	Road Location	Count #	Miles Counted	Total Signs	Sign Density	Cumulative Miles	Cumulative Signs	Overall Sign Density
Interstate	Divided	Rural							
		Urban							
US Route	Undivided	Rural							
		Urban							
	Divided	Rural							
		Urban							
NC Route	Undivided	Rural							
		Urban							
	Divided	Rural							
		Urban							

Table 3: Sign Count Results and Calculations for Road Segment Combinations

2.2 Approach Details

The estimation of the total number of signs located in North Carolina was accomplished through the use of sign densities. Because the base data was extrapolated over the entire state, great attention to detail was essential to ensure that the samples taken were highly representative of those that might be taken anywhere in the State. Before any sign density data could be collected, the detailed approaches and the rules that were used to collect the sign density data had to be determined, documented, evaluated, and implemented. The development of these approaches and rules required key decisions concerning study routes, factors influencing sign density, and counting procedures to be made. These key decisions concerning the approaches and rules for data collection (that make up the methodology used to conduct this study) are presented in the following subsections.

2.2.1 Study Routes

2.2.1.1 *Mileage*

It was necessary to first decide how many miles of each road type to count in order to produce sign densities that could be confidently considered as reasonably representative of those statewide. It was decided that a percentage of miles of each road type would be counted. These percentages were determined using the total number of North Carolina highway miles of each road type.

It was expected that each of these percentages would not necessarily be the same since the total number of North Carolina highway miles varies significantly between the highway types. Thus, separate percentages were set for Interstates, NC Routes, and US Routes, depending upon each highway type's total number of miles as well as on the speed and efficiency with which each highway type could be counted. A percentage was not set for secondary routes since the collection of data for this highway type is being completed in a follow up study relating to this project (Source 5). It should be noted that because the counting process was divided up not only by road type but also by road location, the percentage of miles of each road type was used for both road locations and road type.

The existing roadway mileages and target mileages can be seen in Tables 4 and 5 below. Table 4 shows the actual number of miles of existing highway in North Carolina (Source 2) as well as the target percentages of the number of miles of roadway that would be counted. The number of miles and percentages are expressed with respect to each of the four roadway types, and with respect both municipal and rural areas. Column one lists the four road types for which each row of information relates. Column two lists the number of existing municipal (urban) and rural highway miles and column three lists the selected target percentages for the number of municipal and rural highway miles to be counted are shown for both divided and undivided highways.

Table 5 shows the actual total number of roadway miles counted, and the actual percentage of roadway miles counted. This table has the same format as Table 4 where the number of miles and percentages are expressed with respect to each of the four roadway types, and with respect both municipal and rural areas.

Although secondary roads were not included in this study their mileages are included in Tables 4 and 5 for completeness.

Road Type	Existing Highway Miles				Target Count Percentage			
	Divided		Undivided		Divided		Undivided	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Interstate	262.1	821.1	0	0	40.0%	40.0%	0.0%	0.0%
US Routes	381.45	1150.31	893.97	3028.15	10.0%	10.0%	10.0%	10.0%
NC Routes	112.91	151.3	1027.52	6787.52	5.00%	5.00%	5.00%	5.00%
Secondary	101.36	43.24	4197.52	59124.94	0.00%	0.00%	0.00%	0.00%
Individual Totals	**857.82**	**2165.95**	**6119.01**	**68940.61**	**17.3%**	**20.8%**	**2.3%**	**0.9%**
Combined Totals	**78083.39**				**1.8%**			

Table 4: NC Roadway Mileages and Target Percentages (Source 2)

Road Type	Total Miles Counted				Actual Percentage Counted			
	Divided		Undivided		Divided		Undivided	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Interstate	129	469	0	0	49.2%	57.1%	0.0%	0.0%
US Routes	70.7	162.7	113.8	323.6	18.5%	14.1%	12.7%	10.7%
NC Routes	6.3	5.4	58.2	346.5	5.6%	3.6%	5.7%	5.1%
Secondary	0	0	0	0	0.0%	0.0%	0.0%	0.0%
Individual Totals	**206**	**637.1**	**172**	**670.1**	**24.0%**	**29.4%**	**2.8%**	**1.0%**
Combined Totals	**1685.2**				**2.2%**			

Table 5: Actual NC Roadway Mileages and Percentages Counted

2.2.1.2 *Roads*

A determination of which roadsto be counted (and the identification of their types) was also necessary before counting could begin. A preliminary identification of the road types that would be included in the sign counts and the general locations of these roads had to be predetermined. Any roads that would be excluded from the sign counts also had to be identified.

In the selection of routes that would be counted, it was first decided to focus on routes located within the regions of North Carolina roughly bounded by Charlotte and Wilmington since these areas were within acceptable driving distance from Raleigh. The selection of the route segments to be counted was done in such a way as to get the most benefit out of driving time and to avoid backtracking on route segments that had been previously driven. Route segments were also selected according to well-defined stopping and starting points, when possible. The counting of the entire extent of a route was not deemed to be necessary nor feasible since a route's characteristic and location is

constantly changing. Instead, smaller segments of each individual primary route were selected with location and characteristic in mind.

Table 6 below, lists each of the specific North Carolina routes that were included in the sign counts. For a description of the specific segments of each route that was counted, the reader is refered to the geographic descriptions of each individual sign count in Appendices C, E, and F.

Interstates	US Routes		NC Routes	
I-85 North	74 East	158 West	55 West	150 East
I-85 South	74 West	601 South	27 West	22 South
I-77North	501 South	64 East	50 South	902 East
I-77 South	501 North	64 West	130 East	751 South
I-40 East	17 North	401 North	904 East	751 North
I-40 West	17 South	401 South	73 East	86 North
I-26 East	52 South	117 North	49 South	86 South
I-26 West	220 South	117 South	8 North	157 North
I-240 East	17 North	76 East	87 South	157 South
	421 North	76 West	87 North	54 West
	421 South	1 South	62 North	54 East
	601 North	29 South	801 North	
	21 South	29 North		
	70 East	311 North		
	70 West	311 South		

Table 6: Inventoried North Carolina Routes

As discussed in section 2.2.2.3, North Carolina's roads can be divided into four different types, of which only three (Interstates, US Routes, and NC Routes) were decided to be included in the sign counts of this project. Each road type can also be divided into two road locations, urban and rural. Finally, certain roads can be further categorized as having either a divided or undivided road structure. Each road type, road location, and road structure combination was therefore considered individually during the data collection process. Thus, a sign density for each such combination was calculated.

2.2.1.3 *Data Collection Order*

It was decided that interstate data collection should be completed first since these roads would be the easiest and fastest to count signs on. Following the collection of sign count data for interstates the data collection for US and NC Routes was completed simultaneously. This allowed for greater efficiency in the counting process with respect to driving time and route planning. By counting the US and NC Routes together it was possible to minimize the number of miles of previously counted roadway that had to be backtracked in order to reach uncounted roadways. Still, the reader should note that the actual sequence of data collection has no bearing on the result.

2.2.2 Possible Factors Affecting Sign Density

Sign density will undoubtedly fluctuate from one roadway to another, so a very detailed and organized approach was necessary in order to take these fluctuations into account. During the preliminary sign counts, it was quickly realized that a road's sign density is possibly influenced by several factors. These include the aforementioned road location, road type, and road structure. Thus, before any estimation of road sign densities could be made, it was first necessary to lay out in detail, the procedures for handling these factors influencing sign density.

2.2.2.1 *Road Location: Urban vs. Rural*

Making a distinction between urban and rural areas could add a greater degree of accuracy in the final sign estimates. For the purposes of this project it was initially assumed that the population of a given area influences sign density, meaning that as the population of an area increases, the need for road signs will also increase. Thus, when considering a segment of road, it was important to observe its geographic location in order to determine whether the segment of road fell within an urban or rural area.

For the work reported herein, all road segments were assumed to be rural unless they were located within the pink shaded areas of the 2001 North Carolina State Transportation Map (this area represents city limits with populations over 10,000) or unless they passed directly through a circle with a solid dot inside (a map symbol that represents city limits with populations between 5,000 and 10,000).

No driving and sign surveying was done in small population urban areas where there was doubt about whether the area was rural or urban, except for one segment of NC-55 that passed through Holly Springs (accepting this count should have very little if any impact of the final results). When an urban area was driven, it was unquestionably urban since a population greater than 10,000 is definitely greater than a population of 5000 which was the minimum population for an area to be considered urban.

Any road segments located within this pink shaded area of the map were assumed to be urban. For example, the segment of I-85 Northbound between the left star and the middle star in Figure 1 below was considered rural since the segment does not pass through the gray shading (note that the gray shading in Figure 1 is pink on the 2001 North Carolina State Transportation Map) and since it does not pass directly through a circle with a dot inside. The segment of I-85 Northbound between the middle star and the right star in Figure 1 was considered to be an urban area since the segment passes through the gray shading. After making this distinction, data collection was completed for each separate location.

Figure 1: North Carolina Map Section

2.2.2.2 *Road Structure: Divided vs. Undivided*

North Carolina roadways can be divided into two different road structures, divided and undivided. Since it was recognized that there could be significant differences between the sign densities of each road structure, it was decided that a sign density for each separate road structure should be calculated. In order to do so it was necessary to separately complete the sign counts for divided and undivided highways.

Many times the structure of a road can be determined from a road map. Divided highways are generally denoted as double lines and the undivided highways as single lines and so during the sign counting process it was very helpful to reference a North Carolina State Transportation Map from time to time in order to separate the sign counts for each road structure. However, the structure of a road can change suddenly and without warning and so it was important to pay careful attention to the changing road structures during the counting process. It is important to note that interstates are always divided.

Since the data collection for this project relies heavily on the determination of when a highway is divided or undivided it is necessary to define what a divided highway is. A divided highway is defined as a highway with separated roadways for traffic traveling in opposite directions (Source 2). It should be noted however, that a highway with a center lane for use by turning vehicles, are considered to be undivided. The separation of a divided highway can be in several forms including a grass median, a concrete barrier, vegetation, etc. During the sign counting process it was sometimes difficult to determine whether a highway segment should be considered as divided or undivided due to the rapid change from a divided highway to an undivided highway and back again. This type of circumstance was especially prevalent in urban areas where short barriers are often

necessary to allow for safer traffic movements on an otherwise undivided highway. These short barriers are often in the form of six to eight inch tall concrete or asphalt cement barriers but could also be in the form of grass medians or tall concrete barriers.

For the purposes of this project, it was decided to count a highway segment having separations that extend for only short distances and that are sporadically placed, as undivided highways. Many times, such a decision was made quickly and required the judgment of a reasonable person.

2.2.2.3 *Road Type*

There are three different types of roads that fall within the scope of this project; interstates, US Routes, and NC Routes. Since it is obvious that each of these road types will have differing sign needs and consequently varying sign densities, it was necessary to perform individual sign counts for each road type.

2.2.3 Sign Counting Procedures, Methods, and Issues

Before beginning the process of counting signs, decisions were made concerning what signs would be included in the sign counts and the procedure for counting signs had to be developed and tested. Recall that the purpose of this project is to provide a reasonable estimate of the number of road signs located in North Carolina. Because some of the signs lining North Carolina's roadways will create liability and maintenance costs for the NCDOT, decisions regarding what signs to count and what signs not to count were made after preliminary sign counting test drives of various highway segments were completed. The following subsections detail the procedures and methods used to complete the data collection for this project and identify and present solutions for some of the counting problems encountered.

2.2.3.1 *Data Recording*

Determining a sign counting method, approach, or procedure was the first step in obtaining an estimation of the number of signs located in North Carolina. Following the preliminary counts of various road segments it was decided that the best method for counting road signs was to use an audio micro-recorder for field collection of the necessary data. The counting procedure was therefore completed by verbally counting signs, using a microphone, as the signs were passed in a vehicle. After the completion of a segment of road, the collected data was transcribed and transferred to paper.

This procedure proved to be very accurate and was chosen for its efficiency since one person could perform the counting and the driving process at the same time. Recall that from the discussion of Section 1.4 that during the preliminary sign counts it was realized that a purely tabular counting process (in which signs were recorded on paper as they were passed) was extremely difficult to accomplish because of slow recording speeds and high vehicle speeds. Also, the tabular counting processes required two people in the vehicle, one to drive and one to count.

2.2.3.2 *Sign Differentiation and Color*

In the estimation of the total number of signs located in North Carolina it was thought that it would be beneficial to the NCDOT if the number of each type of sign were determined. However, this was not feasible due to the fact that there are hundreds of different signs. It would not have been possible to efficiently and safely count every sign type individually, so an alternative beneficial approach to categorizing road signs was utilized.

It was decided that signs would be counted by color; a method of counting that proved to be reasonable and feasible during the preliminary sign counts. Color coding is a basic principle of any traffic signing system (Source 3). According to the MUTCD, color coding has the basic purpose of assigning colors to be used for specific signs and types of signs with the intent of helping road users identify the sign or sign type (Source 3). Seven major sign background colors were counted in this project. These seven background colors and their respective purposes are shown in Table 7. Examples of various sign types for each color are shown in Table 8.

Background Color	Color Description(Reference 2)
Red	Indicates right-of-way control, prohibition, or exclusion
Yellow	Warns of a typical potential hazard
White	Indicates a law, regulation, legal requirement, or direction
Green	Indicates movement permitted or gives directional guidance
Blue	Indicates services available to road users
Brown	Indicates recreational and cultural facilities.
Orange	Warns of temporary traffic conditions with a high hazard potential

Table 7: Sign Background Color Descriptions

Red	Yellow	White	Green	Blue	Brown	Orange
Stop	Merging Traffic	Speed Limit	Bike Route	Hospital	Camping	Detour
Yield	Merge Left	Keep Right	Exit	Food	Monument	Men Working
Do Not Enter	Pedestrian Crossing	No Parking	Directions	Gas	Fishing	Construction Zone
Wrong Way	Deer Crossing	JCT	Mile Post	Rest Area	Boating	Speed Limit
	Soft Shoulder	North		Airport	Historic Site	Flag Man Ahead
	Stop Sign Ahead	Route Marker		Route Marker		
	Sharp Curve Ahead					

Table 8: Sign Types by Background Color

2.2.3.3 *Direction of Travel*

It is not feasible to count, by color, all of the road signs located on a road (divided or undivided) without traveling in both directions, because signs face both directions. To do this would be virtually impossible and would require extremely slow travel speeds for the survey vehicle. This could create a dangerous driving situation. It would also require a passenger to assist in the counting of signs seen while facing opposite to the direction of

travel. It was therefore decided that only signs whose color can be seen while facing in the direction of travel would be included in the sign counts. To do so thus requires travel in both directions.

When counting undivided highways it must be realized that most of the signs counted using this rule will be on the right side of the road. But there are signs on the left side of every road that must be counted also. Examples of such signs are shown in Figure 2. For divided highways the counting process is a little more difficult since there are signs located on both sides of the road as well as across the median. To better understand this, refer to Figures 3 and 4 below. These figures illustrate typical sections of both divided and undivided highways. They also show the location of countable signs for a north to south direction.

Figure 2: Examples of Signs Located in the Median Portion of Divided Highways

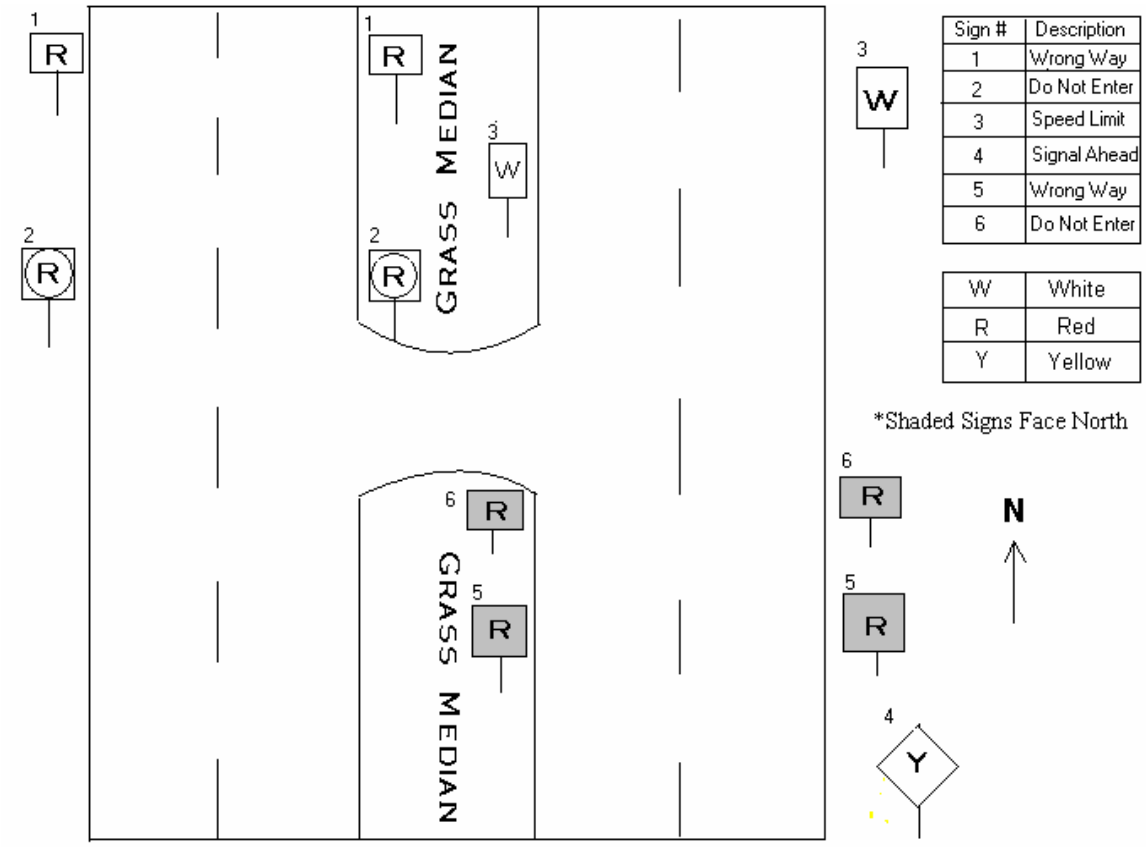
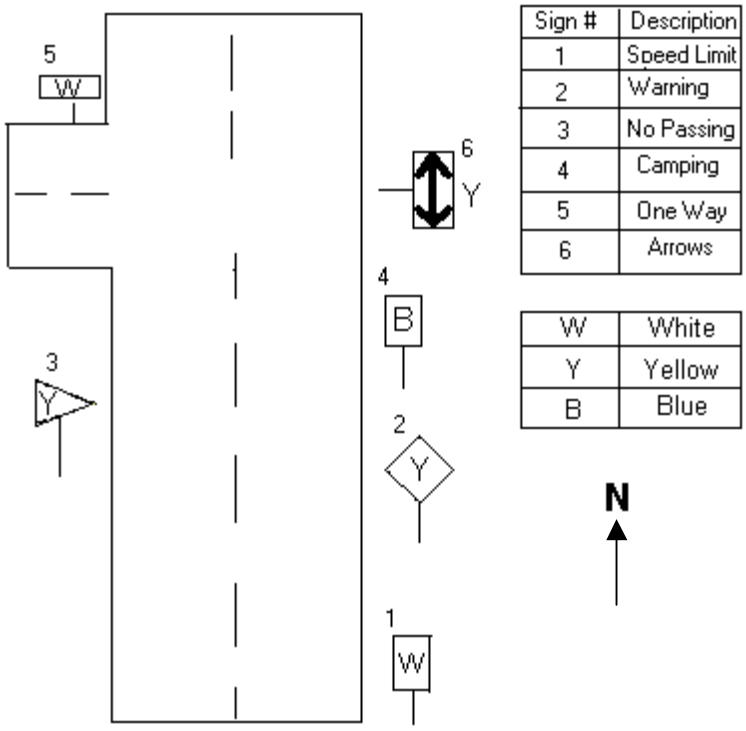


Figure 3: Countable Signs on Divided Highways

First consider Figure 3. Based on the sign counting procedures just mentioned, 7 signs (1,1,2,2,3,3,4) would be counted when traveling north while 4 signs (5,5,6,6) would be counted when traveling south. In Figure 3, the signs are each assigned a number. When traveling north, the signs numbered 1 and 2 would be counted as red signs, the signs numbered 3 would be counted as white signs, and the sign numbered 4 would be counted as a yellow sign while the signs numbered 5 and 6 would be overlooked because they face the opposite direction. When traveling south, the signs numbered 5 and 6 would be counted as red signs.



Sign #	Description
1	Speed Limit
2	Warning
3	No Passing
4	Camping
5	One Way
6	Arrows

W	White
Y	Yellow
B	Blue

Figure 4: Countable Signs of Undivided Highways

Next consider Figure 4 as an example of an undivided highway segment. Based on the sign counting procedures mentioned, 5 signs (1-5) would be counted when traveling south to north. The signs numbered one and five would be counted as white signs, the signs numbered two and three would be counted as yellow signs and the sign numbered four would be counted as a blue sign. The sign numbered 6 would not be counted since it is facing parallel to the direction of travel. It would be included in the count of the incoming road when traveling in a west to east direction. Note that the signs facing the opposite direction have not been shown here.

In order to calculate the total number of signs located in North Carolina using the sign density information that was collected from all of the sign counts, the total number of miles of roadway in North Carolina must first be known. To arrive at the final sign total, each of the calculated sign densities had to be multiplied by the total number of miles of roadway of that type (Total Signs = Signs/Mile * Total Miles). When the road sign counts for this project were determined by field survey, only those signs whose color

could be seen while facing in the direction of travel were counted. In many of the sign counts, signs were only counted in one direction of travel for a given road and so it is important to understand the difference between mileage of travel and mileage of highway so that sign calculations are performed correctly.

The total mileage of any given segment of highway of any type and of any structure is always expressed as a distance from one end to the other. Highway mileage is not expressed as a sum of the travel mileage in each direction. Travel mileage will always be double the highway mileage since every highway has two directions of travel. Thus, the calculated sign density for a given segment of roadway only represents the number of signs facing one direction of travel. It follows then, that in order to calculate the total number of signs on all of North Carolina's highways, each calculated sign density must be multiplied by the total travel mileage or by twice the total highway mileage.

2.2.3.4 Perpendicular Facing Signs

The first decision made after the completion of the preliminary drives was that all signs facing perpendicular to the direction of travel would be counted with the exception of specific signs deemed excludable per section 2.2.3.5 and section 2.2.3.6.

2.2.3.5 *Parallel Facing Signs*

After completing the preliminary sign counts it was realized that before the sign counting process could begin, questions about how to count parallel signs needed to be addressed. In order for the final sign total estimates and sign densities to be accurate, it was necessary to ensure that every countable sign was accounted for in one and only one sign count. It was quickly realized that if only perpendicular facing signs were counted, some parallel facing signs would be omitted from a sign count.

Initially, it was assumed that all signs facing parallel to the direction of travel on one road would be facing perpendicular to the direction of travel on another roadway. Sign 1 in Figure 5 illustrates this situation. This sign would logically be counted when traveling East on Route 50. If it were also counted when traveling North on Route 70 it would get counted twice. This is not acceptable and the presently adopted strategy prevents it.

However, some "one-way" and other signs facing parallel to the direction of travel may not face perpendicular to the direction of travel on another road because of their location on divided highways across from driveways and parking lots of businesses. Thus, any parallel signs, regardless of the type of highway on which they are located, that would not otherwise be included in a sign count of another road by a reasonable person and that is not deemed excludable, were included with the count of the road being traveled. Figure 5 also illustrates this situation. In Figure 5, sign 3 would not get included in the normal sign count of any road and so it must be included in the sign count of US-70 North. Sign 2 in Figure 5 however, conveys directional information to vehicles traveling west on Route 2010 and should therefore be included in the normal sign count of Route 2010.

Utilization of this counting procedure while driving to conduct the sign counts proved to be especially difficult for counting parallel facing, "one-way" signs located on divided highways. This difficulty stemmed from the fact that there are a large number of parallel facing "one-way" signs to be counted as well as from the fact that it is sometimes difficult to determine whether or not these signs would actually be included in the sign count of another road by a reasonable person in the short time that these decisions need to be made. It was therefore decided that the sign counting procedures for a divided highway would deviate from this project's standard procedural guidelines for counting signs.

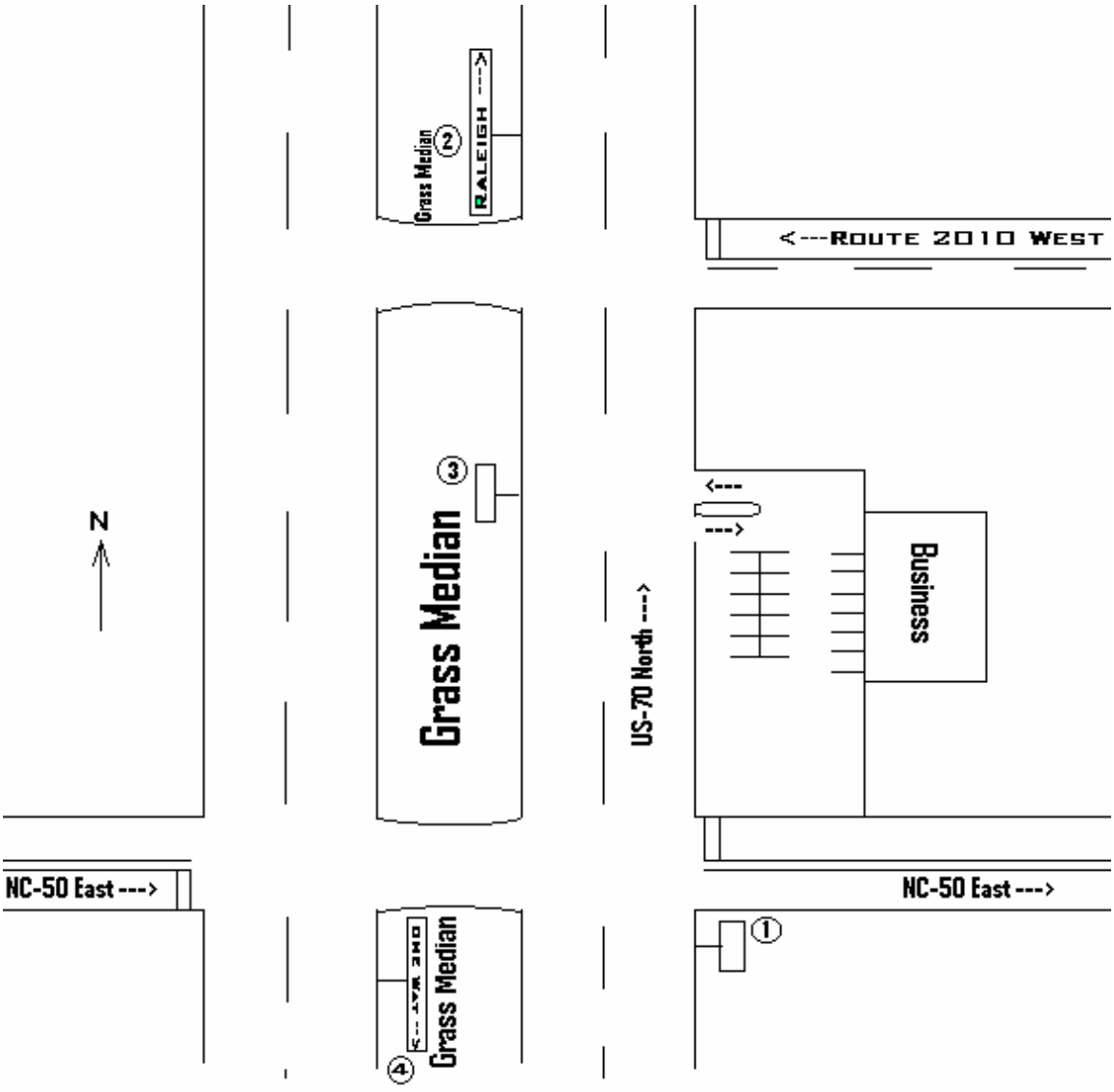


Figure 5: Parallel Signs on a Divided Highway

In order to insure that all one-way signs on a divided highway are included in one and only one sign count, it was decided that all parallel facing, one-way signs located on a divided highway will be included in its respective divided highway road count. Thus, it

follows that any one-way signs located on (and facing parallel to) a divided highway will not be included in another road's sign count. In other words, when counting signs while traveling on an undivided highway or secondary road, any perpendicular facing one-way signs located at intersections with a divided highway will be excluded from the count of the road being traveled. In Figure 5 for example, sign 4 would be included in the sign count of US-70 South, not in the sign count for NC-50 East, because it is a "one-way" sign located on a divided highway.

The number of countable parallel facing signs located on undivided highway segments is very small because the majority of parallel facing signs (on an undivided highway) are located at intersections with other highways and secondary roads or they are located on the property of businesses, schools, factories, etc. Parallel facing signs located at intersections with other routes were counted according to the standard methodology that includes them in the intersecting route's sign count. Also, per section 2.2.3.6, those parallel facing signs located on the property of businesses, schools, factories, etc. were not counted.

2.2.3.6 *Excluded Signs*

Not all road and highway signs lining North Carolina's highways belong to or were placed there by the state of North Carolina. Such signs, which are not state maintained, do not have the potential to incur liability and maintenance costs for the NCDOT. Thus, it was necessary to create a list of signs that should not be included in the sign counts before the counting process could begin. Similarly, as discussed in Section 1.3, signs located within city limits were not counted unless they were located on interstates, US Routes, or NC Routes.

When traveling in any given direction on any given highway type, there are parallel and perpendicular facing signs located on the right side of the road at entrances of businesses, factories, or schools. It was assumed that these signs were owned and maintained by the businesses, factories, or schools, and not by the NCDOT. This assumption was made because of the sign's locations on properties that are not owned by the state of North Carolina and because they were not highway signs.

Signs meant to provide drivers with directional information for businesses such as hotels and restaurants are located along many highways. Examples of these signs can be seen in Figure 6 below. The signs with a business name on them have customized backgrounds for the respective business that do not correspond with the eight major signs colors utilized by the NCDOT and so it was assumed that these signs are installed by their respective business. However, the directional arrow sign (blue background) that is located on the same sign post below the business signs was assumed to be maintained by the NCDOT and was therefore included in the sign count for the road being traveled.

Figure 6: Business Advertisement Signs

When performing sign counts of many highways, especially in urban areas, bus stop signs such as the one shown in Figure 7 were observed. It was assumed that these signs are maintained by the bus company or by the city in which they are located and so they were not included in any sign counts.

Figure 7: Bus Stop Sign

Secondary route markers and directional markers such as those shown in Figure 8 were also encountered when conducting many sign counts. These signs do not have reflective properties and were not deemed to be important to the objective of this study and so they were not included in any sign counts.

Figure 8: Secondary Route Directional Markers

Many construction related signs are made of some type of cloth or nylon instead of metal. These signs were not included in any sign counts. Also, metal construction signs that are located on portable stands are often leaned on their side during non-construction hours. These signs were not included in any sign counts.

Finally, street signs such as those shown in Figure 9 were also excluded from this study.

Figure 9: Street Signs

2.2.3.7 *Interstate Entrance and Exit Ramps*

The entrance and exit ramps of an interstate are considered to be part of the interstate itself but the length of each ramp is not considered to be a part of the total interstate mileage. Thus, the mileage or distance traveled on each entrance and exit ramp was not considered as additional mileage when calculating the sign density for a segment of interstate highway, and appropriately so. However, the calculation of sign densities for interstates not only depended on the number of signs located on the continuous route itself, but also on the number of signs located on the entrance and exit ramps of each interchange. These would not otherwise be included in the inventory of any other route. In other words, signs located on entrance and exit ramps will affect overall sign density, while the individual mileages of each ramp will not affect sign density.

In order to determine the total number of signs on each interstate interchange, the number of signs for each half of an interchange along the direction of travel were counted and multiplied by two. This study has assumed that each interchange has two halves, one entrance and one exit ramp in each direction of travel. However, instead of multiplying each interchange half by two, a sign density per half interchange was determined. This sign density was then multiplied by two and then multiplied by the total number of whole interchanges in North Carolina in order to determine the total number of signs located on North Carolina's interstate interchanges.

Perpendicular facing signs located on entrance and exit ramps were counted in the same manner as perpendicular signs located on the continuous interstate route. Any parallel signs that were encountered (very few) were only counted if a reasonable person would not have included them in the sign count of another intersecting road. Because interstate entrance and exit ramps contain "Wrong Way" and "Do Not Enter" signs that would not be included in any other sign count, it was also necessary to include these in the ramp counts. It should be noted that these signs face opposite to the direction being traveled, making them slightly more difficult to count.

Figure 10 shows a typical interchange for a divided interstate segment. Each interchange is considered to have two entrance and two exit ramps. When counting signs while traveling in the North direction, a total of 16 signs would be counted. This 16 is comprised of one yellow sign, two blue signs, two green signs, six red signs, and three white signs. Notice that there are only one yellow sign and three white signs counted while there are two yellow signs and four white signs that are visible. This is done because the white and yellow signs with the asterisk (*) beside them would have been included in the count of the continuous interstate segment since they are clearly visible to cars traveling on that section of highway. Also notice that the signs with gray coloring are really rear facing signs having red background colors. These are typically "Do Not Enter" and "Wrong Way" signs.

The ramp section for the southbound portion of interstate illustrates how the red background color for the typical "Do Not Enter" and "Wrong Way" signs that are located on entrance ramps can only be seen when facing the opposite direction of travel. Again, the signs with an asterisk (*) would not be included in the ramp count since they would be included in the count for the continuous interstate segment.

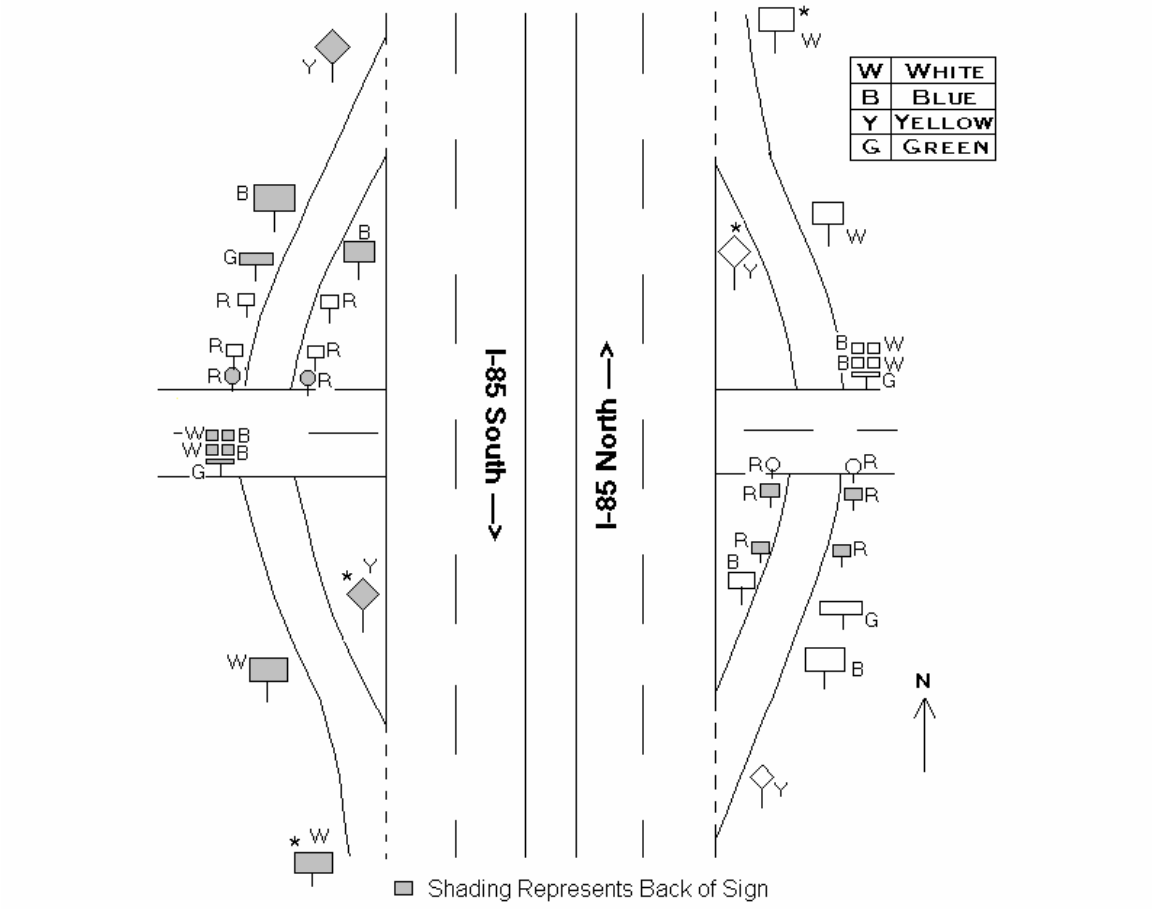


Figure 10: Interstate Entrance and Exit Ramp Signs

2.3 Assumptions, Problems, and Issues

In order to effectively count signs, a few assumptions had to be made. During the driving and counting process as well as during strategy discussions, problems were recognized that had to be addressed and solved. Some of these problems were solved immediately by the person doing the counting and later detailed in writing while others required contemplation and an educated decision. This section identifies and describes the problems encountered in the course of this study and gives an explanation of the assumptions and methodologies that were used to solve them.

2.3.1 Construction Signs

During the preliminary driving and counting stages the question of whether or not to count signs that are used during roadway and other such construction activities arose. Construction signs are usually denoted by an orange background color and are usually meant to be temporary. These signs are generally erected before a construction activity begins and they are taken down after the construction activity is finished. The length of time that these signs remain in place depends on the length of the construction activity. This may last for only a few days or up to several years depending on the complexity of the construction being undertaken.

Because of the fact that the NCDOT is ultimately responsible for the maintenance of construction signs, it was decided that all construction signs fabricated from metal and erected to face oncoming traffic would be counted. On the other hand, construction signs that are fabricated of cloth were not counted. Also, construction signs attached to temporary or portable stands or to posts that were determined to have been purposefully leaned over were not counted.

2.3.2 Sign Work In Progress

During the sign count of the interstate roads, several signs were seen being lifted into place by construction crews. That is, the signs were being erected at the time of the sign count. Those signs were included in the count. All signs seen along any highway that were obviously in the process of being erected were included in their respective sign count. The reasoning behind this decision was that these signs were, for all intents and purposes, essentially installed. However, signs that are in planning and design stages were not included in these counts. Only signs that were already in place or that were being physically installed at the time of the counting survey were included.

2.3.3 Sign Color

Signs are divided into eight major categories that are denoted by the background colors black, red, yellow, white, orange, green, blue, and brown. In general, every sign is comprised of two colors, its background color and the color of its symbol or writing. It is usually fairly easy to determine a sign's background color. However, in rare cases it is difficult to discern a sign's true background color because of an approximately equal use

of its two colors. For this reason it is necessary to state that, for the purposes of counting, a sign's background color was considered to be the color that was not used for its lettering or symbol.

The only exception to this rule is yield signs. These are considered to have a red background color. Also, note that this eliminates the counting of signs with black backgrounds since signs that technically have black backgrounds still have black lettering on top of white. Finally, in rare cases, signs with split background colors were observed. For these unusual signs, the background color was determined by the background color covering the majority of the sign. In the extremely rare case that a sign had an equally split background, the top or left background color was used for counting purposes. Examples of signs with split background colors are shown Figure 11. Picture A shows a green sign located above a sign that is half green and half brown. Since the green portion of the bottom sign covers the majority of the sign, it was counted as a green sign. Picture B shows a similar situation with a half brown and half green sign located above a hospital sign with a blue background. The top sign was counted as a green sign because it covers the majority of the sign. In the case of the dual color chevron pattern signs discussed in section 2.3.8, the background color was always considered to be yellow.

A. B.

Figure 11: Signs with Double Backgrounds

2.3.4 Rear-Facing Signs

In special cases there are signs that face opposite to the direction of travel. These signs are meant to be warning a to drivers who inadvertently steer their car in the wrong direction of traffic. These signs are generally limited to 'Do Not Enter' and 'Wrong Way' signs and are usually only found on divided highways and interstate ramps. Examples of these signs are shown in Pictures A and B of Figure 12 below.

Since it is difficult to see these signs coming up on the side of the highway that is being traveled and because it would be too dangerous to look in the rear view mirrors to count these signs, they were accounted for by counting the opposite side of the road. Rear-facing signs located on one side of a divided highway are visible to a driver traveling on the other side of the highway in the opposite direction, simplifying the counting process.

This method is satisfactory because there are generally an equal number of opposite facing signs on each side of a divided highway.

A. B.

Figure 12: Rear Facing 'Wrong Way' and 'Do Not Enter' Signs

2.3.5 Interstate Signs

Since interstate routes are continuous and without the presence of intersecting roads, all signs (both perpendicular and parallel) should be counted. The only exception to this counting procedure is that mile markers were not included in the sign counts. However, since the number of mile markers directly corresponds with the total number of miles traveled, the number of mile markers was separately determined and added to the final interstate totals.

This determination was not entirely accurate however. In rare cases, notably in mountainous regions, small segments of interstate contained half-mile markers. Because these half-mile markers were not consistently placed at every half-mile of interstate roadway, it was impossible to determine their exact number using the procedures generally followed in this study. Thus, half-mile markers were not included in, or added to, any sign counts. Due to the very small number of half-mile markers, the inaccuracy generated by their exclusion was considered to be negligible with respect to their affect on the end results of this project.

Aside from excluding half-mile markers, the sign counts of interstates followed all of the same rules for counting as were followed for the sign counts of any other roadway type.

2.3.6 Stop Signs

A 'Stop' sign represents the highest level of danger on the road and perhaps creates the greatest amount of potential liability for the NCDOT. For this reason it was decided that it would be beneficial to specifically count 'Stop' signs. As stated earlier, all other road signs were counted by their background color alone and not by sign type. The only exception to this practice was 'Stop' signs. Stop signs also were not included in the red background category; rather, they were included in their own separate category. Thus, 'Stop' signs were totaled in column 13 of Table 2 while all other signs having red backgrounds were totaled in column 12.

2.3.7 Composite/Cluster Signs

Composite or cluster signs are actually groups of individual signs that are grouped together sequentially (usually ordered from top to bottom) to create or convey a message, an order, a hierarchy, or a set of directions. In the same way that a complete sentence is created through the combination of different words, composite signs are created through the combination of different signs. A composite or cluster of signs is usually placed on the same post or on multiple connected posts. Cluster signs occur frequently along highways and are especially prevalent at junctions and intersections. Examples of cluster signs can be seen in Figure 13.

A. B. C.

Figure 13: Composite/Cluster Signs

For the purpose of completing the necessary sign counts, each individual metal sheet within a sign cluster was counted. For example, the sign cluster in Picture A of Figure 7 is constructed with two posts and connecting bars and would be counted as eight white signs and one green sign. Picture B would be counted as two green signs. The cluster or composite sign seen in the forefront of picture C of Figure 7 was placed on two posts that are connected to each other by horizontal connectors. This cluster would be counted as eight individual signs, two green signs and six white signs. Note that the yellow sign seen in the background is not part of the sign cluster because it is located on its own post in a separate physical location.

2.3.8 Guardrail Markers and Chevron Signs

Many signs seen along North Carolina's roadways have a pattern of alternating black and yellow lines, usually placed in a diagonal pattern. As can be seen in Figure 14, there are many different variations to this pattern. The most common of these signs are Patterns A and B of Figure 14.

Pattern A is a chevron and is generally found at curves in the road while Pattern B is an obstruction marker generally found at large obstructions such as bridge columns, guardrail ends, and medians. Patterns C and D are also obstruction markers but these are seen less frequently along North Carolina's highways.

Notice that each of the signs in Figure 14 has approximately equal amounts of black and yellow backgrounds. In this study these signs are always considered as having yellow backgrounds; thus, they are properly counted as yellow signs. This is logical since the yellow portion of the chevron sign is the only portion that is reflective and, therefore, of interest.

A. B. C. D.

Figure 14: Chevron and Obstruction Marker Signs

During the count of the interstate roads it was noticed that the ends of many of the guardrails found along the roadside were marked by a reflective solid yellow or alternating black and yellow pattern in the shape of a square. Examples of these reflective markers can be seen in Pictures A, B, and C of Figure 15 below. Upon close inspection of these markers, it was determined that the squares are reflective stickers that are attached to the guardrail surface. Because they are not actually metallic signs it was decided that these markers would be excluded from all sign counts.

It is important, however, to differentiate between the guardrail stickers and the rectangular obstruction markers often seen beside the ends of guardrails and in front of bridge columns. The tall rectangular chevron markers are fabricated of metal and so they are considered to be signs and were included in all sign counts.

A. B. C.

Figure 15: Reflective Guardrail Stickers

2.3.9 Covered Signs

There are some signs that are purposefully covered so that they cannot be seen or read, such as temporary construction signs that are no longer in use and permanent signs covered during construction. It is assumed that these signs will be eventually uncovered, putting them back into service and thus reestablishing NCDOT's responsibility to maintain them. Thus, these signs will be included in the highway counts if their background color can be determined by a reasonable person.

2.3.10 Bridge Markers at Underpasses

Many bridge underpasses are marked in each direction with a bridge marker (identifier) in the form of a small rectangular sign with a green background and a name or number in white font. These bridge markers are placed in front of one of the bridge columns on a metal post, directly on one of the bridge columns, or on the beam of the bridge deck overhead. However, not all bridges have bridge markers. Thus, it was not possible to determine the number of bridge marker signs simply by determining the total number of bridge underpasses in North Carolina. Thus, the bridge markers were included in the surveys and inventory conducted herein. In other words, these signs were counted as they were encountered during driving.

2.3.11 One-Way Streets

In rare cases, some primary routes are part of a system of one-way streets through urban areas. In the counting of signs, one way streets were considered to be divided highways. Thus, the rules for counting signs on a divided highway were used when counting signs on one way streets. When determining the total mileage for a route that is comprised of one-way streets, it was assumed that each direction of travel on the route was equal in distance. Thus, the total sign estimation for routes with one-way streets was determined in the same manner as all other routes.

2.3.12 Routes with Multiple Names

Some highway segments have more than one name and can sometimes constitute two different road types. For example, the highway segment from Chapel Hill to Sanford is a US Route having two different names, 15 South and 501 South. Part of this highway segment (between Pittsboro and Sanford) is also a NC Route named 87 South. Since highway segments having multiple types (like US and NC Routes in the example just given) exist throughout North Carolina, the determination of the total number of miles for each type of highway used rules of precedence in order to account for these special circumstances. The order of precedence begins with Interstates and is followed by US Routes and then by NC Routes. Thus, a highway segment that is both a US Route and a NC Route was considered to only be a US Route when calculating total highway mileages. In the same respect, a highway segment that is both an Interstate and a US Route was considered to only be an Interstate.

Since the mileage for highway segments having multiple types was only counted once using set rules of precedence, the same rules of precedence were used in the sign counting process. For example, a sign count of a segment of a highway segment that was both a US Route and a NC Route was considered to only be a US Route sign count. This procedure prevented sign densities for highway segments from being used twice in order to determine the total number of signs. In the case of highway segments having only one type but having two or more names, a decision was simply made as to which name would be used since the highway's name has no effect on final sign totals.

Note that an exception to this rule was made for the count of NC-55 between NC-27 and US-1. This route was driven before a decision concerning roads with multiple names was made. However, the small segment having multiple names (NC-55 and NC-401 that was included in the NC-55 count does not significantly affect this projects final results.

3. RESULTS, FACTS, AND FINDINGS

3.1 Interstates

The calculation of the total number of signs located on North Carolina's interstate system was completed in three steps. The first step began with the collection of data on the continuous interstate routes defined as all portions of interstate excluding entrance and exit ramps. Following this data collection, the sign density and the total number of signs were calculated for continuous interstate routes using the procedures described in Section 3.1.1 below.

The second step began with the collection of data from interstate interchanges, which were defined as the entrance and exit ramps of an interstate. This data collection was followed by the calculation of sign densities and total number of signs for the interchanges using the procedures described in Section 3.1.2 below.

The third step was to determine the total number of mile markers on North Carolina's interstates. Finally, the total number of signs for interstates was calculated by adding the continuous interstate count totals, the interchange count totals, and the mile marker total.

3.1.1 Continuous Routes

Data collection for continuous interstate routes involved counting signs on selected interstate highway segments utilizing the methodologies described earlier in this report. The sign count totals for each road location are shown in rows 3 and 4 of the 'sign colors' column in Table 9. After the desired number of interstate highway miles was counted, sign densities for each background color as well as for the combined sign total was calculated for both urban and rural areas by dividing the number of signs counted by the total number of miles traveled. These calculated sign densities are shown in rows 5 and 6 of the 'sign colors' column in Table 9.

Once the sign densities were calculated, the total number of signs in North Carolina (for each urban and rual road location) was calculated. The total number of signs of each background color was also calculated for each road location. These calculations were made using the formulas for their respective road type:

Rural Sign Totals = 2 * Total Rural Interstate Mileage * Rural Sign Density

Urban Sign Totals = 2 * Total Urban Interstate Mileage * Urban Sign Density

The calculated sign totals for each road location are shown in rows 7 and 8 of the 'sign colors' column in Table 9. (The total rural interstate mileage is multiplied by two in each formula because the sign densities are only representative of one direction of travel for the continuous interstate routes.) After the total number of signs for each road location was calculated, they were added together to determine the final total number of signs

located on the entire continuous interstate system for North Carolina. This estimate is shown in row 9 of the 'sign colors' column in Table 9.

	Road Location	Sign Colors								Total Signs
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Sign Count Totals	Rural	551	406	1149	601	257	15	0	0	2979
	Urban	331	202	733	267	57	15	0	0	1605
Sign Densities	Rural	1.17	0.87	2.45	1.28	0.55	0.03	0.00	0	6.35
	Urban	2.57	1.57	5.68	2.07	0.44	0.12	0.00	0	12.44
Estimated Sign Totals	Rural	1929	1422	4023	2104	900	53	0	0	10431
	Urban	1345	821	2978	1085	232	61	0	0	6522
2 * Sign Density * Interstate Mileage	Urban + Rural	3274	2242	7002	3189	1131	113	0	0	16953

Table 9: Final Results for Continuous Interstate Routes
(excluding interchanges and mile markers)

3.1.2 Interchanges

The data collection for interstate routes not only involved the counting of signs on selected continuous interstate segments, but it also involved the counting of signs located on selected interstate interchanges. The interstate interchange portion of the data collection was completed utilizing the methodology described in Section 2.2.3.7.

After sign counts for the desired number of entrance and exit ramps were completed, an average sign density per entrance and exit ramp combination, for each sign background color, and for the total signs (for each urban and rural interchange location), was calculated. These average sign densities were multiplied by two and then multiplied by the total number of interchanges (for their respective urban and rural road locations) in order to determine the total number of signs.

Table 10 summarizes the sign counts for each entrance and exit ramp combination in one direction of travel. Columns 1-3 give the road name, road location (urban/rural), and collection date respectively. Columns 4-11 give the total number of signs of each respective color that were counted for each interchange. The last column gives the sign total for all colors at each half interchange for all 41 half interchanges.

The bottom row of the spreadsheet totals the signs for all half interchanges and shows the calculated number of signs per exit for each color. The total numbers of signs for all half interchanges are shown first. The number of signs per interchange is shown next and was obtained by multiplying the total number of signs per half interchange by two to get the entire interchange and then dividing by 41 to get a single interchange. Then the total number of signs in NC was obtained by multiplying the signs per interchange by the total number of interchanges (347) in NC.

	Sign Color								Sign Totals
	Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Total Signs (41 Half Interchanges)	118	41	53	200	32	3	140	41	628
Signs Per Interchange	5.76	2.00	2.59	9.76	1.56	0.15	6.83	2.00	30.36
Total Signs (All NC Interchanges)	1997	694	897	3385	542	51	2370	694	10630

Table 10: Final Results for Interstate Interchanges

3.1.3 Mile Markers

Since the mile markers were not included in the continuous interstate route counts, the number of mile markers must be determined by mileage alone. It is assumed that there is a mile marker at every mile of interstate. Thus, since there are 1,083 miles of interstate, then 1,083 green signs must be added to the final interstate sign total.

3.1.4 Interstate Totals

Table 11 shows the final interstate sign count results for each interstate portion (continuous route, mile markers, and interchanges) as well as for the combined interstate portions. Column 2 contains the road location while columns 3-10 show the final results by sign color. Column 11 shows the totals for each highway portion and road location combination. A subtotal for each sign color and road location for the continuous routes and mile markers is shown in row 4. The total number of signs for each color is shown for the combined road locations in the last row.

	Road Location	Sign Colors								Totals
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Continuous Routes	Rural	1929	1422	4023	2104	900	53	0	0	10431
	Urban	1345	821	2978	1085	232	61	0	0	6522
Mile Markers	Rural	0	0	821	0	0	0	0	0	821
	Urban	0	0	262	0	0	0	0	0	262
Subtotal	Rural	1929	1422	4844	2104	900	53	0	0	11252
	Urban	1345	821	3240	1085	232	61	0	0	6784
Interchanges	Rural + Urban	1997	694	897	3385	542	51	2370	694	10630
Total Signs	Rural + Urban	5271	2936	8982	6574	1673	164	2370	694	28666

Table 11: Final Interstate Results

3.2 US Routes

The calculation of the total number of signs located on North Carolina's US Routes was completed in the same manner as that for the continuous interstate highway system. The data collection for the US Routes also involved counting signs on selected US highway segments. After the desired number of US Route miles was counted, sign densities for each background color as well as for the combined sign total was calculated for both urban and rural areas for each highway type (divided or undivided). These densities were obtained by dividing the number of signs counted by the total number of miles traveled.

The total number of signs (for each color, for total signs, and for each urban and rural road location) was then calculated using the same formulas discussed in Section 3.1.1. The sign totals for the urban and rural locations were then added together to determine the final estimate for the total number of signs located along North Carolina's US Routes. Tables 12 and 13 display the final results for undivided and divided US Routes respectively. These tables were created in the same manner (and have the same format) as Table 9 described in Section 3.1.1.

	Road Location	Sign Colors								Total Signs
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Sign Count Totals	Rural	214	831	329	1774	57	16	8	0	3229
	Urban	313	365	348	2313	63	43	11	0	3542
Sign Densities	Rural	0.66	2.57	1.02	5.48	0.18	0.05	0.02	0	9.98
	Urban	2.74	3.25	3.11	20.08	0.65	0.37	0.11	0	3.30
Estimated Sign Totals	Rural	4005	15552	6157	33201	1067	299	150	0	60432
	Urban	4918	5735	5468	36340	990	676	173	0	54174
2 * Sign Density * US-route Mileage	Urban + Rural	8923	21287	11625	69541	2057	975	323	0	114606

Table 12: Final Results for Undivided US Routes

	Road Location	Sign Colors								Total Signs
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Sign Count Totals	Rural	70	477	238	1178	60	24	766	0	2813
	Urban	122	315	278	1459	71	17	292	3	2559
Sign Densities	Rural	0.43	2.93	1.46	7.24	0.37	0.15	4.71	0.00	17.29
	Urban	1.73	4.46	3.93	20.64	1.00	0.27	4.13	0.04	36.20
Estimated Sign Totals	Rural	990	6743	3365	16654	848	339	10829	0	39768
	Urban	1248	3221	2843	14921	726	174	2986	31	26150
2 * Sign Density * US-route Mileage	Urban + Rural	2237	9965	6208	31575	1574	513	13815	31	65918

Table 13: Final Results for Divided US Routes

3.3 NC Routes

The calculation of the total number of signs located on North Carolina's NC Routes was completed using the same procedures used for the US Routes discussed in Section 3.2. Tables 14 and 15 display the final results for undivided and divided NC Routes

respectively. These tables were also created in the same manner (and have the same format) as Table 9 described in Section 3.1.1.

	Road Location	Sign Colors								Total Signs
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Sign Count Totals	Rural	63	1022	233	1520	79	34	3	20	2974
	Urban	193	313	86	972	49	12	9	0	1634
Sign Densities	Rural	0.18	2.89	0.66	4.30	0.22	0.10	0.01	0.06	8.41
	Urban	3.32	5.38	1.48	16.70	0.84	0.21	0.15	0.00	28.08
Estimated Sign Totals	Rural	2417	39213	8940	58321	3031	1305	115	767	114110
	Urban	6815	11052	3037	34321	1730	424	318	0	57696
2 * Sign Density * NC-route Mileage	Urban + Rural	9232	50265	11977	92643	4761	1728	433	767	171807

Table 14: Final Results for Undivided NC Routes

	Road Location	Sign Colors								Total Signs
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Sign Count Totals	Rural	0	15	3	44	0	0	20	1	83
	Urban	29	82	8	159	12	4	47	0	341
Sign Densities	Rural	0.00	2.78	0.56	8.15	0.00	0.00	3.70	0.19	15.37
	Urban	4.60	13.02	1.27	25.24	1.90	0.63	7.46	0.00	54.13
Estimated Sign Totals	Rural	0	841	168	2466	0	0	1121	56	4651
	Urban	1039	2939	287	5699	430	143	1685	0	12223
2 * Sign Density * NC-route Mileage	Urban + Rural	1039	3780	455	8165	430	143	2805	56	16874

Table 15: Final Results for Divided NC Routes

3.4 Sign Totals

Table 16 below summarizes the final estimations for the number of road signs in North Carolina.

	Road Location	Sign Colors								Totals
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Interstates	Rural	1929	1422	4844	2104	900	53	0	0	11252
	Urban	1345	821	3240	1085	232	61	0	0	6784
US Routes	Rural	4995	22296	9522	49855	1915	639	10979	0	100200
	Urban	6165	8956	8311	51261	1716	849	3159	31	80448
NC Routes	Rural	2417	40053	9108	60785	3031	1305	1235	823	118758
	Urban	7804	13849	3310	39745	2140	560	1921	0	69328
Final Totals For All Primary Routes	Rural	9341	63771	23474	112744	5846	1996	12214	823	230210
	Urban	15314	23626	14861	92091	4087	1471	5080	31	156560
	Rural + Urban	24656	87397	38335	204835	9933	3466	17294	854	386770

Table 16: Estimated Total Number of Primary Road Signs in North Carolina

4. CONCLUSIONS

The estimation of the number of road signs in North Carolina was found to be much more difficult than initially thought. In the beginning, the task at hand seemed to be very straightforward and easy to accomplish. This was not the case however. After preliminary counts were conducted, many situations and problems were encountered and needed solving. Solving these problems required critical thinking and a rational approach.

Despite these difficulties, a reasonable estimation was able to be made using the methodologies, assumptions, and rules for counting signs that were set forth herein. This project has presented these methodologies, assumptions, and rules in detail and for good reason. Without them, it would be impossible to arrive at an accurate estimate of the total number of road signs in North Carolina that are located on it's primary routes.

Although the results presented in this report are acceptable, more work still needs to be done in order to achieve a more complete estimation of the total number of signs. The work that is still needed should be in the form of both extensions and improvements, which are being completed in another project (Source 4). Extensions to this project will be in the form of rules and methodologies for the estimation of the number of road signs located on North Carolina's secondary highway system. Improvements to the work undertaken here will include the addition of rest areas and truck sign counts as well as any other items that might provide a more rigorous study.

Table 15 provides interesting insight with respect to the study results. We see that overall there are nearly 390,000 primary signs. Of these there are approximately 230,000 rural (60%) and 160,000 urban (40%) signs. Another breakdown is approximately 18,000 interstate signs (5%), 180,000 US signs (45%), and 190,000 NC signs (50%). Also, by far, the greatest number of any sign is white signs at approximately 205,000 (53%) in number.

Particularly of interest with regard to safety, there are only 854 'Stop' signs. This is a surprisingly low number that represents only 2 tenths of a percent of the total. No color has such a low number of signs. Furthermore, 96% of these (823) are rural! This raises two things. First, many of the remaining 'Stop' signs are expected to be on secondary roads. This will be explained in the subsequent study. But even more important, most of the 'Stop' sings are on city streets. This means retroreflectivity standards will have a far greater impact on cities and towns than in the State!

Of the colors of particular interest, red signs represent approximately 17,000 (4%) and yellow signs 87,000 (22%) out of the 390,000 total. Strictly speaking then, if the NCDOT were to focus on 'Stop,' red, and yellow signs it would be concerned with approximately 105,000 signs (or about 25% of the total) statewide.

5. RECOMMENDATIONS

The scope of this project did not include sign counts of rest areas and truck weigh stations that are found along North Carolina's highways. However, these specialized areas are assumed to have many road signs that are maintained by the NCDOT. Thus, in order to get a more complete estimate for the number of signs located in North Carolina and maintained by the NCDOT, the signs located in these areas should be included in the final North Carolina sign total estimates. (This is being accomplished in another study [Source 5]).

Although this project included the signs located on interstate entrance and exit ramps, it did not include signs located on US Route entrance and exit ramps. Sign densities for interstate interchanges are very easily counted because of their large numbers and close proximity to each other. Also, the total number of interstate interchanges can be determined from the North Carolina State Transportation Map. The number of interchanges that are located on US Routes, however, cannot be determined from the State Transportation Map and they are located much more sporadically and in much smaller numbers than interstate interchanges. These differences require a much larger investment of time in order to accurately estimate the number of signs located on US Route interchanges. Therefore, due to time restrictions on this project, it was not possible to determine sign densities for US Route interchanges and include their signs in the sign totals of this project.

In the estimation of the total number of signs located on US Routes, a distinction was not made between roadway segments that have fully controlled access and segments that do not fully controlled access. Highway segments that do not have fully controlled access contain a lot of 'Wrong Way' and 'Do Not Enter' signs that are not generally found on fully controlled segments. A segment of a US Route that has fully controlled access will probably have a smaller sign density than a segment of a US Route that does not have fully controlled access. It is therefore recommended that the sign counts be further divided between highway segments that have fully controlled access and those that do not.

Since the sign counts were mostly done within the regions bounded by Charlotte and Wilmington, it is recommended that future sample sign counts be done in the mountainous regions of North Carolina. These sample counts and the corresponding sign densities should then be compared to the sign count results presented in this paper. If a large difference is found, then it will be necessary to rethink the route selection process and to make an adjustment to the final results of this paper. However, if there is very little difference between the sample results and the results presented in this report, further validation will be given to the results of this report.

6. REFERENCES

Source 1: **http://www.mccormicktaylor.com/glossary.htm**

Source 2: Highway and Road Mileage. North Carolina Department of Transportation. Division of Highways. Geographic Information Systems Unit. P.O Box 25201, Raleigh, NC 27611. In Cooperation With the U.S. Department of Transportation Federal Highway Administration.

Source 3: Traffic Signing Handbook. Institute of Transportation Engineers. Washington, D.C. 1997

Source 4: 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.

Source 5: 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

7. APPENDICES

Appendix A: Sign Count Summarization Tables for Road Segment Categories and Combinations

Appendix B: Summary of Roads Counted

Appendix C: Interstate Sign Count Tabulation Tables

Appendix D: Interstate Interchange Counts

Appendix E: US Routes Sign Count Tabulation Tables

Appendix F: NC Routes Sign Count Tabulation Tables

Appendix A

Summary of Roads Counted

The following table was created using Microsoft Excel. It lists all of the highway segments by type that were counted and shows the total number of miles that were counted for each type and location combination for each respective segment. Column one gives the road name and is divided into sections for each highway type. The columns to the right of column show the mile totals for divided and undivided highways segments in both urban and rural areas. The totals for each road type are displayed in the last row of each road type section.

Appendix B

Sign Count Summarization Tables for Road Segment Categories and Combinations

The following tables were created using Microsoft Excel. Table B1 summarizes the results for each sign count and calculates the sign densities and total miles that have been counted. Columns one through three define the road segment combination. Columns 4 through 7 show the count numbers with their respective mileages, number of signs, and calculated sign density. Columns 8 through 10 show the cumulative mileages, sign totals, and sign density.

The top portion of Table B2 summarizes the sign count results by sign color and for each count's respective road segment combination while the bottom portion of Table B2 summarizes the sign count totals and calculated sign densities by background color for the combined counts and shows the final calculated sign totals for all of North Carolina by background color. Columns 1-3 define the road segment combination. Columns 4 and 5 show the sign count number and the miles traveled for that count number respectively. Columns 6-13 give the sign totals for each background color while column 14 shows the total number of signs for each sign count. Note that the interstate results account for only the signs along the continuous route and do not include the interchanges signs.

Tables B3 and B6 relate to US and NC route sign counts respectively and have the same format as Table B1. Tables B4 and B7 relate to undivided US and NC route sign counts respectively and have the same format as Table B2. Tables B5 and B8 related to divided US and NC route sign counts respectively and also have the same format at Table B2.

Appendix C

Interstate Sign Count Tabulation Tables

These tables were created using Microsoft Excel. The tables summarize the sign counts for each individual interstate highway segment that was counted. The upper left half of each sign count conveys the information and details pertaining to the sign count. This information and detail include the count number, date of count, name of highway segment, highway type, highway location, total miles counted, and total signs counted. A geographic description describing the beginning and ending of the sign count is displayed in the upper right half of the table. Note that the interstate results account for only the signs along the continuous route and do not include the interchanges signs.

The lower half of the table shows the number of each color of sign counted. The first column of the lower half of the table shows the interstate mileposts for which each row of values pertains to. This column was also used to determine the total number of miles that were traveled instead of using starting and ending odometer readings. The last row of each table tabulates the total number of each color of sign counted.

Note that Tables C1 and C2 are identical to Tables B1 and B2 respectively. They are provided here to allow for easier referencing.

Appendix D

Interstate Interchange Sign Count Summarization Table

This table was created using Microsoft Excel. It summarizes the sign counts for each entrance and exit ramp combination in one direction of travel (half interchange). Columns 1-3 give the road name, road location (urban/rural), and collection date respectively. Columns 4-11 give the total number of signs of each respective color that were counted for each half interchange. The last column gives the sign total for all colors at each half interchange for all 41 half interchanges.

The bottom row of the spreadsheet totals the signs for all half interchanges and shows the calculated number of signs per exit for each color. The total numbers of signs for all half interchanges are shown first. The number of signs per interchange is shown next and was obtained by multiplying the total number of signs per half interchange by two to get the entire interchange and then dividing by 41 to get a single interchange. Then the total number of signs in NC was obtained by multiplying the signs per interchange by the total number of interchanges (347) in NC.

Appendix E

US Routes Sign Count Tabulation Tables

These tables were created using Microsoft Excel. These tables are very similar to the tables described in Appendix C. The only differences between the tables are the geographic description the first column of the lower half of the table and the addition of a road characteristic description to the information and detail section. The geographic description for these tables is meant to allow the reader to determine exactly where the sign count for the given highway segment, type, and location is located. It also allows for a reproduction and verification of the sign count data.

Since there are generally not highway mileposts on US and NC routes, it is only possible to show the total number of signs of each color that were counted. Unlike the interstate mileage calculation, the number of miles that were traveled for a US route highway segment was calculated by taking the difference between a starting and ending odometer reading of each sign count.

Note that Tables E1, E2, and E3 are identical to Tables B3, B4, and B5 respectively. They are provided here to allow for easier referencing.

Appendix F

NC Routes Sign Count Tabulation Tables

These tables were created using Microsoft Excel. They are exactly the same tables as described in Appendix D. Note that Tables F1, F2 and F3 are identical to Tables B6, B7, and B8 respectively. They are provided here to allow for easier referencing.