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A Proposed Sign Managemnt System for the South Carolina Department of Transportation

Research Report Volume I: Bar Code Application Pilot Projects

Mozart Menezes,
Bob Blackmon
and
Lansford Bell

Department of Civil Engineering
Clemson University
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16. Abstract

An investigation was performed for the South Carolina Department of Transportation (SCDOT) to evaluate and recommend a sign management system. System parameters established by SCDOT included the ability of the system to interact with state-of-the-art data management technologies, including bar coding, voice recognition, global positioning systems (GPS), geographic information systems (GIS), and digital photography. A commercial sign management system was selected and a number of data management technologies were incorporated into a demonstration system that utilized inventory and inspection data for 185 highway signs in Anderson County, SC. The GPS/GIS interface permitted computer generation of sign data displays overlaid on highway maps, which was determined to be a very powerful management tool. Bar code technology was judged to be an effective means of loading sign characteristic data into the inventory and inspection data file before sign installation.

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INTRODUCTION

SCDOT Sign Management

Highway traffic signs represent a major annual investment of public funds. The investment includes acquiring new signs, maintaining sign production facilities and sign inventories, providing trucks and personnel to maintain adequate signage on highways, providing signs for new roadways, and meeting legal challenges concerning liability in traffic accidents. Inventories are maintained by the South Carolina Department of Transportation (SCDOT) at regional sign shops to meet demands from District sign shops and at District sign shops to meet the daily demand for new and replacement signs. District sign shops are staffed with crews responsible for installing, inspecting, cleaning, and replacing signs within that District's area. The state-wide system is estimated to contain over 500,000 signs on all state maintained highways.

During the 10 May 1995 Workshop sponsored by SCDOT and Clemson University on the use of bar code technology, participants identified management of highway signs as a major problem that could be addressed using bar code technology. Applications discussed included inventory control, maintenance records, and information needed for management decisions.

In the current economic conditions of reducing operating cost and making optimum use of both human and financial resources, SCDOT management realized that the tools needed to improve management of this major investment did not exist. A research contract was awarded to demonstrate the use of bar code technology as a part of a sign management system. The research project scope was later altered for the selection or development of a sign management system that utilized other data acquisition technologies.

At the time the research contract was awarded, signs were being managed on the basis of traditional practice with little data on installed signs or statistical data generally needed for decision making. Deteriorated signs were identified for replacement based on an annual visual night inspection by district personnel using subjective criteria. Records pertaining to installed signs were manually maintained on card stock in District sign shops and only included the sign code and location of each installed sign. Managers depended on institutional knowledge to make several types of decisions. Information was not available to forecast future requirements and plans were limited to very short time horizons. Several different types of films are bonded to sign blanks but no performance data are collected to guide future decisions. Statistical questions such as how many signs are currently in use, how many signs of a particular type are currently in use, what is the approximate useful life of each type of sign, and does the useful life of a sign vary by geographical region within the state cannot be addressed. The federal government is currently in the process of developing standards for reflectivity of traffic signs, however, little information is available on the reflectivity of the currently installed sign inventory. No estimates can be made on the potential impact of the new federal standards on the state inventory.

SCDOT is not unique in searching for a better method for managing their traffic signs. Some state DOTs have adopted a commercially available computer-based management system while others have turned to consultants for development of a state-unique system. A few states collect data in database applications such as FoxPro or dBASE for future analyses. Generally state DOTs are slowly integrating computer technology to improve management activities.

Research Objectives

The primary objective of the research described herein was to develop or select a computer based sign management system for the SCDOT. A secondary objective was to integrate various state-of-art technologies into the system that would enhance data collection and system utilization. These technologies included bar coding, global positioning systems (GPS), voice recognition, and geographic information system (GIS). When integrated into the sign management system, these technologies will serve as demonstration projects for other possible applications of the technologies within SCDOT.

Research Methodology Overview

The research began with the definition of the main data elements to be controlled by the system through consecutive meetings between Clemson University representatives and SCDOT personnel. These parameters are data elements that define the physical characteristics of a sign, its location, condition, and installation and inspection history. Later, after additional discussions, new parameters were added to the list, others were deleted.

The next step was to define a set of requirements needed for a computer based system. These requirements are related to system data management capabilities, flexibility, connectivity, and user interface. Again, meetings involving several levels of SCDOT personnel provided sufficient data to formulate a list of system requirements.

Clemson University researchers then compared the system requirements to the capabilities provided by various commercial software packages. The option of developing a custom system using Clemson University and SCDOT resources was also considered.

After selecting a commercial software package, a pilot test was executed in an area defined by the SCDOT. The area chosen was located in Anderson County. Sign inspection data conforming to SCDOT requirements were obtained and analyzed for 185 signs.

A workshop was held at Clemson University to demonstrate the commercial package and related technologies. After the workshop, another evaluation was made to incorporate some of the attendees expectations, i.e. the need for system data security. The research methodology is described in more detail in Chapter III.

Report Organization

The data management technologies investigated as part of the research are summarized in Chapter II. System development and system utilization are addressed in Chapters III and IV respectively. Guidelines for system implementation are presented in Chapter V, and general conclusions summarizing anticipated system benefits are discussed in Chapter VI.

Chapter II

DATA MANAGEMENT TECHNOLOGIES

Bar Code Technology

Discussion

Bar code technology is a mature technology widely used in industry for inventory control, part identification, etc. Over the past few years bar code readers have become sophisticated and are now capable of supporting keyboard operations on the reader and communication by wire or RF signal. Bar codes consist of a sequence of lines and spaces of varying width conforming to one of the industry standards. Bar codes facilitate accurate data collection and transmission without human intervention, significantly reducing the possibility of recording errors.

Analysis

Bar coding could strongly support inventory control in both the regional and district sign shops. The use of bar code readers in the field by the sign crew while performing inspection operations is questionable. Crews should be able to access sign information by providing location data rather than leaving the truck to visually read the sign's identification number. During the initial data base loading, crews will be placing labels on the signs which can be read without the use of a scanner. Scanners may be useful in situations where the sign label is too high above the ground for convenient reading or the human readable text on the label becomes unreadable due to weathering or other causes. The scanner demonstrated in the project workshops included a keyboard and large memory card. With limited possible uses for bar code scanners in the field, a much less expensive scanner tied directly to a laptop computer would be adequate.

The use of bar codes is particularly helpful when used for very repetitive readings in a small amount of time (situation usually encountered in grocery stores), or in situations where the manual typing could generate inaccuracy of the information due to a large quantity of characters being typed. For the purpose of this study, it was decided that bar code scanners were not an essential part of the hardware needed by the sign inspection crew. This technology should be however, considered for inventory control within the sign shops and system initiation. Specific recommendations and a discussion of bar code reader software developed as part of the research are discussed in Chapter IV.

Global Positioning System - GPS

A GPS receiver is a small hand held device capable of reading information from GPS satellites that repeat the same ground track as the earth turns beneath them. The received information provides a basis for determining the latitude and longitude of the receiver.

The set of satellites provides the system user with at least 5 signals, which can be up to 8 signals visible from any point of the earth. The reader selects 3 signals to determine longitude and latitude if the readings are in a known altitude, or 4 signals to determine three position dimensions and time. The result is converted to latitude, longitude, altitude, and time.

Five or more satellites signals can be used to determine position. That provides more accuracy and sufficient information to detect out-of-tolerance signals.

According with Peter H. Dana in "The Geographer's Craft Project", a publication of the Department of Geography, University of Texas at Austin, there are 24 GPS satellites, 21 of which are fully operational and 3 functioning as spare satellites. They are controlled by the U. S. Department of Defense (DOD), which provides two services as follows:

1. Precise Positioning System (PPS): This system is used by U. S. and Allied military and U. S. Government agencies. It has a predictable accuracy of 22 meters horizontal accuracy.
2. Standard Positioning System (SPS): This system is an intentionally corrupted signal that increase the error possibilities generating a predictable horizontal accuracy of 100 meters

The SCDOT will probably have access only to the SPS service, therefore the sign location error can be up to 100 meters from a precise location.

There is a way of getting a more precise reading from the GPS receiver through the use of the Differential GPS (DGPS) Techniques. This technique consists of using a base station to correct these errors, and can be provided by different sources such as Coast Guard radiobeacons, private DGPS services using FM broadcasts, and others. Another way of correcting the readings is post processing. Public agencies record DGPS corrections for distribution. This type of correction may not be appropriate for this application since it requires complex manipulation of satellite position data.

Using DGPS, in a SPS service, the accuracy is usually between 1 and 10 meters. Since the objective of this system is to have the whole image of the signs in a area using

GIS software, this accuracy is more than necessary. For exact location purposes the system records distances from nodes, the sign position, and the offset.

GPS accuracy can be as low as 1mm, but the costs are directly proportional to the accuracy. As the accuracy improves equipment costs are higher. The GPS receiver used in the pilot test cost between $300 and $500. But costs can exceed $40,000 if a very highly accurate device is required.

Voice Recognition System

Voice recognition technology is the technology by which sounds, words or phrases spoken by humans are converted into electrical signals, and these signals are transformed into coding patterns to which meaning has been assigned.

Computer capabilities and current voice recognition technology has made it feasible to provide a wide range of voice recognition software, with variation in vocabularies of 30,000 to 60,000 words, with an accuracy over 90%. Inexpensive software currently available can recognize up to 60 words per minute.

Voice recognition technologies are classified by their capabilities of recognizing a single person's voice or any person's voice without training (speaker dependent vs. speaker independent); and by the capability of recognizing the voice in a normal rate of a normal speech against the need to speak with a pause between words (continuous speech vs. discrete speech).

Currently, only one software package on the market is capable of recognizing truly continuous speech. In all others, the pause between words does not have to be long but it must exist. This is not a major concern when using the software to give commands to the computer, but can be frustrating when dictating to word processor software.

Usually the most advanced software in this area is speaker dependent, although there are numerous applications of the speaker independent mode, i.e. telephone companies use it to find telephone numbers when using operator assistance.

The term speaker dependent implies that the user must interact with the software over a period of time so the unique voice characteristics of the user will be recognized. However, multiple users can utilize a given software package.

Voice recognition technology is well suited to capturing sign inventory and inspections data because data entry consists of a small vocabulary of key words and numbers. Applications that utilize a limited vocabulary do not require extensive operator training periods of time.

Geographic Information System - GIS

GIS is a set of new technologies grouped to provide data for decision making based on graphical representations linked to a spatial reference. It uses, as a rule, all decision making techniques such as regression analysis, modeling, and database queries to generate reports. GIS is also capable of utilizing data generated by other technologies such as aerial photographs, satellite images, computer aided design systems and digital maps.

There are many GIS software packages on the market. For example, there is ARC/Info produced by ESRI, the Intergraph Corporation's MGE/BGA system and others. These two GIS packages can be directly connected to the selected sign management system. In this project, the sign management software was tested with ArcView, a subset of Arc/Info. This project used digital maps and collected data from the Anderson County test site to demonstrate system capability.

GIS software could enable SCDOT management to investigate highway traffic control devices with relation to geographical features, population centers, traffic patterns, or other dynamic characteristics. For example, a film supplier discovers that a batch of his products is inferior and will have a shorter life than expected. Using GIS and the sign system database, managers could quickly locate all signs made with inferior film, schedule their early replacement, and plot a map of the signs to simplify sign crew activities. Managers, using GIS through a simple query, could display on a road map all of the speed limit signs, the distance between signs, the road speed limit, the constraints (i.e., intersections, schools, etc.) and all other information needed for an informed decision.

The major use of GIS will be in macro analysis of the highway signs. If a more accurate representation of sign locations is needed, the data base includes distance between signs and reference points, position on the road, travel direction, and offset which could be used to manually draw the required map.

Retroreflectivity

During the May 1997 workshop two retroreflectivity devices were demonstrated one from Advanced Retro Technology (ART), currently available to SCDOT personnel, and a new Delta unit. Comparative readings were taken on a new stop sign and on a badly deteriorated stop sign. Much of the red ink area was missing on the deteriorated sign but the reflectivity film appeared to be in good condition. The retroreflectometers determined that both signs produced the same readings when a sample of the white area was tested. These results opened a discussion on several issues concerning how should reflectivity readings be utilized within a sign management system. The major issues are listed below:

1. If signs were evaluated primarily on reflectivity, the deteriorated sign would not have been replaced. How important is the overall appearance of the sign ?

2. Tests were performed on stop signs which drivers should be able to recognize by its unique shape. Should there be different replacement criteria for easily recognized signs as compared to generally rectangular or circular signs ?

3. Manufacturers recommend taking several readings and then using an average to rate the overall sign. If this approach is used, what should be the ratio between the white and red areas of the stop signs ?

4. The proposed sign inventory system database provides two fields for retroreflectivity values which can be used to record the last and the current readings. What retroreflectivity information would be most useful in the replacement decision ? Or should those fields be used for recording different areas results from the same sign ?

There appears to be a need for a comprehensive sign replacement criteria for field implementation. If the sign is physically acceptable and there is a noticeable decrease each year in the average retroreflectivity values, at what point does the sign become unacceptable and a candidate for replacement. If the rate of deterioration were known, sign replacement could be predicted for the purpose of maintaining inventory but actual replacement could still be controlled by the criteria.

There appears to be a need for establishing the rate of sign deterioration by film type due to the various environmental conditions within the State. Some preliminary data could be collected by measuring retroreflectivity of signs of known film type and age from various locations in the State. Long term evaluation would require identification of groups of signs in each type of environment in the State and collecting annual performance data. Such a testing program would either set deterioration rates for State signs or confirm weather data generated by the film manufacturers. Very little is currently known about the retroreflectivity of highway signs and the centerline markers on highways being maintained by the SCDOT.

The Federal Highway Administration (FHWA) agency has an on-going project related to reflectivity of highway signs. The project is divided in two parts: evaluation of retroreflectometer equipment for measuring the nighttime visibility of signs, and evaluation of the feasibility of establishing guidelines and their impact on the maintenance operation of state and local highway agencies. According to the FHWA WEB page "The result of this project should establish appropriate retroreflection guidelines for signs and pavement markings. The guidelines will help state and local highway agencies identify and determine when signs and pavement markings have reached the end of their useful life and need to be refurbished." These guidelines will establish a minimum retroreflectivity value for highway signs. SCDOT generally specifies the use of engineer grade film which is the least expensive and incorporates a minimum level of retroreflectivity. It now appears that the new federal guideline will require a retroreflectivity that will exceed the properties of the engineer film, even when new, and the super engineer grade film will become standard. Super engineer films are currently on the market but they are more costly than the engineer grade. Publication of new federal standards may result in a major effort to determine retroreflectivity of existing signs and upgrade of highway signs across the State.

Retroreflection measuring equipment available in the market varies from small hand-held units to a complete mobile system developed for the FHWA. These units measure the retroreflection of the signs by reading the coefficient of retroreflected luminance. The reading result is related to the nighttime brightness of a sign.

Digital Photographic Camera

Digital cameras record images in digital form and store them on memory cards rather than exposing film as with conventional cameras. Digital images may be transferred into a computer for use in a variety of applications or used to produce prints or slides.

The major advantages of digital cameras includes elimination of conventional photographic steps in developing, printing, and digitizing images; consumption of film and print materials; a large number of images may be stored in the memory cards. The cards are erasable and reusable. Additional memory cards may be purchased to increase capacity of the camera. Images may be reviewed in the field and unacceptable images immediately replaced. Digital images may be incorporated into other software packages or used to produce hard copy prints or slides.

The disadvantages of digital camera systems include a lower image resolution than photographic images. The more expensive cameras have higher resolutions making it possible to approximate conventional print resolution. If the camera is intended primarily for storing highway pictures in the sign management system, the low resolution of the images does not present a problem. Digitized images can however, consume a large amount of hard disk space on a computer and should be limited to critical sign locations or for temporary illustrations.

Chapter III

SYSTEM DEVELOPMENT

System parameters

Sign inventory data elements or system parameters were developed through a series of meetings with SCDOT personnel. During the Fall of 1996, Mr. Gant Taylor, Clemson University established contact with personnel from the SCDOT Headquarters, Columbia, and the Anderson County District Office. Through this effort an initial list of system parameters was developed for the proposed system and an area of Anderson County was designated for sign data collection and prototype testing. During the course of the research the parameters evolved to those listed in Figure 1. Responsibilities for the project were transferred to Mr. Mozart Menezes in December 1996 for execution and completion.

System Requirements

On 18 December 1996, a meeting was held with SCDOT maintenance personnel to establish a set of overall system requirements. As a result of this meeting and subsequent discussions it was decided that all signs will be given a unique bar coded label for identification. The code will not include any other intelligence other than the identification number. All related data on a particular sign can be easily accessed in the management system. The assigned identification number will allow tracking the sign through its useful life.

Parameters List

The following are the basic parameters that should be recorded during sign maintenance activities.

Parameter:	(*value*) a brief description of the parameter.
***Crew:**	(name) the name of the crew members.
Activity:	(type of activity) description of what was done.
Activity Date:	(Date & Time) date that the activity began.
Reason:	(Routine, Stolen...) reasons for why the activity was needed.
Last Activity:	(Date) date when the last activity occurred in that sign.
Installation:	(Date) date of the sign installation.
Removal:	(Date) date of sign removal.
Sign number:	(number) the unique number on the label.
MUTCD Code:	(alphanumeric) the sign code as defined in the MUTCD.
Size:	(alpha) sign size in inches.
Route:	(name) route identification number or name.
Intersection:	(name) name or number of a intersection to be used as reference.
Travel Direction:	(N,S,E,W) direction of the traffic flow.
Mile Marker:	(miles) the last mile marker number (expressed as MM number plus distance to location). It gives the approximate location.
Distance Back:	(miles) distance to the last reference point.
Sign Direction:	(N,S,E,W) direction the sign is facing.
Position:	(Left, Right, Overhead...) position related to the road flow.
Height:	(number) the distance from the ground to the sign bottom edge.
Visibility:	(Reference Code), the sign visibility from the driver's view.
Sign Rating:	(Reference Code) overall current condition of the sign.
****Reflectivity:**	(good, fair , poor) pertaining to the sign's reflective visibility at night.
Offset:	(feet) distance of support from the edge of asphalt pavement.
Observations:	(general information) this field should exist for each sign and each activity.
Latitude:	(degrees, minutes, seconds) GPS coordinate of the sign.
Longitude:	(degrees, minutes, seconds) GPS coordinate of the sign.
***Warehouse:**	(name) name of the warehouse the sign is stored before installation.
***Manufacturing:**	(Date) date the sign was manufactured.

** These field requirements were added later, after understanding all capabilities available in a computer inventory system.*
*** Reflectivity: Later in the research it was agreed to replace the codes good, fair and poor, by a reading using a retroreflectometer.*

Figure 1. Parameters for SCDOT Sign Maintenance System

The regional sign shops will affix the labels to new signs and record initial information in the data base including type of ink used, type of metal, and type of sheeting. Data base information can be easily transferred from the regional sign shop to the district sign shop as the sign inventory is distributed among the district shops.

District sign crews should be able to use the system to identify missing signs in the field (type and location) for immediate replacement. Crews should be able to display a list of signs and locations in the system during the field inspection. Data and time should be recorded for the discovery of missing signs. Installation of replacement signs should also be recorded in terms of date and time. Common signs could be replaced from the inventory on the truck.

Sign data should be retrievable from the data base by inputting sign location or number. The data base could provide information for determining average age of signs and durability of sheeting.

The full district data base should be accessible by the sign crews in the field rather than selected parts based on daily work assignments. This capability will require that sign crews be equipped with a laptop computer.

Requirements Approval

On 4 February 1997 a meeting was held with SCDOT maintenance personnel to review a draft paper, "Sign Management System: System Requirements". The requirements were approved with additional capabilities suggested.

Sign inventory records will be maintained on the stock in the district sign room but not of the signs on the truck. Each day, the sign room inventory will be decremented as signs are provided to the sign crews. Signs removed from service are returned to the district sign shop and either recycled or sold for scrap. There needs to be a sign rating system that could be used to record sign condition as signs are cleaned and/or inspected. The rating system should consider physical condition as well as reflectivity. The state needs to develop an objective method for evaluating signs rather than using subjective night inspections.

Signs for district sign shops are only ordered to fill near term needs. They do not have the statistics needed to predict requirements for new signs. Signs are now tracked by location and the system should provide the data needed to continue the practice.

A proposed report to track installation of new signs as compared to replacement signs was not approved. Sign crews generally do not make a special trip to install new signs which would significantly increase the unit cost of the activity.

Sign information will be used in weekly work planning. The Maintenance Management System will be modified to delete all sign data requirements since the proposed sign management system will be the sole source of data for sign management.

System Selection

The author developed the criteria for evaluating the packages based in the needs that the author felt could impact in a better and/or easier interaction between user and system. Each item of the evaluation criteria was given the same weight, except price, that was important only in case of tie.

The selection process was also based on an examination of system capabilities comparing to SCDOT requirements. Five software packages were evaluated as illustrated in Figure 2. The evaluation criteria are as follows:

1. Friendly interface: The feature of a menu driven system avoiding a command line type of interface.

2. Graphic interface: The characteristic of using a graphical interface utilized by Windows or similar software. It is well known that a graphical interface impacts the user learning curve

3. Stand-alone application: If the software is a stand-alone application (.EXE), it means that there is no need for any other auxiliary software to run the application. For example, if the software was developed as a dBASE application, system users would be required to purchase dBASE software.

4. Easy Connectivity: This requirement is related to the application capability of interfacing with other popular software packages (Excel, Access, dBASE...).

5. Flexibility to arrange the entry screen: The assumption that workers have minimal computer skills makes this item very important. Data fields can be selected for showing on the screen for a particular activity and easily changed to show another activity. The screen configuration must be pre formatted.

6. Use of disk space: This is a technical analysis of how the database is basically arranged. If the database is a combination of related files to produce a reasonable economy in the disk space, then the application is considered good, otherwise it is rated bad.

7. Sign maintenance history: The capability of storing the maintenance activity data in an orderly manner that facilitates the information retrieval for reconstituting the sign history.

8. Data Security: Capability of blocking access to fields based on passwords.

9. User defined fields: Feature of defining new fields to satisfy different needs of users, as well as accommodating future changes in the system. This feature give the flexibility to add data parameters that are unique to the SCDOT.

10. Address all SCDOT parameters: Measure the capability of addressing all SCDOT data parameters defined in Figure 1.

11. Schedule preventive maintenance: Capability of being used for planning preventive maintenance.

Software \ Features	SUPPLIER	Friendly Interface	Graphic Interface	Stand Alone Application	Easy Connectivity	Flexibility to arrange the Entry Screen	Good Use of Disk Space	Sign Maintenance History	Data Security	User Defined Fields	Address all SCDOT Parameters	Schedule Preventive Maintenance	Network capabilities	Merge data collected from different crews	Predicts Date for Removal	Flexibility to Format Reports	Control Signs by Geog. Coordinates	Read Directly from GPS	GIS Connectivity	Attachment of Pictures	History Log	Sheeting, Film & Backing Control	Control Sign from the Birth	Price (US$)
SignView	Cartegraph	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	***	✓	N/A	✓	✓	✓	✓	✓	✓	✓	✓	2,085
TOSS	University of Florida	✓		✓	✓			(*)							N/A									100
NDSMS **	North Dakota DOT					✓									N/A									****
VIMMS	Vulcan Traffic Mgt. Services	✓	✓	✓			✓	✓	*		✓	✓	✓	✓	✓	✓	*	*	*	✓	✓	✓	✓	11,000
Sign Inventory System	University of Florida	✓		✓			✓				*				N/A						*	✓	✓	100

✓	Conformance with requirements / Conform features description
blank	Does not conform to the requirement/feature descripted.
N/A	Feature not tested / Not available for testing…
(*)	Requirement partially met.
(**)	NDSMS is not a software package but a set of dBase files.
(***)	The network version of Cartegraph SignView will be released Fall '97.
(****)	This system is property of North Dakota DOT.

Figure 2. Comparison Chart

12. Network capabilities: Relates to the basic need for the software to run in a network environment.

13. Merge data collected from different crews: This is the feature of merging data from different crews collected on the same day. It must be "intelligent" for evaluating the most recent information and making the update.

14. Predict dates for removal: Software capability of predicting the useful life for a sign based on tables provided by the DOT personnel.

15. Flexibility to format reports: Capability to provide a user-defined report format against a standard non-flexible report.

16. Control signs by geographic coordinates: Utilization of GPS data to define sign location.

17. Read direct from GPS: Since manually entering coordinates could introduce errors, it is required that these coordinates be entered directly from the GPS receiver to the laptop computer.

18. GIS connectivity: Capability of connecting the application software to a GIS software package.

19. Attachment of pictures: This defines the possibility of attaching bitmap pictures of the road, sign, location, etc. to the database.

20. History log: The feature of keeping the changes in a record under control. It is important to be able to reconstitute changes in a file or trace the history of a sign location.

21. Sheeting, film and backing control: Capability of recording these fields in a sign record. They are special fields due to the fact they can generate a listing of signs with similar characteristics.

22. Control sign from the birth: The capability of keeping track of the sign from the workshop or warehouse until the sign is recycled or sold for scrap.

23. Price: The basis for a decision are the requirements, but if two or more software packages deliver the same capabilities, then price will play a major role.

The software package SignView from CarteGraph was the highest rated of the group that was evaluated as part of the research. This system met all criteria except one, the item 8 Data Security. Other alternative software packages failed to satisfy this requirement as well. Therefore SignView was utilized for the pilot demonstration.

The SignView software was also the only software package available as a demonstration copy. TOSS and SIS had to be purchased to obtain an evaluation copy. CarteGraph demonstrated during the whole evaluation process a very good level of technical support. CarteGraph offers training either in their facility or on-site with potential users.

The weak points encountered during the evaluation of SignView were the lack of data security, lack of user's manual, and cumbersome method for moving from field to field using the keyboard.

Alternative Ways to Provide Software

An evaluation was made to determine if a commercially available system would be the best approach to providing a useable system.

There were three approaches to be considered:

1. Develop a custom software system using Clemson University personnel supplemented with contractor assistance.
2. Hire a consultant to develop and maintain the system based on requirements developed under this project.
3. Adopt a commercially available software system with the capability of meeting requirements.

Clemson University researchers, with contract assistance, could develop a custom system within six months based on the stated requirements. The alternative was rejected for several reasons.

1. Clemson University is not organized to furnish long term technical computer program support or providing periodic programs for training SCDOT personnel. Initial training of SCDOT personnel, in a phased implementation strategy could require several years to complete since operators should not be trained until the system becomes available in their offices. As operating personnel change assignments, additional training would be required. As an alternative, the training function could be supported by in-house SCDOT personnel.

2. The new system would have to be refined with operating experience which could result in having to implement several changes in the first few years. After the original system was developed, it would be field tested, as SCDOT users begin to gain experience with the system. Further revisions may be required to eliminate situations that can cause field failures or add new capabilities.

3. SCDOT system users would need someone to be on-call in case of technical problems. Initially this "help desk" should be able to assume the responsibilities until SCDOT personnel gain experience and develop their own in-house support activity.

A consultant could be hired to develop the needed system but the approach was rejected for the following reasons:

1. With a lack of experience in the field, the firm would have to start from scratch investing time in learning the management process.

2. In order to have a competitive price, the firm would be counting on selling the system to others and gaining part of the market. Without this profit incentive, the firm may not be interested in developing a unique program and SCDOT would have to pay a high price for the product. Firms are reluctant to invest resources to develop a custom product with no potential of future sales.

3. Upgrades would carry a very high price since the market may be limited to South Carolina. Firms may have to establish a full time position to support SCDOT to ensure knowledgeable support rather than assigning other personnel to solve problems with expensive learning curves.

4. Since the firm, like SCDOT, would have no previous experience with this kind of system, software implementation may have a high risk of frustration.

A commercially available software package should overcome all of the problems mentioned above. The selected vendor firm is committed to enlarging their customer base, other customers are currently using the software, and all obvious system problems have been corrected. Firms, after product acceptance, may invest in refinements or methods to expand the systems capability which should be economically attractive to their customer base. The cost of this alternative is very low in comparison with two other alternatives. Single office copies of SignView sell for about $1,200 without any discounts. No information is available on the cost of licenses for multi-office users. This would be much less expensive than investing several man-years of effort to develop a new system which would have to be tested and revised with field experience. This approach was selected as the better alternative method of providing SCDOT with the needed software.

Pilot demonstration project using CarteGraph.

In order to demonstrate the capabilities of SignView as a solution for meeting SCDOT system requirements, SignView was tested using actual field data. A copy of CarteGraph Signs was obtained from the vendor for familiarization and demonstration. The Anderson District office identified an area that contained several types of highways and sign environments. The area is bound by US highway 76, interstate I 85, and SC 187. The demonstration area is shown in Figure 3. An effort was made to use a laptop to record data in the field. Operational tests were performed with CarteGraph Signs system to ensure that SCDOT criteria could be satisfied. GPS data were used to produce GIS maps with various parameters.

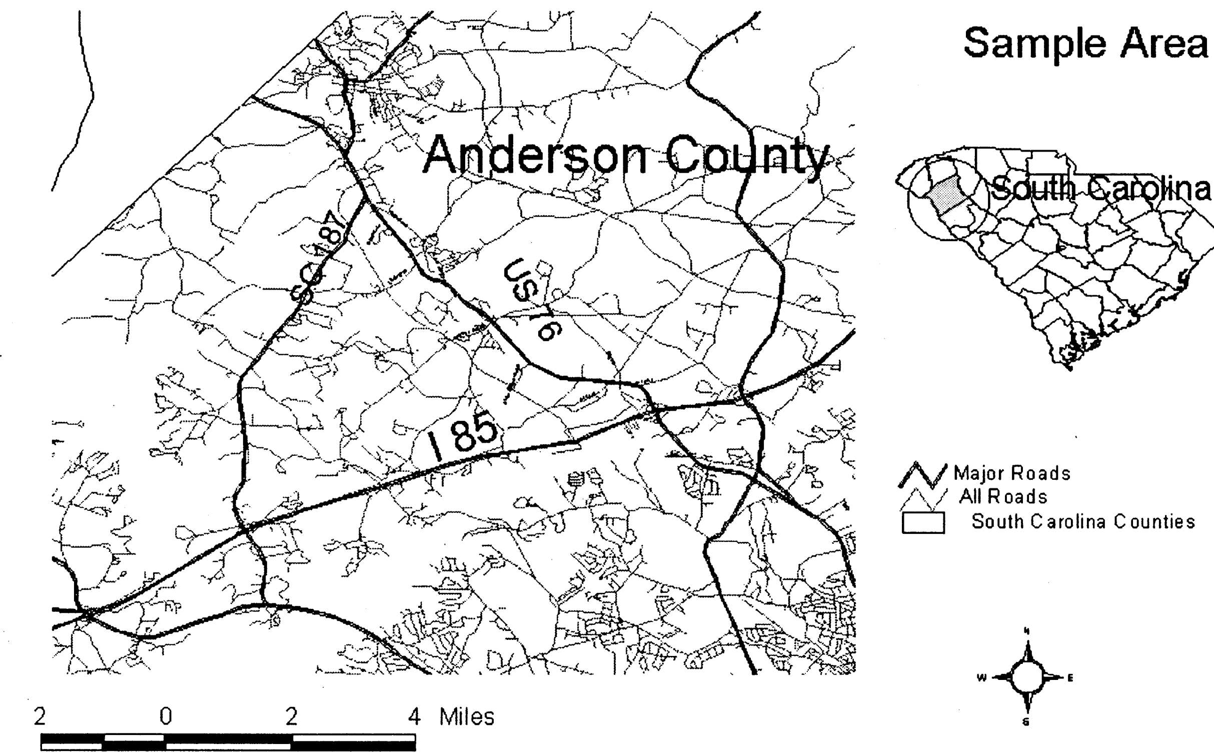

Figure 3. Pilot Demonstration Test Area

A field survey was conducted to inventory 224 signs within the demonstration area. Only 185 of these signs were used as a test sample in the software. Selected fields for the database file associated with the demonstration are reproduced in Appendix A.

The first step of the field survey was defining nodes and links on a map of the survey area. The concept of links and nodes is described in Chapter IV. Sample links and node data are illustrated in Figure 4. The second step was to prepare the inspection vehicle for this activity. The vehicle requires a place to hold the GPS, a board to hold the laptop computer or to write on in the case of preprinted forms, a measuring device that can be used inside the truck to measure the sign offset, and a notebook for collecting information on signs that apparently do not match any MUTCD code.

It was decided to begin the field survey by recording latitude and longitude of all nodes, and measuring link lengths before collecting other sign data . Thus the same route is driven twice.

The preprinted form shown in Figure 5 was used to capture the field data. The use of this manual data entry form permitted the inventory of approximately 60 signs per hour.

Entering field data manually on a data collection form has the disadvantage that the data must later be verified and entered into the computer system . As a part of the pilot sign demonstration, the researchers alternatively entered selected inventory data directly into the system using a laptop computer. Some difficulties were encountered when attempting to manipulate the mouse while the vehicle was in motion.

	Node		Link		Node		
Item	#	Start	Number	Name	#	Ends	Route
1	1	US76/SC187	1	US76-A	2	US76/S162	US76-A
2	2	US76/S162	2	US76-B	24	US76/S933	US76-B
3	24	US76/S933	3	US76-C	3	US76/S58	US76-C
4	3	US76/S58	4	US76-D	4	US76/S273	US76-D
5	4	US76/S273	5	US76-E	5	US76/S373	US76-E
6	5	US76/S373	6	US76-F	6	US76/S161	US76-F
7	6	US76/S161	7	US76-G	7	I85/US76	US76-G
8	7	I85/US76	8	I85-A	8	I85/SC187	I85-A
9	8	I85/SC187	9	SC187-A	9	SC187/S482	SC187-A
10	9	SC187/S482	10	SC187-B	10	SC187/S233	SC187-B
11	10	SC187/S233	11	SC187-C	11	SC187/S71	SC187-C
12	11	SC187/S71	12	SC187-D	12	SC187/S162	SC187-D
13	12	SC187/S162	13	SC187-E	13	SC187/S62	SC187-E
14	13	SC187/S62	14	SC187-F	1	US76/SC187	SC187-F
15	13	SC187/S62	15	S62-A	14	S62/S162	S62-A
16	14	S62/S162	16	S62-B	15	S62/S58	S62-B
17	15	S62/S58	17	S62-C	17	S62/S600	S62-C
18	17	S62/S600	18	S62-D	18	S62/S273	S62-D
19	3	US76/S58	19	S58-A	16	S58/S600	S58-A
20	15	S62/S58	20	S58-B	16	S58/S600	S58-B
21	21	S71	21	S71-A	22	S58/S71	S71-A
22	22	S58/S71	22	S71-B	23	S71/S233	S71-B
23	23	S71/S233	23	S71-C	11	SC187/S71	S71-C
24	16	S58/S600	24	S600-A	17	S62/S600	S600-A
25	17	S62/S600	25	S600-B	25	S600/S716	S600-B
26	25	S600/S716	26	S600-C	21	S71	S600-C
27	23	S71/S233	27	S233-A	10	SC187/S233	S233-A
28	2	US76/S162	28	S162-A	14	S62/S162	S162-A
29	14	S62/S162	29	S162-B	12	SC187/S162	S162-B
30	15	S62/S58	30	S58-C	22	S58/S71	S58-C
31	4	US76/S273	31	S273	18	S62/S273	S273
32	18	S62/S273	32	S62-E	19	S62/S373	S62-E
33	19	S62/S373	33	S62-F	20	S62	S62-F
34	#N/A	#N/A			#N/A	#N/A	#N/A
35	#N/A	#N/A			#N/A	#N/A	#N/A

Figure 4. Link and Nodes Data

SIGNS

Input Data Sheet

Inspector:

Date:

#	Sign Description	Route	Local. (mi)	Travel Direction	Position	Sign Direction	Route		Link ID	Node		GPS	
							Ahead	Back		Ahead	Back	Meridian	Parallel
1				N / S / E / W	R O M L	(+) (-)							
2				N / S / E / W	R O M L	(+) (-)							
3				N / S / E / W	R O M L	(+) (-)							
4				N / S / E / W	R O M L	(+) (-)							
5				N / S / E / W	R O M L	(+) (-)							
6				N / S / E / W	R O M L	(+) (-)							
7				N / S / E / W	R O M L	(+) (-)							
8				N / S / E / W	R O M L	(+) (-)							
9				N / S / E / W	R O M L	(+) (-)							
10				N / S / E / W	R O M L	(+) (-)							
11				N / S / E / W	R O M L	(+) (-)							
12				N / S / E / W	R O M L	(+) (-)							
13				N / S / E / W	R O M L	(+) (-)							
14				N / S / E / W	R O M L	(+) (-)							
15				N / S / E / W	R O M L	(+) (-)							
16				N / S / E / W	R O M L	(+) (-)							
17				N / S / E / W	R O M L	(+) (-)							
18				N / S / E / W	R O M L	(+) (-)							
19				N / S / E / W	R O M L	(+) (-)							
20				N / S / E / W	R O M L	(+) (-)							
21				N / S / E / W	R O M L	(+) (-)							
22				N / S / E / W	R O M L	(+) (-)							

Figure 5. Preprinted Sign Inventory Data Entry Form

later perform data entry in an office environment. It should be noted that the pilot demonstration sign inventory consisted of gathering the data parameters shown in Figure 5. Measurements such as distance from pavement and retroreflectivity were not taken.

It should also be noted that the pilot demonstration was conducted with an inexpensive GPS receiver. At some future point in time SCDOT may wish to integrate all maintenance operations and roadside features into a GPS system, in which case GPS receivers with a higher degree of accuracy, and much higher cost, may be required. Such receivers, with associated 2 to 5 m accuracies, requires additional time to obtain a position reading, as much as 3 minutes per sign location.

The voice recognition software package Dragon Dictate was interfaced to the SignView software and utilized to enter the pilot demonstration inventory data. Clemson University researchers trained for approximately 12 hours on the package prior to the data entry trial. Although the software performed satisfactorily, the brief experiment did not provide a significant reduction in data entry time. This may be due in part to the researcher's familiarity with the mouse and keyboard. (However, it should be noted that voice commands can be used within voice recognition software to perform mouse manipulations as well as keyboard data entry.) The voice recognition data entry option could become more efficient if some additional interface modules were written to facilitate the verbal manipulation of data screens, scroll lists, etc.

System Demonstration Workshop

As a final step in the system development process a half day demonstration workshop was conducted at Clemson University on May 28, 1997. A part of this workshop was used to demonstrate the overall capabilities of the CarteGraph SignView software using the Anderson County inventory data. The inventory data was supplemented with hypothetical data entered into selected fields to demonstrate selected system capabilities. Attendees were given the opportunity to execute a number of "hands on" exercises related to adding signs to the inventory, retiring a sign, replacing a sign, and generating reports using filters. The workshop agenda also included a demonstration of the voice recognition software and demonstrations of two retroreflectometers units. Linking SignView to GIS was discussed and the basic recommended link and node definition process was presented.

Chapter IV

SYSTEM UTILIZATION

To properly use the SignView system some initial steps must be taken, including the assignment of nodes and links. These are the basic units for locating a sign in a given area. This process must be planned carefully because it will impact the inventory use with no chance of changing it. Link and node definition is discussed in the following section. The use of SignView menus, toolbars and fields is discussed in the remaining sections of the chapter.

Methodology for Defining NODES

Definition of Nodes

Nodes are imaginary points in the road - a non dimensional position in a map, which indicates an intersection, a bridge, an underpass, a special marker, a mile marker, or a change in the road characteristic (size, pavement type...). They are assigned with a unique number, in a sequential or randomized way.

The purpose of assigning nodes is to facilitate the inventory organization by breaking long extensions of road into small units called links. The nodes define start and end points of a link.

Model Adopted

In this project, nodes were assigned based on rules as follows:

1. A node is placed at each intersection (junction) between an interstate road and a federal, a primary, or a secondary road.

2. A node is placed at each intersection between a federal road and a primary or a secondary road.

3. A node is placed at each intersection between a primary and a secondary road.

4. Whenever needed, nodes can be assigned to an overpass or underpass. When there is no connection between the roads, the node will be located just in the minor road.

5. County road signs are not controlled by the SCDOT, although the intersection signs are under their responsibility. The intersection with county roads will have to be considered if Stop signs or Yield signs are encountered in the intersection.

6. In the case where a road is intersected just on one side, the consideration is that the intersection still exists, therefore there will be a node assigned for that intersection.

Node location

To guarantee a uniform procedure in the node location process, it was established that the exact node locations follow certain rules. At an intersection, the exact location of a node is the geographic center of the intersection. This is established as the imaginary intersection of the center line of the roads as shown in Figure 6.

For node definition all signs will be related in relation to an imaginary line (short dashed line) that crosses the node at a 90° angle with the road axis. For the other road the line (long dashed line) will be defined the same way. Shown in Figure 6, signs in the gray areas are difficult to identify using the above criteria. To avoid this it was determined that all signs in the gray area are related to the major road. This same approach is valid in other situations.

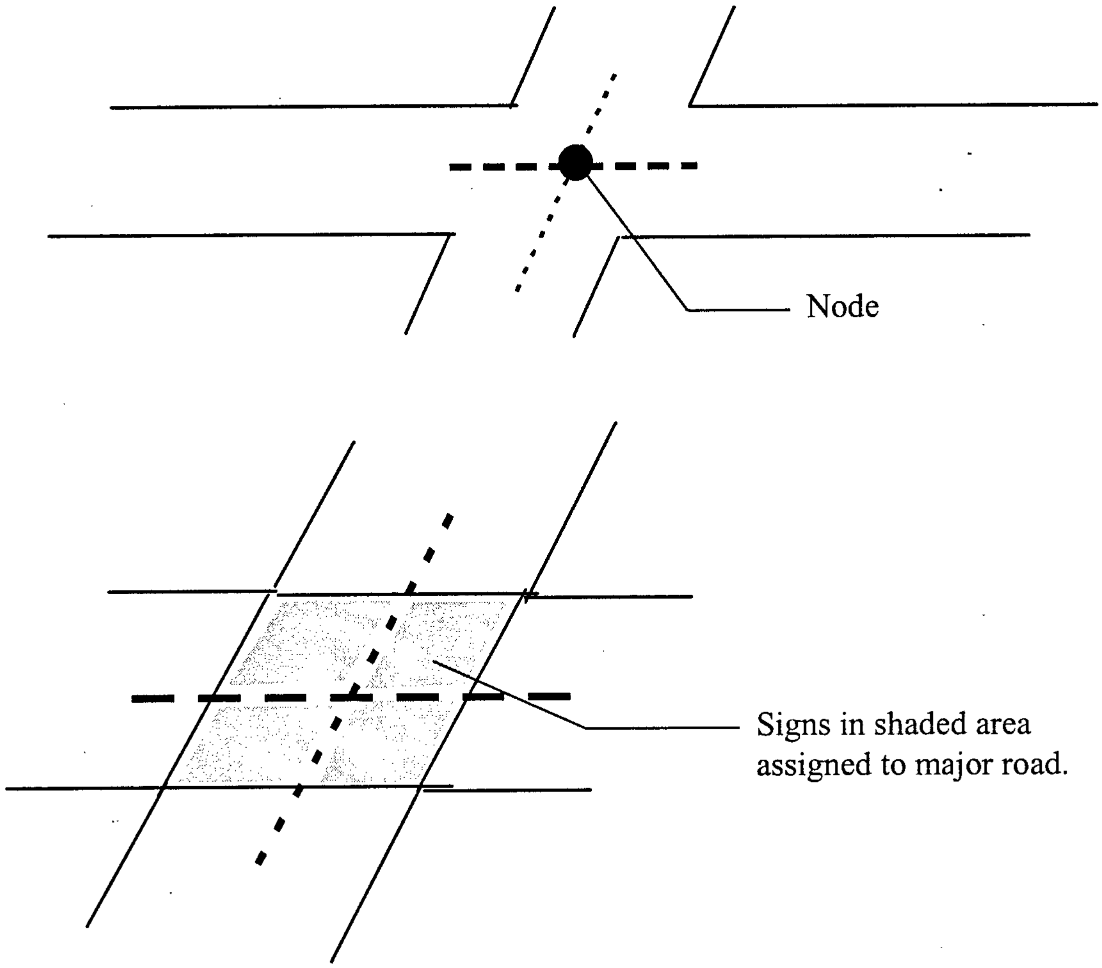

Figure 6. Node Definition

At a bridge, overpass or underpass, the node will be located at the center of the intersection.

Whenever an intersection between a county road and other roads is not defined by a node, the signs located in the intersection are related to the node of the major road. The indication that the signs are actually on a road other than the primary is entered in a memo field and the offset distance field.

Node Names

Node names are assigned in accordance with the highway intersection. For the intersection between Interstate 85 and Federal Highway 76 the node name would be I85/US76. The major road should come first, separated by a slash, followed by the name of the minor road.

Defining Links

Once the nodes are defined then names are assigned to the links between the nodes. The link name should be the route name where the link is localized. When there is more than one route in the same link, then the major route should be assigned.

Consecutive links on the same route should be named by adding a dash and a letter, beginning from a to z, and starting from north or west depending on the route direction. Sample link names include US76-A, US76-B, I85-D, SC187-G Link names appear on the data sheet illustrated in Figure 4.

Using SignView

The following sections explain the basic capabilities of the SignView software and provide very general guidelines for system utilization. This section should not be interpreted as a replacement for a user's manual. System users are strongly encouraged to participate in formal training provided by the system vendor.

Data Fields

Data entry is accomplished by accessing data entry fields as shown in Figure 7. Clicking on the selected screen button displays a list of choices to facilitate data entry. A list of all field descriptions is contained in Appendix B. Some data fields are tied to a calculator to facilitate data entry.

Screen Configurations

SignView provides a large number of versatile screen configurations. Selecting the View menu option displays a list from which the screen configuration can be selected. One such configuration is shown in Figure 8.

Toolbar

Most system capabilities can be accessed from the toolbar. Toolbar buttons are used for system capabilities that include GPS and bar code data entry, and sorting and filtering records. Filters provide a powerful system capability that permit selecting records that match a specific query.

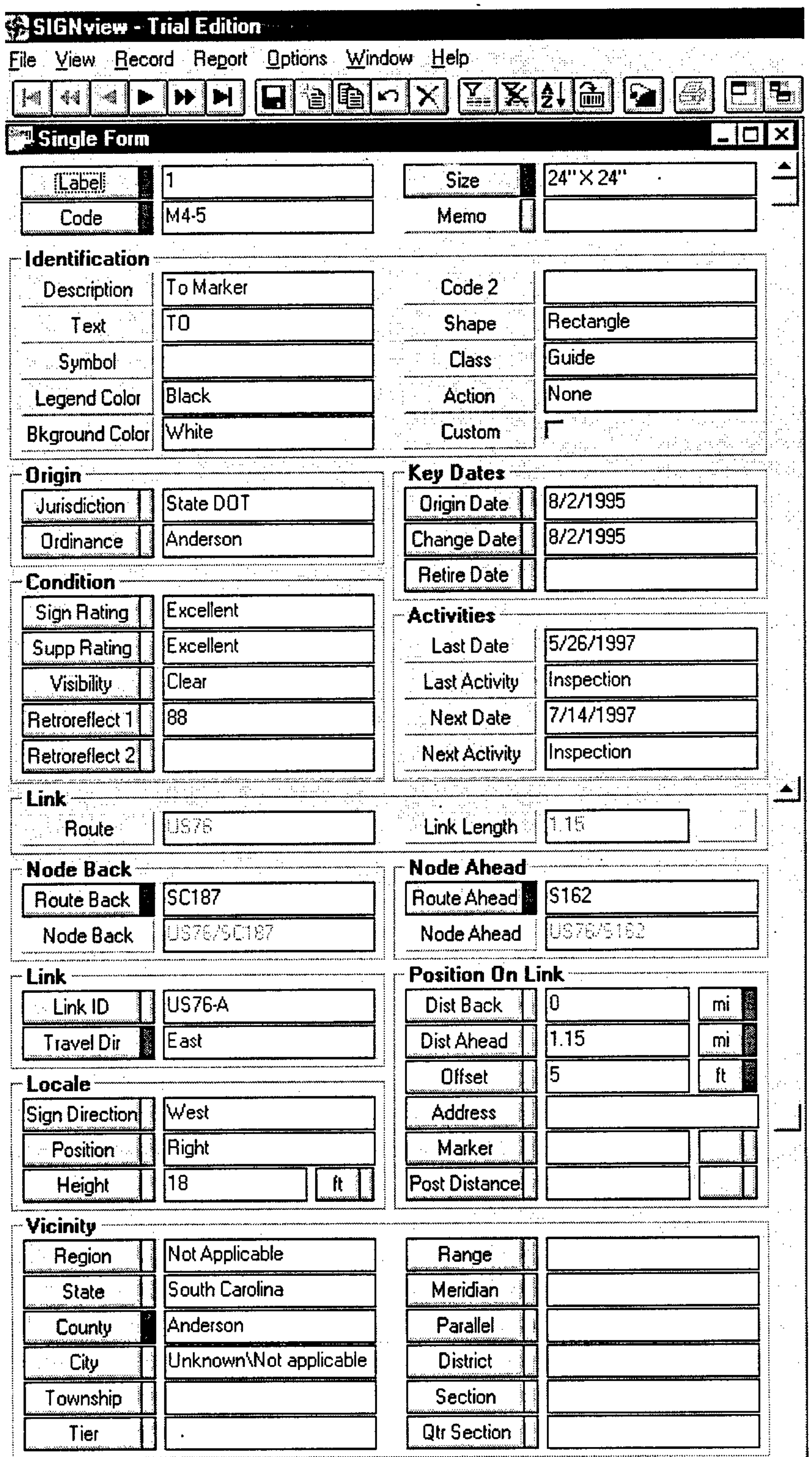

Figure 7. CarteGraph SignView Entry Data Fields

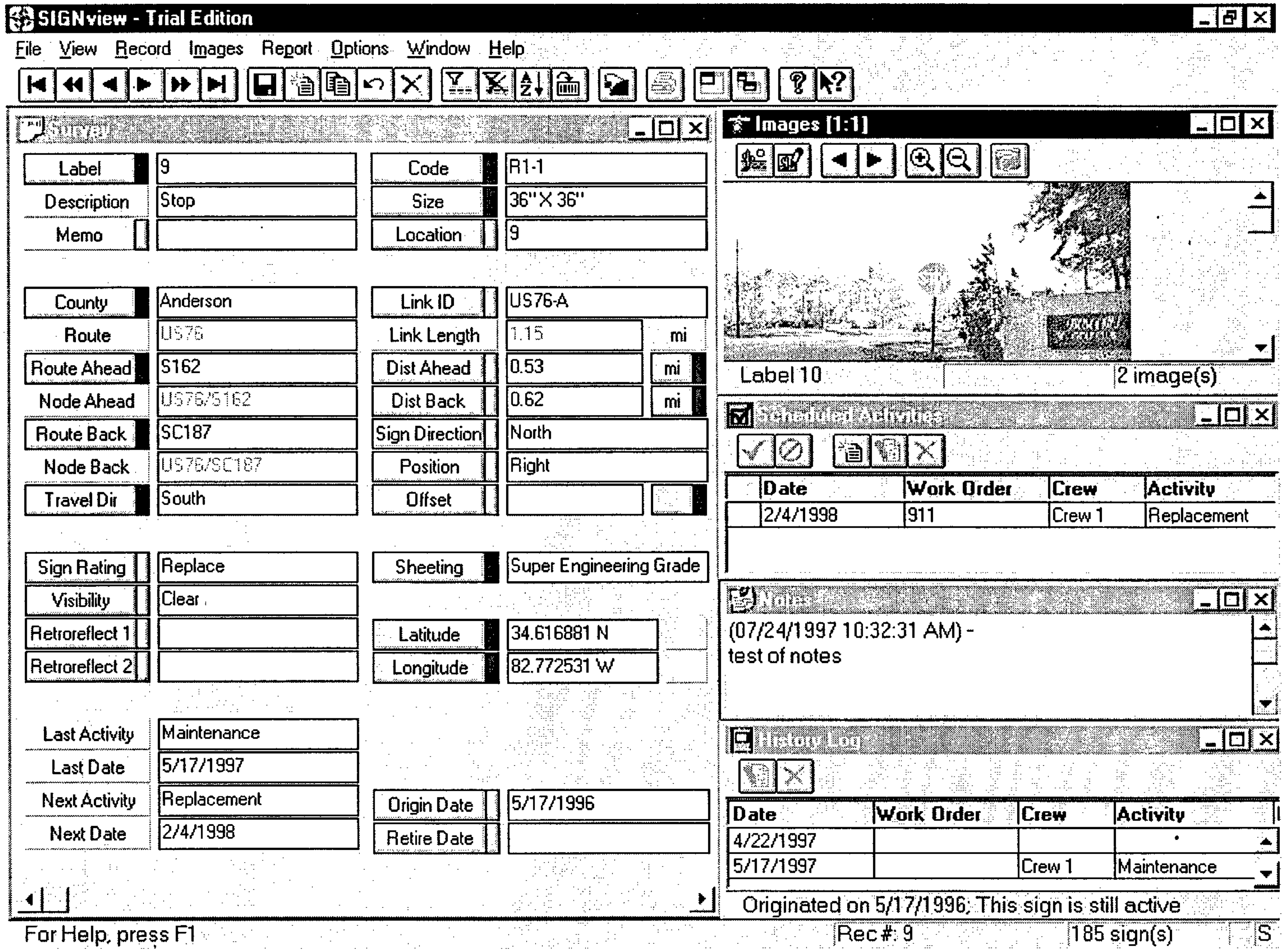

Figure 8. Sample Screen Configuration

Automatic Data Generation

SignView has a feature that permits automatic data entry for records that have a repeated value in the same data fields. For example, a large number of signs may be entered that have the same value for county name, link identification, travel direction, etc. The thin button that separates the field button and the data display (see Figure 7) can be depressed to activate this feature.

Node Data Entry

Node data entry is initiated by selecting the View menu and then the Node Library option. The Node Library screen is displayed as shown in Figure 9. The node ID is entered into the [Node ID] field using the node naming convention described in a previous section of this chapter. The field [Node ID 2] permits the use of an alternate node designation convention if desired.

Links Data Entry

Link data entry is accomplished by clicking on the View menu button and then the Link Library option. The Link Library screen appears as shown in Figure 10. Link names are entered using the naming convention described in a previous section of this chapter. The link length, obtained from the inspection vehicle odometer, and the route name are entered using this screen. Start and end nodes for the link are selected by clicking on the [Node ID] button. Links can be searched using the arrows at the bottom of the screen.

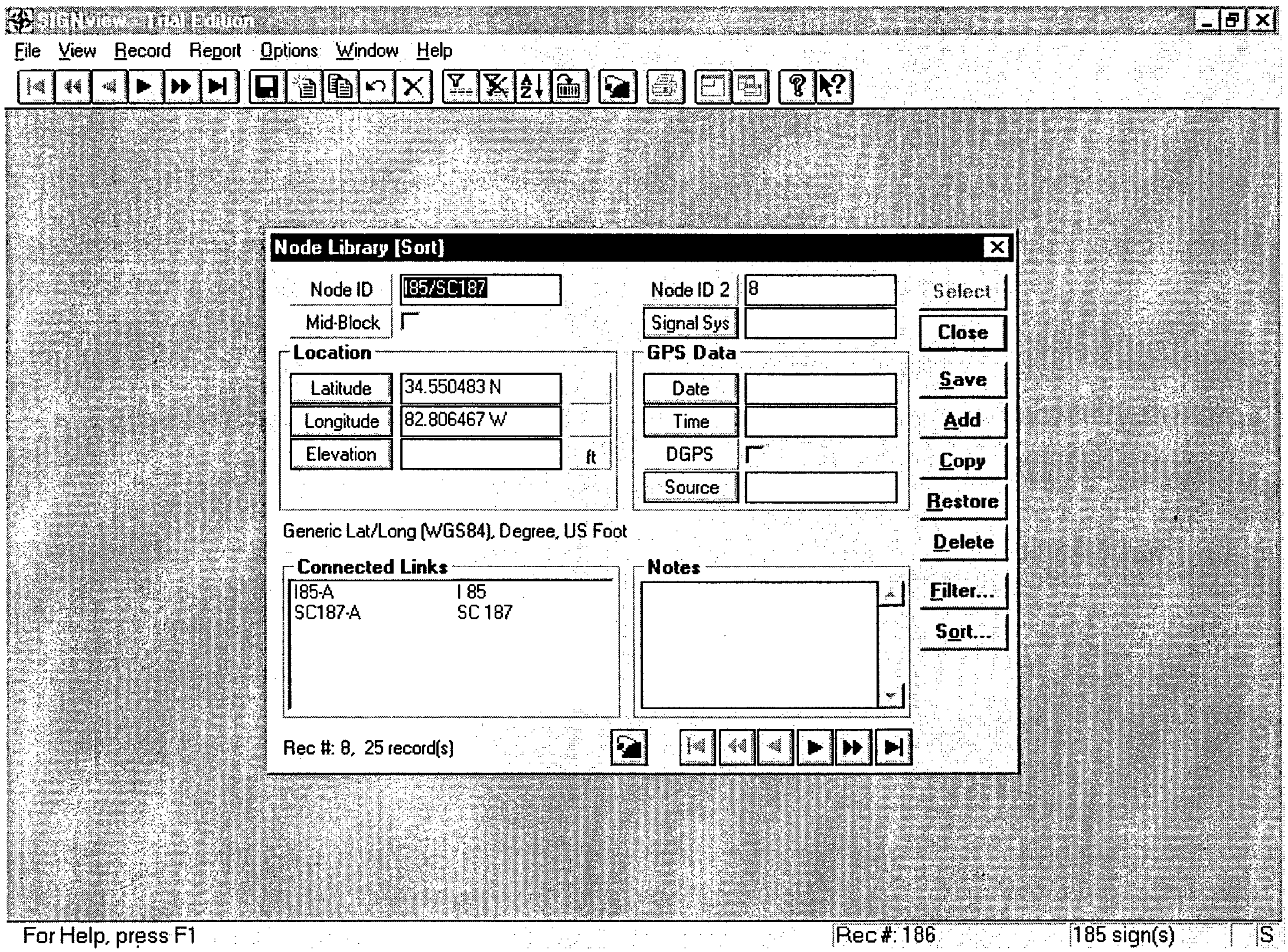

Figure 9. Node Library Entry Screen

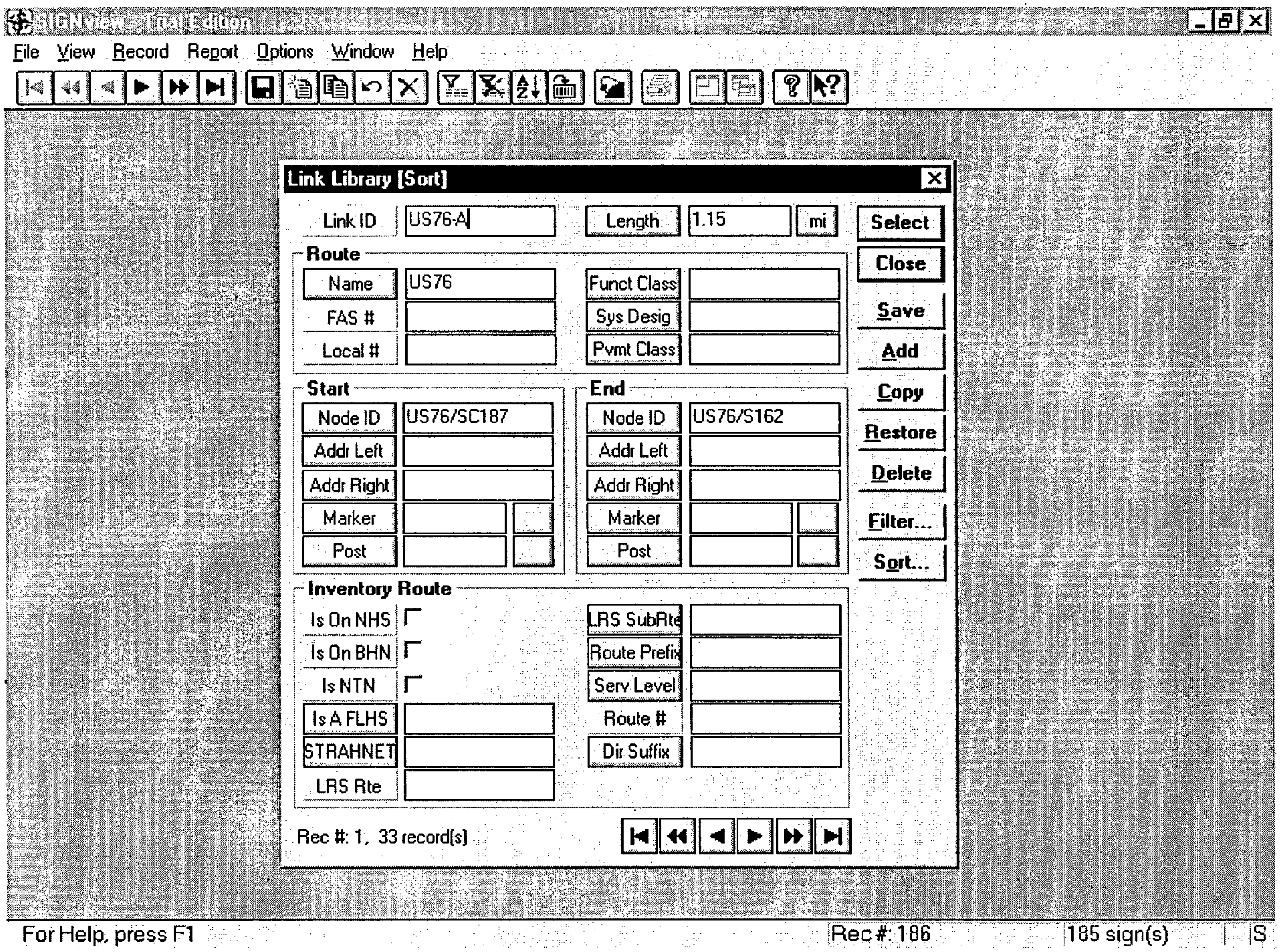

Figure 10. Link Library Entry Screen

Sign Library

The SignView software has an extensive sign library that includes visual sign representations with assigned MUTCD codes. The sign library is accessed by clicking on the View menu and then selecting the Sign Library option. The Sign Library will be displayed as shown in Figure 11. As a part of the data process, a sign code must be entered. Referring to the Sign Library aids the user in assigning the proper code. Once the code is entered for a sign record, all other information contained in the Sign Library (shape, text) is attached to the sign. There will be signs within the SCDOT inventory for which no MUTCD code has been assigned. The Sign Library can be easily modified to add those signs. The [Code 2] field shown in Figure 11 is used if the Federal MUTCD and State codes differ. For this situation, the State code is entered in the [Code] field and the Federal code in the [Code 2] field.

Sign Data Entry

The sign data entry is initiated by clicking on the view record button (sheet of paper symbol with a start in upper left corner) that is located on the toolbar. A data entry form similar to that shown in Figure 7 will be displayed. For data entry fields that have the thin red button depressed, the data will be automatically generated from the previous record. The label field is essentially a sign number. Labels must be assigned such that each sign has a unique designation. When the red button aligned with the label field is depressed, the next number in sequence is displayed. Remaining data entry items (code, size, etc.) proceed by simply clicking on the button associated with the data field.

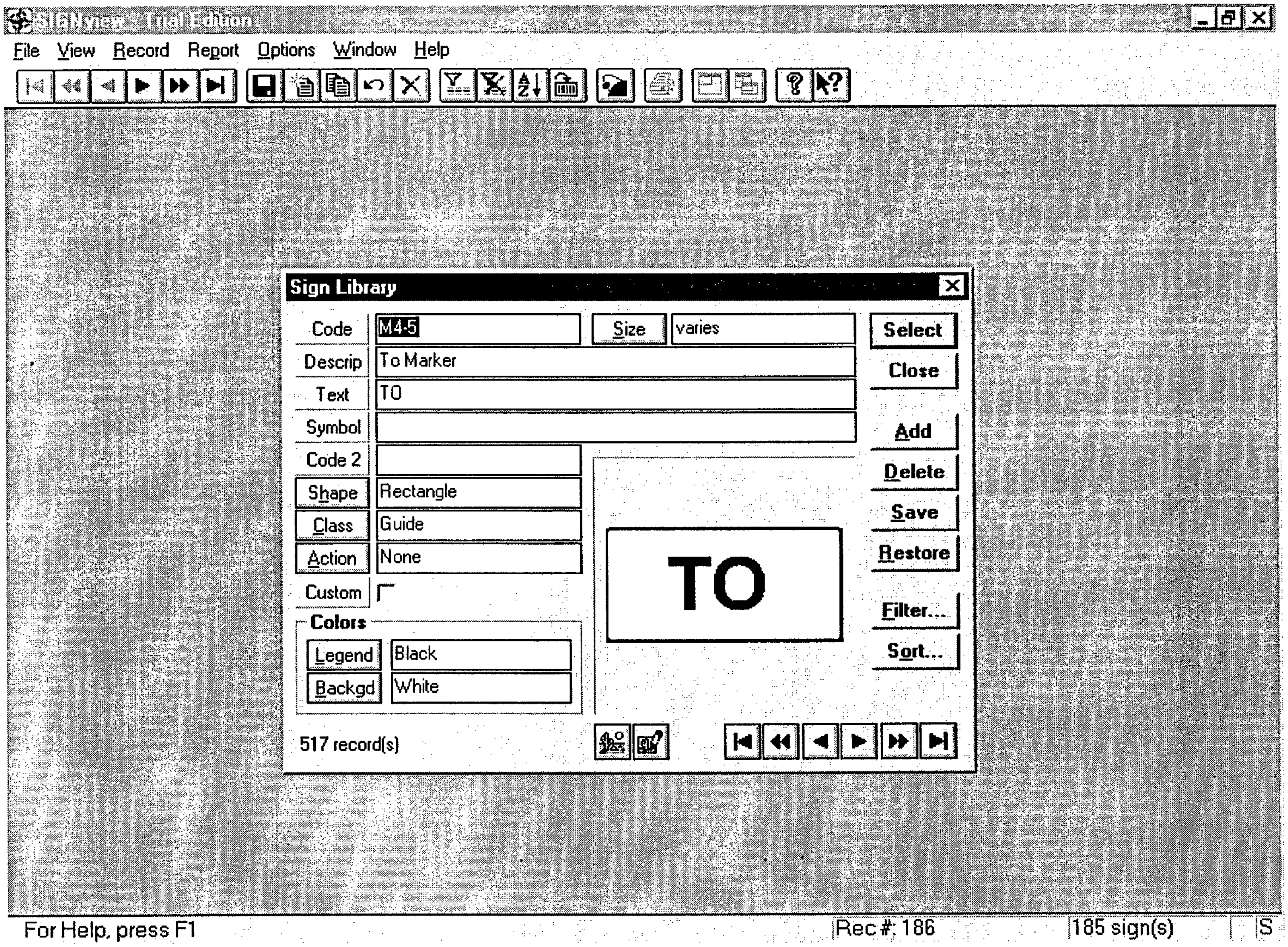

Figure 11. Sign Library Entry Screen

Again, the system provides scroll lists from which selections can be made to speed data entry and minimize data entry errors. The GPS button on the toolbar can be used for automatic transfer of GPS data from the receiver to the system.

Queries and Reports

SignView has multiple capabilities for generating queries and reports. The [Report] menu option is utilized by first selecting a database that forms the basis of the query or report. The database options are Current Database, Sign Library, Link Library, Node Library, Scheduled Events, History events, and Rollback. The current database is the one in current use, for example the database that was created in Anderson County. The Scheduled Events database would pertain to signs for which some inspection or maintenance activity has been planned. The History Events database would pertain to inspection or maintenance activities that have been completed. The Rollback database can be created to examine signs for which some parameters have changed with time.

After selecting the database, one of a set of predefined report formats can be selected. Report format can be altered using the [Edit] button.

The [Edit] or [Filter] buttons permit the user to filter or select signs within the database that meet specified criteria. Filter criteria are established using commands that utilize key words and operators. For example the command (LABEL>=10 AND LABEL<1412) AND ((CODE=R1-1) OR (CODE=R1-2)) AND (ROUTE=US76) would generate reports pertaining to all "Stop" and "Yield" signs located on US76 that have a label number between 10 and 1412.

The filter capability can be used to generate any type of report of interest to the user. Examples include:

- number and type of signs replaced each year;
- average age of signs by film type;
- number of signs rated "poor" and scheduled for replacement;
- signs destroyed by theft or accident;
- location of signs with less than the average useable life.

Another useful feature of SignView is the ability to sort signs by route and distance from a node. This feature enables crews to determine if signs are missing while the inspection process is being carried out.

Other System Characteristics and Capabilities

SignView utilizes a compact database that uses approximately 1 kilobyte per sign (without an attached photograph) plus 500 kilobytes for database control. Therefore, a 500,000 sign inventory would occupy approximately 500 megabytes of disk space. However, if lengthy instructions are used as part of the work order option within SignView, disk space requirements may be increased.

SignView is easily linked to GIS software using the CarteGraph interface package ArcLink. As part of this research project, the Anderson County demonstration database was linked to the GIS software package ArcView (from ERSI, the Environmental Systems Research Institute). No conversion programs or files other than the CarteGraph ArcLink product were required. Figure 3 of this report was generated using the ArcView GIS software package. GIS software permits the visual display of most any type of system query. These visuals include signs with combinations of film type, code, condition, location, reflectivity, and inspection status. Such visuals are valuable tools for planning and executing field operations.

All data files utilized within SignView are in Microsoft Access format. This permits the use of system data for other applications. For example, a software package that prints bar code labels could import data in this format, eliminating a considerable amount of manual data entry.

A very useful feature of SignView is the ability to store and display a photograph of the sign as part of the sign record. SignView accepts photographs in formats that include PCX, TIFF, BMP, WMF, EPS and GIF. A photograph of a sign included in the Anderson County demonstration project is shown attached to other data fields in Figure 8. SignView also accepts bitmap input. Thus an image of a sign can be scanned, or even painted, into the system when modifying the Sign Library.

Finally, the versatility of the system should be noted. A very large number of predefined fields (listed in Appendix B) have been incorporated into the system. However, user created fields were used as a part of the demonstration system to show how the frequency of sign replacements at the same location (due to theft, accidents, etc.) can be tracked. Another possible use for user defined fields within SCDOT system would be to assign a warehouse location or status to a sign immediately after the sign label has been established.

Bar Code Program Modules

Bar code technology is well suited to applications that require repeated or large amounts of continuous data entry. Many inventory or inspection applications require such data entry. For the field inventory and inspection of signs, the data entry process is not continuous, i.e. the user moves from one sign to another before performing a data entry operation. Scanning a bar code on the back of a sign will perform a means of accurately identifying the correct record in the database, but the advantage of reducing time for data entry is not sufficient to recommend this procedure for routine inventory and inspections. However, in the warehouse environment, when initial sign data are being entered into the system, data scanning is continuous and significant reductions in data entry time can be anticipated. Three bar code program modules were developed by Clemson University to permit the integration of bar code technology into the sign management process as described below.

Reader.exe

The program module Reader.exe was written for the purpose of assisting with the warehouse data input process. Bar code identification labels are placed on the signs in the warehouse. Using the Janus 2020 bar code reader with the Reader.exe module in memory, the user scans the bar code and then enters initial data parameters that include MUTCD code, backing material, sheeting material, and other data common to the sign lot. The program is initiated by typing the command "reader". Typing the number 0 permits the user to begin entering data for another sign lot that has common data. The source code for the program is reproduced in Appendix C.

BC.exe

Bar code technology would be useful when sign information must be retrieved from a given sign, and the portable laptop computer is not available. The sign bar code could be scanned with the Janus unit and selected sign parameters displayed. The program BC.exe displays the sign MUTCD code, route, route back, route ahead, distance back, distance ahead, structural material, and type of film. Additional data fields could be displayed through program modification. It should be noted, however, that the Janus unit does not have the memory requirements to store all data fields associated with a large number of signs. The program is initiated using the command "bc". The program can be exited by typing zero and then enter. The program module source code is reproduced in Appendix D.

ImpExp.exe

The two bar code applications described above require importing /exporting data to/from the SignView database and the Janus 2020 bar code scanner. The program ImpExp.exe performs this process within the desktop computer. Program initiation is accomplished by typing "ImpExp" followed by the action desired, where the action desired is either :ToSystem" or "ToReader" , which in turn is followed by the name of the file to export or import. Within SignView software, the export and import system are utilized. The ImpExp source code is reproduced in Appendix E.

Chapter V

SYSTEM IMPLEMENTATION

Phased Implementation

It is recommended that the SCDOT develop a written sign maintenance system implementation plan. The plan should address elements that include a data acquisition strategy, hardware and software procurement, software installation and maintenance, and the training of field inspectors and system users. Some guidelines to be observed during the planning and execution stages of the implementation plan are reproduced in Appendix F. Formal CarteGraph training would be appropriate for one representative from both SCDOT data processing, and the maintenance division who would in turn be available to train other system users.

A number of alternate strategies could be pursued by SCDOT to accomplish statewide implementation. It is recommended that implementation begin through the utilization of a stand alone version of SignView in the Anderson County district office. SCDOT should monitor crew productivity to determine the resources and budget that will be required to complete the overall effort. If sign crews are assigned the task of collecting data for specific groups of signs as part of their normal duties, cost could be minimized but it will be difficult to establish productivity baselines. Using a full time survey crew could minimize disruptions and provide better assurance that all signs are properly inventoried.

Data collection could proceed initially using paper forms in the field to avoid purchasing laptop computers for the field crews. However, this will require additional effort for data verification and computer entry at the district office. Purchase of a GPS receiver for use in building the initial inventory is essential, and the use of a digital camera to document unusual or hazardous conditions is strongly recommended. Additional research may be needed before selecting retroreflectometer hardware, although currently available units could be utilized during initial inventory efforts and the effectiveness of those units evaluated as the inventory progresses. Similarly, the use of voice recognition software should be integrated into the data collection effort at some point in time, but need not to be used initially. Estimated hardware and software costs for an integrated sign management system are shown in Figure 12.

After completing the inventory and inspections within the Anderson County office, the written implementation plan can be put in place. Persons that had received CarteGraph system training should be made available to train other system users. At some point in time the network version of SignView should be purchased and installed in the regional sign shop that serves the district offices. Funds should be budgeted to upgrade the hand held GPS receivers to units that are installed in the inspection vehicles and/or sign trucks.

Personnel Requirements

It is difficult to estimate the total personnel requirements that will be required to complete the state inventory and inspection because the total number of signs within the state system is not known. However, some guidelines based upon the experience of the Clemson University researchers during the Anderson County demonstration inventory can be formulated. Inventory data , including GPS locations, were obtained at the rate of approximately 26 signs per hour. There may be as many as 50,000 signs in some counties within South Carolina. Using the demonstration project productivity data, a 2 man crew working 36 hours per week could complete a county inventory of 50,000 signs in approximately 53 weeks. If using a laptop computer the county inventory could be completed in approximately 39 weeks.

HARDWARE AND SOFTWARE COSTS.

The average market cost of the items are as follows:

CarteGraph SignView	$1,195.00
CarteGraph Cartemaster	$495.00 (link with GIS program)
CarteGraph XYZlink	$395.00 (link for GPS receiver)
Laptop computer	$2,500.00
GPS Receiver (Magellan DLX - 10)	$500.00
Retroreflectometer (Hand-held unit)	$6,000.00
GIS System ESRI - ArcView software.	$1,200.00
Voice Recognition Software	$299.00
Digital Camera	$300.00
Intermec Janus 2020 unit	$4,000.00
Bar code labels - 1000 package. (Polyester / Teflon) *minimum order of 3000 units.	$142.00

Figure 12

Chapter VI

CONCLUSIONS

The original objective of the research described herein was to demonstrate the use of bar code technology as a data acquisition tool to support sign inventory and inspection. The research objective was later modified to include the evaluation of commercially available sign management software (or recommend an in-house development effort) and to demonstrate the utility of additional technologies, including GIS/GPS and voice recognition, as they pertain to sign management. SCDOT sign management system capabilities were compiled and the software package SignView (CarteGraph Systems) was judged to meet all SCDOT requirements except some security concerns, which can be addressed through periodic backups of the database.

A pilot project was completed whereby SCDOT Anderson County sign inventory data was entered into the SignView software and links were created to demonstrate GIS/GPS software interactions. Software modules were written for an Intermec Janus 2020 bar code scanner that will permit tracking of sign history from sign manufacture to sign retirement. The Dragon Dictate software package was used to demonstrate the use of voice recognition as a means of capturing sign inventory and inspection data in a moving vehicle, an environment that may make a mouse and keyboard data entry difficult. Recommendations were formulated with respect to system hardware and software requirements.

Adoption of the SignView software and related technology enhancements will permit the SCDOT to plan and budget sign inventory and inspection related activities, create a system wide inventory, respond to future Federal mandates pertaining to film grades, identify signs in need of replacement, execute efficient replacement operations, track sign material performance, and minimize liability that may arise from substandard or missing signs. Implementing the system with the technological enhancements recommended will also provide a means of exposing SCDOT personnel to those technologies, all of which have potential application within other engineering and management systems utilized by SCDOT.

Appendix A

Selected Fields of the Demonstration

Project Database

Anderson County Pilot Data

Label	Code	Description	Route	Link ID	Link Le	Node Back	Dist B	Travel	Sign D	Position	X/Latitude	Y/Longitud
1	M4-5	To Marker	US76	US76-A	1.15 mi	US76/SC187	0.00 mi	East	West	Right	34.624447 N	82.778150
2	M3-1	Cardinal Directi	US76	US76-A	1.15 mi		0.00 mi	East	West	Right	34.624447 N	82.778150
3	M1-1	Interstate Shiel	US76	US76-A	1.15 mi		0.00 mi	East	West	Right	34.624447 N	82.778150
4	M3-2	Cardinal Directi	US76	US76-A	1.15 mi		0.00 mi	East	West	Right	34.624447 N	82.778150
5	M1-4	US Route Mark	US76	US76-A	1.15 mi		0.00 mi	East	West	Right	34.624447 N	82.778150
6	M1-6	State Route Ma	US76	US76-A	1.15 mi		0.00 mi	East	West	Right	34.624447 N	82.778150
7	R2-1	Speed Limit	US76	US76-A	1.15 mi		0.00 mi	East	West	Right	34.623697 N	82.777247
8	R1-1	Stop	US76	US76-A	1.15 mi	US76/SC187	0.60 mi	South	North	Right	34.617517 N	82.773367
9	R1-1	Stop	US76	US76-A	1.15 mi	US76/SC187	0.62 mi	South	North	Right	34.616881 N	82.772531
10	R2-1	Speed Limit	US76	US76-A	1.15 mi	US76/SC187	0.70 mi	East	West	Right	34.616064 N	82.771714
11	W3-3	Signal Ahead	US76	US76-A	1.15 mi	US76/SC187	1.00 mi	East	West	Right	34.612664 N	82.769200
12	D1-1	Destination/Arr	US76	US76-A	1.15 mi	US76/SC187	1.00 mi	East	West	Right	34.610531 N	82.767917
13	0		US76	US76-B	0.64 mi	US76/S162	0.88 mi	East	West	Right	34.609733 N	82.767547
14	0		US76	US76-B	0.64 mi	US76/S162	0.88 mi	East	West	Right	34.609664 N	82.767297
15	0		US76	US76-B	0.64 mi	US76/S162	0.88 mi	East	West	Right	34.609664 N	82.767297
16	S3-1	School Bus Sto	US76	US76-B	0.64 mi	US76/S162	0.91 mi	East	West	Right	34.609433 N	82.767050
17	W8-5	Slippery When	US76	US76-B	0.64 mi	US76/S162	0.96 mi	East	West	Right	34.608883 N	82.766717
18	W1-2L	Left Curve	US76	US76-B	0.64 mi	US76/S162	1.01 mi	East	West	Right	34.608433 N	82.766467
19	W12-2	Low Clearance	US76	US76-B	0.64 mi	US76/S162	1.08 mi	East	West	Right	34.607381 N	82.765964
20	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.11 mi	East	West	Right	34.606850 N	82.765800
21	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.14 mi	East	West	Right	34.606433 N	82.765850
22	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.16 mi	East	West	Right	34.606114 N	82.765850
23	0		US76	US76-B	0.64 mi	US76/S162	1.18 mi	East	West	Right	34.605964 N	82.765850
24	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.20 mi	East	West	Right	34.605567 N	82.765664
25	W12-2	Low Clearance	US76	US76-B	0.64 mi	US76/S162	1.21 mi	East	West	Right	34.605347 N	82.765664
26	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.22 mi	East	West	Right	34.605217 N	82.765600
27	CD-1	Evacuation Ro	US76	US76-B	0.64 mi	US76/S162	1.23 mi	East	West	Right	34.605147 N	82.765514
28	CD-1	Evacuation Ro	US76	US76-B	0.64 mi	US76/S162	1.23 mi	East	West	Right	34.605147 N	82.765514
29	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.24 mi	East	West	Right	34.605067 N	82.765333
30	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.26 mi	East	West	Right	34.604947 N	82.765033
31	W1-8	Chevron Align	US76	US76-B	0.64 mi	US76/S162	1.27 mi	East	West	Right	34.604897 N	82.764683
32	W1-2R	Right Curve	US76	US76-B	0.64 mi	US76/S162	1.28 mi	East	West	Right	34.604817 N	82.764267

Anderson County Pilot Data

Label	Code	Description	Route	Link ID	Link Le	Node Back	Dist B	Travel	Sign D	Position	X/Latitude	Y/Longitud
33	CD-1	Evacuation Ro	US76	US76-B	0.64 mi	US76/S162	1.29 mi	East	West	Right	34.604767 N	82.764000
34	CD-1	Evacuation Ro	US76	US76-C	0.86 mi	US76/S933	0.14 mi	East	West	Right	34.602583 N	82.759314
35	CD-1	Evacuation Ro	US76	US76-C	0.86 mi	US76/S933	0.16 mi	East	West	Right	34.602547 N	82.758847
36	R2-5C	Speed Zone Ah	US76	US76-C	0.86 mi	US76/S933	0.21 mi	East	West	Right	34.602183 N	82.758147
37	R2-1	Speed Limit	US76	US76-C	0.86 mi	US76/S933	0.28 mi	East	West	Right	34.601200 N	82.757431
38	D1-1	Destination/Arr	US76	US76-C	0.86 mi	US76/S933	0.36 mi	East	West	Right	34.600664 N	82.757031
39	W9-1	Right Lane End	US76	US76-C	0.86 mi	US76/S933	0.38 mi	East	West	Right	34.600083 N	82.756533
40	W2-2	Side Road (90	US76	US76-C	0.86 mi	US76/S933	0.66 mi	East	West	Right	34.597731 N	82.753300
41	W3-3	Signal Ahead	US76	US76-C	0.86 mi	US76/S933	0.71 mi	East	West	Right	34.597350 N	82.752233
42	D1-1	Destination/Arr	US76	US76-C	0.86 mi	US76/S933	0.85 mi	East	West	Right	34.595947 N	82.750214
43	M3-2	Cardinal Directi	US76	US76-D	0.14 mi	US76/S58	0.05 mi	East	West	Right	34.594281 N	82.766481
44	M1-4	US Route Mark	US76	US76-D	0.14 mi	US76/S58	0.00 mi	East	West	Right	34.594281 N	82.766481
45	M1-6	State Route Ma	US76	US76-D	0.14 mi	US76/S58	0.05 mi	East	West	Right	34.594281 N	82.766481
46	R2-1	Speed Limit	US76	US76-D	0.14 mi	US76/S58	0.13 mi	East	West	Right	34.593083 N	82.748797
47	R2-1	Speed Limit	US76	US76-E	0.65 mi	US76/S273	0.00 mi	East	West	Right	34.585281 N	82.741631
48	D1-1	Destination/Arr	US76	US76-E	0.65 mi	US76/S273	0.62 mi	East	West	Right	34.581650 N	82.731264
49	R5-1	Do Not Enter	US76	US76-E	0.65 mi	US76/S273	0.64 mi	East	West	Right	34.581600 N	82.730647
50	W2-1	Cross Road	US76	US76-F	0.55 mi	US76/S373	0.33 mi	East	West	Right	34.581083 N	82.722731
51	R2-5A	Reduced Spee	US76	US76-F	0.55 mi	US76/S373	0.05 mi	East	West	Right	34.581183 N	82.721614
52	0		US76	US76-G	0.80 mi	US76/S161	0.10 mi	East	West	Right	34.581450 N	82.718117
53	W3-3	Signal Ahead	US76	US76-G	0.80 mi	US76/S161	0.10 mi	East	East	Right	34.581450 N	82.718117
54	R5-1A	Wrong Way	US76	US76-G	0.80 mi	US76/S161	0.15 mi	East	East	Right	34.581000 N	82.716367
55	R6-1L	One Way/Left	US76	US76-G	0.80 mi	US76/S161	0.20 mi	East	East	Right	34.580733 N	82.716200
56	R5-1A	Wrong Way	US76	US76-G	0.80 mi	US76/S161	0.22 mi	East	West	Right	34.580547 N	82.716231
57	R2-1	Speed Limit	US76	US76-G	0.80 mi	US76/S161	0.25 mi	East	West	Right	34.580217 N	82.715514
58	W3-3	Signal Ahead	US76	US76-G	0.80 mi	US76/S161	0.27 mi	East	West	Right	34.580133 N	82.715333
59	M2-2	Combination Ju	US76	US76-G	0.80 mi	US76/S161	0.30 mi	East	West	Right	34.579817 N	82.714833
60	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.31 mi	East	West	Right	34.579731 N	82.714697
61	R5-1A	Wrong Way	US76	US76-G	0.80 mi	US76/S161	0.40 mi	East	West	Right	34.578817 N	82.714000
62	M2-1	Junction Marke	US76	US76-G	0.80 mi	US76/S161	0.41 mi	East	West	Right	34.578633 N	82.714031
63	M1-1	Interstate Shiel	US76	US76-G	0.80 mi	US76/S161	0.41 mi	East	West	Right	34.578633 N	82.714031
64	0		US76	US76-G	0.80 mi	US76/S161	0.45 mi	East	West	Right	34.578250 N	82.713950

Anderson County Pilot Data

Label	Code	Description	Route	Link ID	Link Le	Node Back	Dist B	Travel	Sign D	Position	X/Latitude	Y/Longitud
65	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.47 mi	East	East	Right	34.578133 N	82.713867
66	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.48 mi	East	West	Right	34.577983 N	82.713700
67	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.50 mi	East	West	Right	34.577614 N	82.713400
68	R5-10A	Selective Exclu	US76	US76-G	0.80 mi	US76/S161	0.55 mi	East	West	Right	34.576847 N	82.712964
69	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.56 mi	East	West	Right	34.576783 N	82.712883
70	CD-1	Evacuation Ro	US76	US76-G	0.80 mi	US76/S161	0.58 mi	East	West	Right	34.576667 N	82.712914
71	M3-3	Cardinal Directi	US76	US76-G	0.80 mi	US76/S161	0.58 mi	East	West	Right	34.576667 N	82.712914
72	M1-1	Interstate Shiel	US76	US76-G	0.80 mi	US76/S161	0.58 mi	East	West	Right	34.576667 N	82.712914
73	0		US76	US76-G	0.80 mi	US76/S161	0.58 mi	East	West	Right	34.576667 N	82.712914
74	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.60 mi	East	West	Right	34.593147 N	82.712964
75	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.63 mi	East	West	Right	34.575981 N	82.712814
76	0		US76	US76-G	0.80 mi	US76/S161	0.68 mi	East	West	Right	34.575333 N	82.712583
77	R1-2	Yield	US76	US76-G	0.80 mi	US76/S161	0.70 mi	East	West	Right	34.575014 N	82.712550
78	0		US76	US76-G	0.80 mi	US76/S161	0.70 mi	West	East	Right	34.574197 N	82.712264
79	0		US76	US76-G	0.80 mi	US76/S161	0.70 mi	West	East	Right	34.574147 N	82.712333
80	M3-3	Cardinal Directi	US76	US76-G	0.80 mi	US76/S161	0.79 mi	West	East	Right	34.574147 N	82.712333
81	M1-1	Interstate Shiel	US76	US76-G	0.80 mi	US76/S161	0.79 mi	West	East	Right	34.574147 N	82.712333
82	0		US76	US76-G	0.80 mi	US76/S161	0.79 mi	West	East	Right	34.574147 N	82.712333
83	0		US76	US76-G	0.80 mi	US76/S161	0.75 mi	West	East	Right	34.574497 N	82.712214
84	0		US76	US76-G	0.80 mi	US76/S161	0.75 mi	West	East	Right	34.574497 N	82.712214
85	0		US76	US76-G	0.80 mi	US76/S161	0.75 mi	West	East	Right	34.574497 N	82.712214
86	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.70 mi	West	East	Right	34.575364 N	82.712314
87	R1-2	Yield	US76	US76-G	0.80 mi	US76/S161	0.70 mi	West	East	Right	34.575600 N	82.712500
88	R2-1	Speed Limit	US76	US76-G	0.80 mi	US76/S161	0.62 mi	West	East	Right	34.576100 N	82.712814
89	M3-4	Cardinal Directi	US76	US76-G	0.80 mi	US76/S161	0.60 mi	West	East	Right	34.576367 N	82.713000
90	M1-6	State Route Ma	US76	US76-G	0.80 mi	US76/S161	0.60 mi	West	East	Right	34.576367 N	82.713000
91	M1-4	US Route Mark	US76	US76-G	0.80 mi	US76/S161	0.60 mi	West	West	Right	34.576367 N	82.713000
92	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.60 mi	West	East	Right	34.576367 N	82.713000
93	R6-1L	One Way/Left	US76	US76-G'	0.80 mi	US76/S161	0.59 mi	West	East	Right	34.576350 N	82.713031
94	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.55 mi	West	East	Right	34.576947 N	82.713300
95	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.50 mi	West	East	Right	34.577833 N	82.713681
96	R8-3	Parking Regula	US76	US76-G	0.80 mi	US76/S161	0.46 mi	West	East	Right	34.578133 N	82.713800

Anderson County Pilot Data

Label	Code	Description	Route	Link ID	Link Le	Node Back	Dist B	Travel	Sign D	Position	X/Latitude	Y/Longitud
97	CD-1	Evacuation Ro	US76	US76-G	0.80 mi	US76/S161	0.45 mi	West	East	Median	34.578433 N	82.713900
98	R5-1A	Wrong Way	US76	US76-G	0.80 mi	US76/S161	0.42 mi	West	East	Right	34.579050 N	82.714081
99	CD-1	Evacuation Ro	US76	US76-G	0.80 mi	US76/S161	0.40 mi	West	West	Right	34.579581 N	82.714317
100	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.36 mi	West	West	Median	34.579617 N	82.714347
101	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.36 mi	West	East	Median	34.579617 N	82.714347
102	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.35 mi	West	West	Median	34.579631 N	82.714517
103	R11-1	Keep Off Media	US76	US76-G	0.80 mi	US76/S161	0.30 mi	West	West	Median	34.580097 N	82.715197
104	0		US76	US76-G	0.80 mi	US76/S161	0.29 mi	West	West	Median	34.580147 N	82.715283
105	W3-1	Stop Ahead	US76	US76-G	0.80 mi	US76/S161	0.29 mi	West	East	Right	34.580147 N	82.715283
106	R2-1	Speed Limit	US76	US76-G	0.80 mi	US76/S161	0.25 mi	West	West	Median	34.580317 N	82.715714
107	R2-1	Speed Limit	US76	US76-G	0.80 mi	US76/S161	0.25 mi	West	West	Right	34.580317 N	82.715714
108	R5-1A	Wrong Way	US76	US76-G	0.80 mi	US76/S161	0.25 mi	West	West	Median	34.580317 N	82.715714
109	R5-1A	Wrong Way	US76	US76-G	0.80 mi	US76/S161	0.25 mi	West	West	Median	34.580317 N	82.715714
110	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.22 mi	West	West	Right	34.580497 N	82.716431
111	R5-1	Do Not Enter	US76	US76-G	0.80 mi	US76/S161	0.22 mi	West	West	Right	34.580497 N	82.716431
112	R1-1	Stop	US76	US76-G	0.80 mi	US76/S161	0.20 mi	West	East	Right	34.580617 N	82.716831
113	R4-3	Slower Traffic	US76	US76-G	0.80 mi	US76/S161	0.10 mi	West	East	Right	34.581083 N	82.718964
114	W2-1	Cross Road	US76	US76-F	0.55 mi	US76/S373	0.54 mi	West	East	Right	34.581664 N	82.721433
115	0		US76	US76-F	0.55 mi	US76/S373	0.10 mi	West	East	Right	34.582517 N	82.729117
116	0		US76	US76-E	0.65 mi	US76/S273	-0.40	West	East	Right	34.590114 N	82.728164
117	R2-1	Speed Limit	US76	US76-E	1.41 mi	US76/S273	-0.65	West	East	Right	34.592883 N	82.730347
118	W3-3	Signal Ahead	US76	US76-E	1.41 mi	US76/S273	0.00 mi	West	East	Right	34.593433 N	82.730747
119	0		US76	US76-D	0.14 mi	US76/S58	0.05 mi	West	East	Right	34.595017 N	82.732267
120	R8-3	Parking Regula	US76	US76-D	0.14 mi	US76/S58	0.04 mi	West	East	Right	34.595131 N	82.732400
121	R2-1	Speed Limit	US76	US76-C	0.86 mi	US76/S933	0.85 mi	West	East	Right	34.596147 N	82.750350
122	M3-4	Cardinal Directi	US76	US76-C	0.86 mi	US76/S933	0.80 mi	West	East	Right	34.596397 N	82.750514
123	M1-4	US Route Mark	US76	US76-C	0.86 mi	US76/S933	0.80 mi	West	East	Right	34.596397 N	82.750514
124	M1-6	State Route Ma	US76	US76-C	0.86 mi	US76/S933	0.80 mi	West	East	Right	34.596397 N	82.750514
125	W2-2	Side Road (90	US76	US76-C	0.86 mi	US76/S933	0.45 mi	West	East	Right	34.599833 N	82.755683
126	0		US76	US76-C	0.86 mi	US76/S933	0.35 mi	West	East	Right	34.600900 N	82.756814
127	R2-1	Speed Limit	US76	US76-C	0.86 mi	US76/S933	0.25 mi	West	East	Right	34.602031 N	82.757767
128	W1-2L	Left Curve	US76	US76-C	0.86 mi	US76/S933	0.20 mi	West	East	Right	34.602597 N	82.758317

Anderson County Pilot Data

Label	Code	Description	Route	Link ID	Link Le	Node Back	Dist B	Travel	Sign D	Position	X/Latitude	Y/Longitud
129	W8-5	Slippery When	US76	US76-C	0.86 mi	US76/S933	0.15 mi	West	East	Right	34.603083 N	82.758697
130	W13-1	Advisory Spee	US76	US76-C	0.86 mi	US76/S933	0.15 mi	West	East	Right	34.603083 N	82.758697
131	G20-2	End Constructi	US76	US76-C	0.86 mi	US76/S933	0.01 mi	West	East	Right	34.604350 N	82.760531
132	0		US76	US76-C	0.86 mi	US76/S933	0.01 mi	West	East	Right	34.604317 N	82.760681
134	S3-1	School Bus Sto	US76	US76-B	0.64 mi	US76/S162	1.00 mi	West	East	Right	34.606433 N	82.765614
135	W3-3	Signal Ahead	US76	US76-B	0.64 mi	US76/S162	1.00 mi	West	East	Right	34.608297 N	82.767050
136	0		US76	US76-B	0.64 mi	US76/S162	0.87 mi	West	East	Right	34.609783 N	82.768117
137	0		US76	US76-A	1.15 mi	US76/SC187	1.10 mi	West	East	Right	34.610350 N	82.768233
138	0		US76	US76-A	1.15 mi	US76/SC187	1.10 mi	West	East	Right	34.610350 N	82.768233
139	R4-7	Keep Right	US76	US76-A	1.15 mi	US76/SC187	0.59 mi	West	West	Median	34.618033 N	82.773767
140	W3-3	Signal Ahead	US76	US76-A	1.15 mi	US76/SC187	0.10 mi	West	East	Right	34.623481 N	82.777950
141	M2-2	Combination Ju	US76	US76-A	1.15 mi	US76/SC187	0.09 mi	West	East	Right	34.623783 N	82.778114
142	M1-6	State Route Ma	US76	US76-A	1.15 mi	US76/SC187	0.09 mi	West	East	Right	34.623783 N	82.778114
143	0		US76	US76-A	1.15 mi	US76/SC187	0.08 mi	West	East	Right	34.624297 N	82.778300
144	0		US76	US76-A	1.15 mi	US76/SC187	0.08 mi	West	East	Right	34.625531 N	82.778867
145	M1-6	State Route Ma	US76	US76-A	1.15 mi	US76/SC187	0.00 mi	West	East	Right	34.625531 N	82.778867
146	M6-2	Directional Arro	US76	US76-A	1.15 mi	US76/SC187	0.00 mi	West	East	Right	34.625531 N	82.778867
147	E5-1A	Gore/Exit Num	I 85	I85-A	6.00 mi	I85/US76	0.00 mi	South	North	Right	34.575781 N	82.711767
148	0		I 85	I85-A	6.00 mi	I85/US76	0.00 mi	South	North	Right	34.575781 N	82.711767
149	WB-1		I 85	I85-A	6.00 mi	I85/US76	0.00 mi	South	North	Right	34.575781 N	82.711767
150	W4-1	Merge	I 85	I85-A	6.00 mi	I85/US76	0.00 mi	South	North	Right	34.575850 N	82.712914
151	D10-5	Expressway Mil	I 85	I85-A	6.00 mi	I85/US76	0.00 mi	South	North	Right	34.575664 N	82.718583
152	M3-3	Cardinal Directi	I 85	I85-A	6.00 mi	I85/US76	0.53 mi	South	North	Right	34.575600 N	82.719567
153	M1-1	Interstate Shiel	I 85	I85-A	6.00 mi	I85/US76	0.53 mi	South	North	Right	34.575600 N	82.719567
154	R2-1	Speed Limit	I 85	I85-A	6.00 mi	I85/US76	0.70 mi	South	North	Right	34.575033 N	82.722881
155	R2-4B		I 85	I85-A	6.00 mi	I85/US76	0.70 mi	South	North	Right	34.575033 N	82.722881
156	D2-2	Double Destina	I 85	I85-A	6.00 mi	I85/US76	0.88 mi	South	North	Right	34.573997 N	82.725483
157	0		I 85	I85-A	6.00 mi	I85/US76	0.98 mi	South	North	Right	34.573167 N	82.726897
158	0		I 85	I85-A	6.00 mi	I85/US76	1.50 mi	South	North	Right	34.570050 N	82.735081
159	D10-5	Expressway Mil	I 85	I85-A	6.00 mi	I85/US76	2.55 mi	South	North	Right	34.566250 N	82.751967
160	0		I 85	I85-A	6.00 mi	I85/US76	2.80 mi	South	North	Right	34.565633 N	82.755533
161	D10-5	Expressway Mil	I 85	I85-A	6.00 mi	I85/US76	3.60 mi	South	North	Right	34.562033 N	82.768197

Anderson County Pilot Data

Label	Code	Description	Route	Link ID	Link Le	Node Back	Dist B	Travel	Sign D	Position	X/Latitude	Y/Longitud
162	R4-3	Slower Traffic	I 85	I85-A	6.00 mi	I85/US76	4.25 mi	South	North	Right	34.558633 N	82.778314
163	0		I 85	I85-A	6.00 mi	I85/US76	4.55 mi	South	North	Right	34.556950 N	82.783297
164	D10-5	Expressway Mil	I 85	I85-A	6.00 mi	I85/US76	4.63 mi	South	North	Right	34.556564 N	82.784714
165	0		I 85	I85-A	6.00 mi	I85/US76	4.72 mi	South	North	Right	34.556233 N	82.786117
166	0		I 85	I85-A	6.00 mi	I85/US76	4.80 mi	South	North	Right	34.555797 N	82.787864
167	0		I 85	I85-A	6.00 mi	I85/US76	4.80 mi	South	North	Median	34.555797 N	82.787864
168	0		I 85	I85-A	6.00 mi	I85/US76	4.85 mi	South	North	Right	34.555617 N	82.788531
169	0		I 85	I85-A	6.00 mi	I85/US76	5.00 mi	South	North	Right	34.554781 N	82.790864
170	0		I 85	I85-A	6.00 mi	I85/US76	5.20 mi	South	North	Right	34.553700 N	82.793914
171	0		I 85	I85-A	6.00 mi	I85/US76	5.35 mi	South	North	Right	34.553064 N	82.795983
172	0		I 85	I85-A	6.00 mi	I85/US76	5.35 mi	South	North	Right	34.553064 N	82.795983
173	D10-5	Expressway Mil	I 85	I85-A	6.00 mi	I85/US76	5.70 mi	South	North	Right	34.551681 N	82.801131
174	0		I 85	I85-A	6.00 mi	I85/US76	5.50 mi	South	North	Right	34.552597 N	82.798250
175	0		I 85	I85-A	6.00 mi	I85/US76	5.50 mi	South	North	Right	34.552597 N	82.798250
176	E5-1A	Gore/Exit Num	I 85	I85-A	6.00 mi	I85/US76	5.80 mi	South	North	Right	34.551100 N	82.803050
177	0		I 85	I85-A	6.00 mi	I85/US76	5.83 mi	North	South	Right	34.550931 N	82.803483
178	W3-1A	Stop Ahead	I 85	I85-A	6.00 mi	I85/US76	5.83 mi	North	South	Right	34.550531 N	82.804500
179	R5-1A	Wrong Way	I 85	I85-A	6.00 mi	I85/US76	5.90 mi	North	South	Right	34.550300 N	82.804917
180	R5-1A	Wrong Way	I 85	I85-A	6.00 mi	I85/US76	5.90 mi	North	South	Right	34.550300 N	82.804917
181	R5-1	Do Not Enter	I 85	I85-A	6.00 mi	I85/US76	0.00 mi	North	South	Right	34.550133 N	82.805617
182	R5-1	Do Not Enter	I 85	I85-A	6.00 mi	I85/US76	0.00 mi	North	South	Right	34.550133 N	82.805617
183	CD-1	Evacuation Ro	I 85	I85-A	6.00 mi	I85/US76	0.00 mi	North	South	Right	34.550214 N	82.806350
184	0		I 85	I85-A	6.00 mi	I85/US76	0.00 mi	North	North	Right	34.550214 N	82.806350
185	R6-2L	One Way/Left	I 85	I85-A	6.00 mi	I85/US76	0.00 mi	North	South	Right	34.550214 N	82.806350
186	R1-1	Stop	I 85	I85-A	6.00 mi	I85/US76	5.90 mi	South	North	Right	34.550400 N	82.806533

Appendix B

SignView Field Description

FIELD DESCRIPTION

The fields below are the fields necessary to control a sign inventory system. They all are presented in the Single Form sheet of the CarteGraph SignView. The Form is a screen mask where input and output movements through the screen are processed. Some of these fields are presented in other forms, and in the case that they can only be changed from those forms, the forms names will be between parenthesis.
The fields are grouped by function and each field is described regarding type of data, information contained and length if important. When the type of data is "Automatically Referenced" it means that it can only be changed in the original files - Sign Library, Node Library, Link Library, and Schedule Activities.
There are more available fields than listed below, only those that have major impact on the control performance are listed.

History Fields Group

These field describes information of historical significance regarding activities in the signs.

Origin Date
[Date]
Records the date that a sign was installed in service.

Retire Date
[Date]
Records the date that the sign was removed from service. The retire date entry is made when the sign is not physically present in the road.

Sign Rate
[List of Options]
The sign rate is a choice among a list of options. Initially the database has options that range from Poor to Excellent based in the supervisor's opinion. When using the retroreflectometer, a system to chose rates without subjectivity choices must be developed.

Support Rating
[List of Options]
Rate attributed to the quality of the sign support. The SCDOT is not at present concerned with the supports.

Visibility
[List of Options]
This field defines sign visibility. The SCDOT personnel must be trained to ensure consistent evaluations.

Retroreflectivity 1
[Number]
This field records the measurement of the reflective capacity of the primary area of sheeting material on the sign. These numbers must be provided by the retroreflectometer.

Retroreflectivity 2
[Number]
This is the same as above except that it is measured in the non-primary area.

Last Date
[Date (History Log Book)]
The last date field records the last time a change in the record was made, originally the field was created to control the date of the last activity, but during the research it was found that keeping the last change in the file would be a more valuable information.

Last Activity
[Date (Schedule Activities)]
This fields records the last work activity date for a sign. The activity can be any of controlled activity including inspections.

Next Activity
[Date (Schedule Activities)]
This field displays the next work activity scheduled for a sign. It is part of a maintenance plan and it must be recorded in the Schedule Activity form.

User Defined Fields Group

These fields are defined by the user. It was determined during the research that four additional user defined fields were required to meet SCDOT requirements.

Warehouse
[List of Options]
This fields assigns a warehouse during the time between manufacturing and installation date. Every time that a sign is moved from one warehouse or workshop to another this field must reflect this change.

Bin
[Number]
Number of the box, or shelf, or bin in the warehouse where the sign is stored. This field is very helpful to warehouse staff since it can facilitate a FIFO (first in - first out) system, or the releasing of signs of specific materials to specific regions.

Location
[Number]
Location is a field that usually has the same number of the first sign installed in a nearby location with the same purpose. The main idea is to keep track of a sign location even if a substitute sign is moved some few yards from the previous one.

Manufac. Date
[date]
Date sign forwarded from the manufacturing facility.

Identification Group

This group contains general information about its type. This information is the same for all signs with the same MUTCD code except for size and some text (in the case of information signs)

Label
[Number]
A unique number to identify a sign. This number will stay the same for the duration of sign life. The labels should have both human readable and bar code label printings.

Code
[Alphanumeric -List of Options (Sign Library)]
The code field is selected from the Federal MUTCD Sign Library following the conventions established in the Federal Highway Administration's "Manual on Uniform Traffic Control Devices". The code is unique for each type of sign (ex: stop sign, speed limit, 4 Way sign...). It is defined based in the sign objective.

Size
[List of Options]
This field contain information about the sign size. A single MUTCD code may have multiple sizes from which to choose.

Memo
[Alphanumeric]
This field permits the recording of specific information related to the selected sign. For example, a sign identifying an interstate road has the format "I [00]" in the MUTCD code, where [00] can be any interstate number. The identification of that specific interstate will be noted in this field. Then the Memo field would thus contain "I 85".

Description
[Automatically Referenced (Sign Library)]
This field describes the nature or purpose of a sign. It is carried from the Sign Library and therefore can be only modified through that library.

Text
[Automatically referenced (Sign Library)]
This field describes the text that appears on the sign face.

Symbol
[Automatically referenced (Sign Library)]
This field gives a name to the symbol that appears on the face of a sign.

Code 2
[Automatically referenced (Sign Library)]
This field is used to take note of the Federal MUTCD original code when the SCDOT code is different. It helps to keep track of the relation between code as well as control all signs that are not part of the Federal standards. An example is the "Bridge Ices Before Road" sign that is used in the state of South Carolina, but it is not part of the Federal set of signs.

Shape
[Automatically referenced (Sign Library)]
The Shape field describes the geometric form of a sign.

Class
[Automatically referenced (Sign Library)]
The Class field defines the functional classification of a sign. The classification is a list of options based on the functional parameters of the sign.

Action
[Automatically referenced (Sign Library)]
Describes the action required of the driver or pedestrian when the sign is encountered.

Legend Colors
[Automatically referenced (Sign Library)]
Identifies the predominant color in which the Text or Symbol appears on a sign. The list of options is based on the regulations, and are available in the Sign Library.

Background Colors
[Automatically referenced (Sign Library)]
The predominant color on the sign background.

Features Group

This group contains information pertinent to a specific sign. This information will probably vary from sign to sign even for signs with the same MUTCD code.

Backing
[List of Options]
The backing field describes the material used to manufacture the sign structure.

Sheeting
[List of Options]
In this field it is recorded the material presented on the face of a sign, usually it is a film with specifications very well known to SCDOT personnel.

Illumination
[List of Options]
Describes, if exist, any auxiliary device that helps to illuminate the sign.

Reflectorization
[List of Options]
List all reflective elements, if any, presented on a sign. Usually these elements are round buttons that helps the driver to see the sign post.

Speed Limit
[List of Options]
The Speed Limit field allows the user to record the posted speed limit at the point along a route where a sign is located. This is very useful to identify places where the distance among signs are not compatible with speed limit, i.e. sign pollution.

Location

This group of fields contains information about the location and the road network organization.

Link ID
[Link Name (Sign Library)]
The link ID field allows the user to record and track the link or segment of roadway with which the sign is associated. When selecting a link all information regarding the link - route, route ahead, route back, link length, etc. - is carried to the sign record.

Travel Dir.
[Geographic Directions Options - North/South/East/West]
This field records the direction of travel. This important information defines the side of the road and defines its relative position related to the nodes back and ahead which are unchangeable.

Node Back
[Name (Node Library)]
When defining the link the node back is also defined and is not modified even for changing the travel direction.

Distance Back
[Number of Miles (Link Library)]
This field records the distance from the node back to the sign. It is the most useful way to find a sign or a missing sign. This distance measure is obtained using the vehicle odometer. Once entered the distance back, the system automatically calculates the distance ahead based on the link length.

Node Ahead
[Name (Node Library)]
When defining the link, the node ahead is also defined and is not modified even for changing the travel direction.

Distance Ahead
[Number of Miles]
As the previous field, it is used to locate a sign. It contains the distance from the node ahead to the sign. When manually entered, the system will automatically calculate the distance back based on the link length.

Offset
[Distance in feet]
The distance from the baseline to the nearest edge of a sign.

Sign Direction
Geographic Directions Options - North/South/East/West
This field defines the direction that a sign is facing. For example, if the travel direction is north and the sign is turned to the driver, then the sign direction will be South. It was assumed during the research that leaving this field blank means that the sign is turned to the driver. Usually Wrong Way signs and Do Not Enter signs are turned against the driver.

Length
[Number of Miles (Link Library)]
The length field is used to record the value for the length of a link contained in the Link Library.

Route Name
[Name - List of Options (Link Library)]
The name of the route on which the sign is installed.

Route Back
[Name (link Library)]
The name of the nearest route that makes an intersection with the route where the sign is located. The back position is defined when creating the link.

Route Ahead
[Name (link Library)]
The name of the nearest route that makes an intersection with the route where the sign is located. The ahead position is defined when creating the link.

Node ID
[Node Name - List of Options (Node Library)]
The name of the node located at the start or end of a link. The name is formed by the name of the most important route plus the "slash" sign, and the name of the minor route. In case of routes with apparently the same importance, the smaller route number comes first, For example, the node at the intersection of US 76 with Interstate 85 is named "I85/US76". The hierarchy is listed in the order below:
1- Interstate Highway
2- U.S Highway
3- State Highway
4- Secondary Road

5- County Highway
6- City Street

<u>Site ID</u>
[List of Options - Defined by the user.]
The user can define a site name to group a related set of signs. For example, a bridge number and name can be defined as Site ID and used to relate all signs over that. This field is not required.

Coordinate Group

This group contains fields that help position a sign based in geographic coordinate system. The information can be obtained using a Global Positioning System - GPS.

<u>Latitude</u>
[Degrees, minutes and seconds]
Degrees of the sign latitude encountered in the GPS. The SignView software can read directly from the GPS into the computer using GPSlink.

<u>Longitude</u>
[Degrees, minutes and seconds]
Degrees of the sign longitude encountered in the GPS. The SignView software can read directly from the GPS into the computer.

Appendix C

Source Code for Program Reader.prg

```
/*

PROGRAM: READER.PRG

*/

#define ONE 1
#define TWO 2
#define THREE 3
#define FOUR 4
#define FIVE 5
#define tTAB 9
#define tESC 27
#define DTA CTOD("01/01/97")
#define PIC Picture
#define CHO When Choice=
#define COR COLOR ("B/W,W/B")
#define BELL ? CHR(7)

#define NewSign 1
#define ExistSign 2
#define InstSign 3

#define ADDMutc 1
#define EDITMutc 2
#define FINDMutc 3
#define Add_Loca 1
#define Edit_Loca 2

#define tUP 5
#define tDOWN 24
#define tLEFT 19
#define tRIGHT 4
#define tPGDOWN 3
#define tPGUP 18
#define tEND 6
#define tHOME 1
#define tINS 22
#define tDEL 7

Procedure  Main

Local vTrue:=.F., x:=0
Public  vMutc:=space(11), vSign:=0, vMate:=space(10), vFilm:=space(10)
Public  vEntr:=DTA, vComm:=space(25)
```

```
clear
SET EXACT ON
SET WRAP ON
SET COLOR TO
BlankAll()
OpenFiles()
vEntr:=DATE()

@ 1,1 SAY "Input NEW Sign"
@ 6,1  SAy "MUTCD :"
@10,1 Say "Backing:"
@12,1 Say "Sheeting:"
@14,1 Say "Comments:"

DO WHILE .T.
        @ 1,1 SAY  "Input NEW Sign"
        @ 6,1  SAy "MUTCD :" GET vMutc PIC "@!" COR
        @10,1  Say "Backing:" GET vMate PIC "@!" COR
        @12,1  Say "Sheeting:" GET vFilm PIC "@!" COR
        @14,1  Say "Comments:" GET vComm PIC "@!" COR
        READ
    DO WHILE .T.
        @2,1  Say "Sign #:" GET vSign PIC "9999999999" COR
        READ
        If vSign=0
            EXIT
        Endif
        Select ReadB
        Seek vSign
        vTrue:=Found()
        If vTrue
            @3,1 Say "Sign Exist"
        Else
            @3,1 Say "          "
            SELECT ReadB
            APPEND BLANK
            CopyVarSignToField()
            BELL
        Endif
    Enddo
    Clear
    @3,1 Say "[Enter]=Continue"
    @4,1 Say "OTHER = End"
    x:=0
```

```
    DO WHILE x=0
        x:=Inkey()
    Enddo
    @3,1 Say "          "
    @4,1 Say "          "
    If x<>13
        Exit
    Endif
Enddo
CLOSE ALL
Clear
Return
/*****************************************************************/
Procedure CopyFieldToVarSign()
    vMutc:=ReadB->CODE
    vSign:=ReadB->LABEL
    vMate:=ReadB->BACKING
    vFilm:=ReadB->SHEETING
    vComm:=ReadB->MEMO
Return

Procedure CopyVarSignToField()

    ReadB->CODE:=vMutc
    ReadB->LABEL:=vSign
    ReadB->BACKING:=vMate
    ReadB->SHEETING:=vFilm
    ReadB->MEMO:=vComm
Return

Procedure OpenFiles()
    Use "ReadB" new
    Index on LABEL to ReadB
Return

Procedure BlankAll()
    vMutc:=space(11)
    vSign:=0
    vMate:=space(10)
    vFilm:=space(10)
    vComm:=space(25)
Return
```

Appendix D

Source Code for Program BC.prg

```
/*
PROGRAM: BC.PRG
*/

#define ONE 1
#define TWO 2
#define THREE 3
#define FOUR 4
#define FIVE 5
#define tTAB 9
#define tESC 27
#define DTA CTOD("01/01/97")
#define PIC Picture
#define CHO When Choice=
#define COR COLOR ("B/W,W/B")
#define BELL ? CHR(7)

#define tUP 5
#define tDOWN 24
#define tLEFT 19
#define tRIGHT 4
#define tPGDOWN 3
#define tPGUP 18
#define tEND 6
#define tHOME 1
#define tINS 22
#define tDEL 7

Procedure  Main

Local vTrue:=.F., x:=0
Public  vCode:=space(8), vLabel:=0, vDist:=0
clear
SET EXACT ON
SET WRAP ON
SET COLOR TO
BlankAll()
OpenFiles()
vEntr:=DATE()

@ 1,1 SAY  "Read :"
@ 3,1  SAy "MUTCD:"
@ 5,1  Say "Route:"
@ 7,1 Say  "Back :"
@ 8,1 Say  "Dist.:"
```

```
DO WHILE .T.
        @ 1,1  SAy "READ :" GET vLabel PIC "999999999" COR
        @ 3,1  SAy "MUTCD:"
        @ 5,1  Say "Route:"
        @ 7,1 Say  "Back :"
        @ 8,1 Say  "Dist.:"
        @ 9,1 Say  "Ahead:"
        @10,1 Say  "Dist.:"

        READ
        @ 2,1 say "              "
        If vLabel=0
            EXIT
        Endif
        Seek vLabel
        vTrue:=Found()
        If !vTrue
            @2,1 Say "Sign NOT FOUND"
            loop
        endif
        @ 3,7 SAy BarCode->CODE
        @ 5,7 Say BArCode->ROUTE
        @ 7,7 Say BarCode->R_BACK
        @ 8,7 Say STR(BarCode->D_BACK,6,2) + (" miles")
        @ 9,7 Say BarCode->R_AHEAD
        @10,7 Say STR(BarCode->D_AHEAD,6,2) + (" miles")
        @12,1 Say BarCode->Sheeting
        @13,1 Say BarCode->Backing
Enddo
CLOSE ALL
Clear
Return
/*****************************************************************/
Procedure OpenFiles()
    Use "ReadB" Alias BarCode new
    Index on Label to ReadB
    Set index to ReadB
Return
Procedure BlankAll()
    vLabel:=0
Return
```

Appendix E

Source Code for Program ImpExp.prg

```
/*
PROGRAM: IMPEXP.PRG
*/

#define ONE 1
#define TWO 2
#define THREE 3
#define FOUR 4
#define FIVE 5
#define tTAB 9
#define tESC 27
#define DTA CTOD("01/01/97")
#define PIC Picture
#define CHO When Choice=
#define COR COLOR ("B/W,W/B")
#define BELL ? CHR(7)

#define NewSign 1
#define ExistSign 2
#define InstSign 3

#define ADDMutc 1
#define EDITMutc 2
#define FINDMutc 3

#define Add_Loca 1
#define Edit_Loca 2

#define tUP 5
#define tDOWN 24
#define tLEFT 19
#define tRIGHT 4
#define tPGDOWN 3
#define tPGUP 18
#define tEND 6
#define tHOME 1
#define tINS 22
#define tDEL 7

Procedure  Main(ACTION,FILE)

Local vTrue:=.F., x:=0

Public  vMutc:=space(11), vSign:=0, vMate:=space(10), vFilm:=space(10)
Public  vEntr:=DTA, vComm:=space(25)
```

```
clear
SET EXACT ON
SET WRAP ON
SET COLOR TO
OpenFiles()

if ACTION="ToSystem"
    Copy To (FILE) DELIMITED
Elseif ACTION="ToReader"
    DELETE ALL
    PACK
    APPEND FROM (FILE) DELIMITED
    reindex
ENDIF

CLOSE ALL
Clear
Return

/****************************************************************/

Procedure OpenFiles()
    Use "ReadB" new
    Index on LABEL to ReadB
Return
```

Appendix F

Guidance for SCDOT Implementation Plan

Sign Location

Clover-leaf

For signs that are located within clover-leaf intersection, the distance from the nodes should be measured from the node to the exact sign location, and the sign direction. However, it should be noted in the memo field that the sign is located in a clover-leaf intersection.

Non-controlled roads

The approach for signs located in non-controlled roads, such as county roads and city roads, is the same as used for other signs, except that the distance from the nodes is measured from the node to the intersection of the controlled road and the non-controlled road. In the memo field it should be noted the distance from the intersection to the sign.

Terminology

In the final stage of the implementation plan the SCDOT Sign Management System would be completely linked in one state network. The major consideration regarding connecting all offices would be related to the terminology used. It is very important to standardize the terminology to avoid conflicts of information.

Consistency

Units

The units used in the survey must be the same for the entire state. The units to be used must be stated in the written implementation plan. Entering different forms for subunits will give unpredictable outputs. Examples of different units are: the measurement of distance in miles by one team, and by feet by another team; measuring distance using miles and feet, and miles and decimal miles; describing geographical coordinates using degrees, minutes and seconds in one form, and degrees and decimal degrees in another one.

SignView

Screens

SignView has screen formatting capabilities. For each screen format there is a corresponding name. The uniformity in the use of the names on different computers of the state network will avoid misunderstandings when issues are discussed or analyzed between different districts.

Link Name Field

When using this field, the user should avoid using the red button, which carries information to new signs. Using the red button feature can cause problems in the association of the link name to the link library.

Typing Information

Whenever there is the option list available, the user should make use of it rather than type the information directly in the field. Sometimes when the user types the information, other information related to that field fails to be updated.

Links Names

Before deciding on link names, SCDOT offices should identify the roads that pertain to more than one district, and then assign different letter suffixes. For example: the road US 76 could be divided in links called US76-AA, US76-AB, US76-AC. . . , US76-ZZ. The SCDOT Pickens office could reserve suffixes AA to BZ, the Anderson office would reserve suffixes from CA to DZ, and so on. Another solution would be to give suffixes beginning with three letters identifying the county (e.g., names for US 76 within Anderson County: US76-AND1, US76-AND2, . . .).

Node Names

Sometimes a road can intersect another road more than once. In these cases the node names must have a suffix to avoid two or more nodes with the same name. A problem arises when intersections occurs in different counties. Before expanding the implementation plan to cover more than one county, SCDOT personnel must identify all occurrences of multiple intersections between two roads.

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