INTEGRATION OF GIS INTO PAVEMENT MANAGEMENT SYSTEMS FOR LOW

VOLUME COUNTY ROADS

Except where reference is made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee. This thesis does not include proprietary or classified information.

_____
David Michael Grass

Certificate of Approval:

_____   _____
David Timm   Mary Stroup-Gardiner, Chair
Associate Professor   Professor
Civil Engineering   Civil Engineering

_____   _____
Wesley C. Zech   George T. Flowers
Assistant Professor   Interim Dean
Civil Engineering   Graduate School

INTEGRATION OF GIS INTO PAVEMENT MANAGEMENT SYTSEMS FOR LOW

VOLUME COUNTY ROADS

David Michael Grass

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Science

Auburn, Alabama
May 10, 2007

INTEGRATION OF GIS INTO PAVEMENT MANAGEMENT SYSTEMS FOR LOW

VOLUME COUNTY ROADS

David Michael Grass

_____
Signature of Author

_____
Date of Graduation

VITA

David Michael Grass, son of Kevin Grass and Ann Cofer, was born July 13, 1982, in Tulsa, OK. He graduated with honors from Cleveland High School in Cleveland, TN, in the year 2000. He attended the University of Tennessee at Chattanooga. In 2005, he graduated magna cum laude and ranked #1 in the College of Engineering with a Bachelor of Science in Civil Engineering. He then entered Graduate School, at Auburn University in August 2005, where he worked as a Graduate Teaching Assistant for the Civil Engineering Department in the materials laboratory.

THESIS ABSTRACT

INTEGRATION OF GIS INTO PAVEMENT MANAGEMENT SYSTEMS FOR LOW

VOLUME COUNTY ROADS

David Michael Grass

Master of Science, May 10, 2007
(B.S., University of Tennessee at Chattanooga, 2005)

165 Typed Pages

Directed by Mary Stroup-Gardiner

Geographic Information Systems (GIS) have often been used for highway pavement management (PM), but rarely for low volume county roadway systems. Methods for implementing GIS as a useful tool for county engineers in pavement management systems were developed and examples of decision making applications are provided. Supplementary data sources and how they can be beneficial to these management systems are also described.

Conclusions include the effectiveness of GIS as a tool within county pavement management systems. Also, some conclusions on how GIS improves the decision making process relating to pavement maintenance and rehabilitation activities are included.

ACKNOWLEDGEMENTS

Manual Used:

Auburn University Graduate School Guide to Preparation and Submission of Thesis and

Dissertations

Computer Software Used:

Microsoft Word

Microsoft Excel

View

ArcMap^{TM}

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION AND LITERATURE REVIEW

Section 1.1 Introduction

Pavement management systems (PMS) have been common place in state and local transportation agencies ever since the Federal Highway Administration (FHWA) issued a mandate that all states implement such a system by the early 1990's. Since the early stages of PMS, agencies have been refining and developing their own management systems to more effectively and cost-efficiently manage their assets. The advancement of PMS has been driven by the continuing progression of available technology. Along with this advancement in technology, more robust and advanced databases have been collected and are now applicable to pavement management. New equipment and systems have allowed these agencies to operate their PMS with less cost and improved efficiency aiding in better decision making when dealing with pavement maintenance.

One such piece of technology, which has most recently been introduced into asset management decision processes, is geographic information systems (GIS). A GIS is a computer based tool used to collect, store, display, and analyze data within a spatially referenced environment. For about the last decade, state departments of transportation (DOT) have been experimenting with and adapting GIS into their current PMS. Many of these implementations and studies have shown that GIS is a very useful tool when dealing with pavement management system data and analysis. GIS gives engineers the ability to monitor and make decisions on all aspects of a road network from construction

to rehabilitation. However, this concept of GIS-supported management systems has been largely confined to the management of larger highway systems such as entire state highway networks. Low volume county and rural roads are often not included in this movement toward the use of GIS, mostly because of the perceived complexity of reading simple, traditionally spreadsheet organized data. There is also concern about the time and cost of implementing GIS into a county PMS. While these concerns are valid, it can be shown that, other than the initial setup of the system, GIS is a relatively simple system to maintain and can be at a low cost depending on the extent an agency utilizes this tool.

Low volume county roads differ from state highway networks in the amount and asset management complexity, but this does not mean that they are a less worthy candidate for a PMS supported by the use of GIS. Most commonly these types of roads are managed by a system that relies heavily on pavement windshield surveys of some form, as well as the experience and judgment of the employees at the county engineer's office. However, these data can be economically and effectively managed, displayed, and analyzed using GIS presentations of condition parameters.

This thesis is the initial work focused upon developing a process of introducing GIS into PMS which includes a large population of low volume county roads, based on typical PMS data collected by Alabama counties. The development of this process is meant to show that through the use of GIS, county engineers have new tools to manage the datasets currently being utilized within their systems. Also, GIS can provide an appropriate platform to display such data in a way that is easily understood by both county officials and the general public. This thesis also presents possible supplementary sources of data; automated condition surveys and Pavement Surface Evaluation and

2

Rating Manual (PASER) based distress surveys, which can be used along with the current county PMS to improve the decision making process related to maintenance and rehabilitation activities for county roads.

The use of GIS as a management tool, along with the supplement data, may serve as a more formalized and informative view of pavement conditions for a network of county roads. The development of this process is designed so that GIS can seamlessly be integrated into the type of PMS typically used by practitioners in Alabama counties. This is important because an agency dealing with low volume county roads should be able to clearly and efficiently present pavement management data to the general public, new employees, and funding sources. Often times on low volume roads, pavement management decisions are made by county engineers based on experience and their own history with the network of roads. This experience may not be possessed by the general public or staff, new to the area. GIS provides a platform for experienced county engineers to clearly convey anything they want to about the pavement management data currently in the system. Seeing the data on a spatial presentation may also help experienced county engineers develop new ideas and concepts concerning their PMS which may have not been explored before.

The following sections contain relevant background information and literature review of GIS, automated condition surveys, PASER surveys, and pavement management systems currently utilizing these tools.

Section 1.2 History of Geographic Information Systems (GIS)

GIS is a computer based program used for handling, storing, and manipulating any type of data that contains a geographical reference (USGS 2007). Using GIS and geographically referenced data, researchers are able to perform acts such as cartography, route planning, sophisticated queries, and in-depth spatially related investigation and analyzes. To gain a better understanding of how GIS operates the following is a history of GIS and its basic components.

Cartography, the art of making maps, has been used by people to record geographic information since the Babylonians in 2300 B.C. (Aber 2007). The use of maps and the information they store has evolved since then to more sophisticated methods. The most recent evolution of maps has come in the last 30 years with GIS. GIS currently allows users to view every type of map imaginable. With the right source of data, users can display anything from land use, weather, population, and resources, to political boundaries, energy consumption, and traffic (Ormsby 2004). The first GIS systems were developed in the 1960's. The U.S. military along with the Canadian Department of Energy, Mines, and Resources both developed their own systems. Even though the architect of the Canadian version, Roger Tomlinson, is considered the "Father of GIS", both systems were very similar (AAG 2007). The first GIS was used for applications such as land inventory, census, and mapping. In the 1960's, these early systems were run on mainframe computers using primarily raster data, which is explained in greater detail in the next section (James 2007).

In the 1980's, GIS usage spread past the realm of the military. For the first time, utility companies began using the system. Along with the increased usage, GIS

underwent several improvements at this time (GIS 2007). Minicomputers were becoming

the machine of choice for GIS, and the introduction of a Graphical User Interface (GUI)

had been implemented to create a more user-friendly program. The improvements in

technology also led to the advancement in data acquisition. Global Positioning Systems

(GPS) had begun to be utilized to collect data. Remote Sensing (RS) had also been

improved through the use of aerial photography and satellite imagery.

By the 1990's, GIS was being used on personal computers by a wide range of

users with a large collection of applications. One of the more recent and vastly important

developments in GIS was the 1994 National Spatial Data Infrastructure (GIS 2007). This

act made the sharing of geographical data more available for users. This was important

because two companies in need of the same information were now able to obtain that

information without both paying for the data acquisition.

Section 1.3 Basic Components of GIS

The Environmental Systems Research Institute, Inc. (ESRI) produces the most

widely used desktop GIS, ArcGIS^{TM}. ArcGIS^{TM} is a collection of several desktop GIS

applications that can be used on personal computers. The different applications include

ArcMap^{TM}, ArcCatalog^{TM}, ArcToolbox^{TM}, ModelBuilder^{TM}, and ArcGlobe^{TM}.

ArcCatalog^{TM} and ArcMap^{TM} are the main two entities which will be covered here.

ArcCatalog^{TM} serves as an organizational application for GIS information. It

manages elements such as maps, tables, datasets, models, and metadata. Metadata is the

information concerning the content, condition, source, and other details about the GIS

data. In ArcCatalog^{TM}, a user may search for files, preview files and databases, view

attribute tables, and view/edit metadata. ArcCatalog^TM also allows users to organize files so that none are misplaced. This is the best place to change locations of GIS files being that many map projects contain several files and these projects are file location sensitive (ESRI$_a$ 2007).

Another main application in the ArcGIS^TM desktop package is ArcMap^TM. This program is the primary location for developing map projects through the addition and manipulation of GIS files. This application utilizes two types of map views; a geographic data view and a page layout view. Building and analyzing maps are both accomplished within the geographic data view (ESRI$_b$ 2007).

Creating a map in ArcMap^TM is accomplished by the addition of geographic layers one on top of another. Layers are a collection of geographic objects that are similar spatially (Ormsby 2004). These layers can be raster data, especially when dealing with land cover, but also will contain vector data. Raster data consists of a layer of grid cell with each cell containing a specific value. Vector data is used when portraying cities, rivers, roads, buildings, lakes and other discrete features (ESRI$_c$ 2007).

Vector data is data based on geometric primitives, located by coordinate measurements in a spatially referenced system (Chrisman 2002). This type of data is an object based data model that contains geometric objects including points, areas, or polygons with topology, magnitude and direction, which also may possess multiple attributes and connectivity between to features. These geometric objects are called features (Ormsby 2004). An example of a vector data layer would be a collection of line feature representing roads. Each road would be comprised of one or more line features which contain data describing the road such as length, direction, name, etc. Such an

6

example of this can be seen in Figure 1.3-1. Here vector data is used to represent streets in a city, as well as, customers and parcels. This also shows how different geometric objects are applicable to different situations. Scale also affects which geometric object is appropriate. For example, when looking an individual county a city may be better represented by a collection of lines representing streets, while that same city may be represented by a point if viewing the entire state.

The other form of data, raster data is defined as "a spatial data model based upon a regular tessellation of a surface into pixels or grid cells" (Chrisman 2002). Layers at times represent things that do not have any distinct shape. Rainfall, temperature, elevation, and soil type do not have defined boundaries (Ormsby 2004). This type of layer would then be comprised of raster data. This layer would consist of a rectangular grid of pixels, or points of color, which may contain a single attribute, or data value, per cell. Raster data is very useful for continuous data such as land cover and is often obtained using remote sensing (ESRI$_c$ 2007). An example of raster data can be seen in Figure 1.3-1. Here raster data is shown to represent both elevation and land usage. Both use individual cell values to comprise a continuous layer of data. Overlaying vector and raster data gives a user a more detailed and comprehensive view of real world situations.
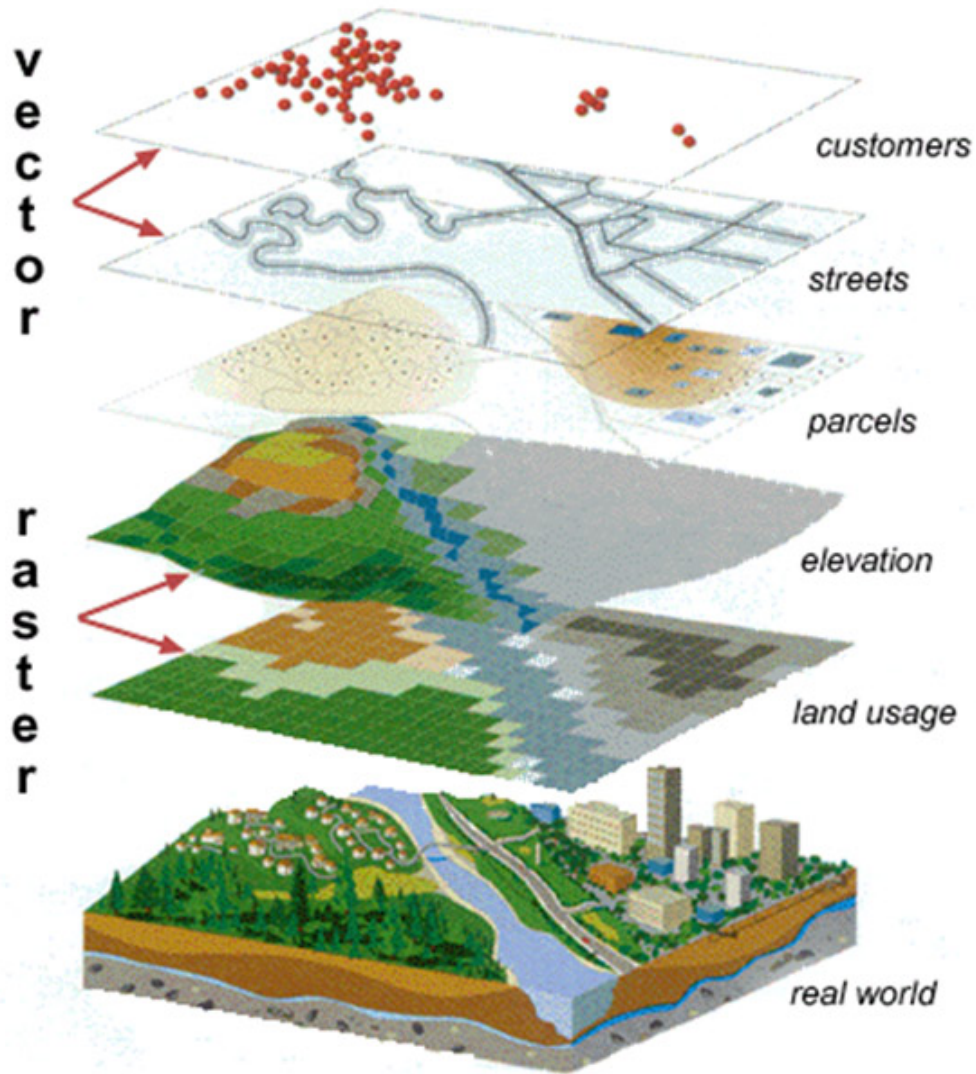
Figure 1.3-1 Vector and Raster Data Examples (Hill 2006)

The two most important aspects of vector and raster data in GIS is the fact that they both contain spatial location and spatial information linked to them. The location in GIS is controlled by coordinate systems. Coordinate systems define location on a plane or sphere. There are two types of coordinate systems that can be used in GIS, geographic and plane rectangular. Geographic coordinate system uses latitude and longitude to define points. Plane rectangular coordinate system uses Cartesian coordinates or easting and northings to define location. The location of different features in relationship to each

other is also governed by the type of projection used. Projections are geometric

transformations used to convert latitude-longitude coordinates into planar coordinates. In

other words, they transform images on a sphere, for example a globe, to flat surfaces such

as a map. These can be based on different developable surfaces such as a plane, cylinder

or cone which gives users the ability to choose a projection such as equal area, conformal

maps, equidistant, or azimuthal. The use of different geometric projections can be seen

in Figure 1.3-2. Different types of projections will keep certain aspects at true distance

while distorting others. For example, an equal area projection will maintain a true area

by distorting shape. Both coordinate systems and projections make it possible to relate

features spatially within GIS (Ormsby 2004).
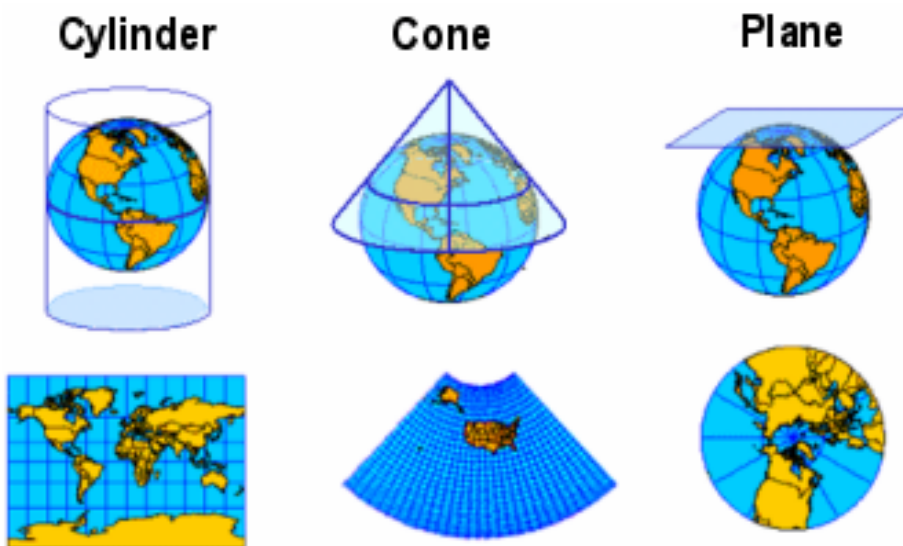
Figure 1.3-2 Geometric Projections (Ocean 2007)

Just as important as location, features in GIS also contain information linked to

each individual feature. This information is referred to as an attribute. Attributes can be

any and all information or data known about a specific feature. For example, a road may

contain attributes of speed limit, length, paved or unpaved, traffic volume and type,

9

pavement condition, and direction. Attributes of each feature are contained within an

attribute table. This table is used to organize attributes about all features within a

particular layer. The particular attributes associated with a layer of features allows users

to query different information and answer specific questions about a GIS layer. For

example if the number of roads with a speed limit under 30 mph was queried, the GIS

systems would consult the attribute table and list all features meeting this specific query

(Ormsby 2004).

All the above being true, GIS is only limited to the type and amount of available

data. Geographic and geographically referenced data that can be displayed and analyzed

in GIS comes in many forms. Data gathered by the U.S. Census Bureau, for example,

has been available in Topologically Integrated Geographic and Encoding Referencing

files (TIGER files) since February of 1989 (U.S. Census Bureau 2006). TIGER files

include GIS layers such as roads, bodies of water, state and county boundaries, census

information, and various points of interest. Other forms of available data include such

raster files as aerial photographs (DOQ files), topographical maps (DRG files), and

elevation maps (DEM files). Having this vast amount of data available is a large

advantage for GIS users. This is especially true when considering that many of these

layers can be overlayed. This allows GIS users to combine different datasets into a more

comprehensive file. These overlays allow a user to enter more sophisticated queries and

perform more in depth analysis (Ormsby 2004).

Section 1.4 PASER Manual Background

The Pavement Surface Evaluation and Rating (PASER) Manual was developed by the University of Wisconsin for the purpose of introducing a more formalized technique of managing local rural and small county pavements that often times are managed largely based on engineering judgment and experience of the staff (Walker 2002). For this research, the Auburn University (AU) Windshield Survey was based on the Asphalt PASER Manual. The following is a background of the PASER manual and some examples of how it has been applied in the past.

The Asphalt PASER Manual was developed to be a simplified rating system that can be used to survey the surface condition of a road. This was done since surface condition can be considered one of the more vital factors within a PMS. The manual was not, however, created to be a stand alone system. The intent was to be able to use the information gained from the PASER surveys in conjunction with other types of inventory data such as width, length, shoulder condition, and pavement type (Walker 2002).

The PASER Manual is a windshield survey based on visual inspection. The survey is designed to identify the different types of pavement distresses present and also link them to their cause. Knowing the cause of the distress(es) present will lead to more effective maintenance and rehabilitation activities used on the network of roads. The four categories of distress and the types of pavement distressed included in each are listed in the following table.

Table 1.1 Pavement Distress Categories within PASER (Walker 2002)

Category	Includes:
Surface Defects	Raveling, flushing, and polishing
Surface Deformation	Rutting, rippling, shoving, settling, and frost heave
Cracks	Transverse, reflection, longitudinal, block and alligator cracks
Patches and Potholes	Patches and potholes

PASER goes on to categorize types of distress as both environmental induced due to weathering and aging, and structural induced by loading or inadequate support. The identification of these distresses and their causes is designed to lead to more cost effective maintenance activities.

PASER rates each pavement surface on a scale from 1 (failed) to 10 (excellent). Ratings of 9 or 10 signify new or like new construction with no visible distresses and require no maintenance. Pavements with initial signs of aging, including transverse cracks, longitudinal cracks, and slight raveling, would be rated between 6 and 8. These pavements would possibly require some maintenance such as a seal coat. Pavements rated as fair (4 or 5) have obvious signs of surface aging and first signs of structural issues. Often times a pavement overlay would be considered for this type of pavement. Lastly, pavements which rate 3 or below and are considered in poor condition, close to failure. These pavements include over 25% of surface alligator cracking, severe distortions, and extensive patching; for these roadways reconstruction of pavement is sometimes considered (Walker 2002).

The manual also provides some practical advice on using this system to manage a network of roads. First, it is suggested that a network of roads be divided into segments and that the pavements in each segment be of similar condition. This allows for an understanding of pavement conditions as they relate to area. Also, when rating a

pavement, small or isolated areas of condition should not be considered or influence the

ratings. The goal of rating the pavement is to represent the majority of the roadway.

Small areas of localized distress should be noted, since they may require spot repairs.

Lastly, the manual suggests comparing pavements of different ratings to ensure that each

rating value assigned is appropriate. All pavements given a certain rating will not all be

the same, but all pavements rated a 6 should be in better condition than all pavements

rating a 4. Comparing the entire network-worth of ratings will ensure that appropriate

ratings were given to each pavement.

The PASER rating systems has been proven a useful tool in pavement

management in small communities outside the state of Wisconsin, as well. Michigan

Department of Transportation (MDOT), in cooperation with the County Road

Association of Michigan, has completed a demonstration project which uses PASER for

surface condition assessment. This project concluded that PASER provided an easy to

learn and easy to apply system of rating pavement condition. Just a little training and

individuals in the project became proficient raters. The system proved to be quick and

accurate (CRAM 2007).

The cities of Mayville and Mt. Pleasant, MI both use PASER within their

pavement management system as well. The Mayville community uses the system to rate

a very small grouping of roads, only 27.32 miles (Partnerships 2007). The city of Mt.

Pleasant, in central Michigan, has been using the PASER rating system since the year

2000. The system here is used to select major streets in need of resurfacing base off of

annual PASER ratings (Mt. Pleasant 2007). Likewise, the city of Sunset Hills, located

just outside of St. Louis, MO., concluded that PASER is a quick and effective means of

creating a snap shot of an entire network of roads and pavement ratings can be related

directly to the maintenance activity required (Sunset Hills 2007).

Section 1.5 Automatic Road Analyzer (ARAN) Van Background

Automated condition survey data were gathered for this research. There data

were gathered through the use of Roadware's Automated Road Analyzer (ARAN)

technology. The following is a brief background of this technology.

ARAN technology was developed in the mid 1980's by Roadware, a company

based out of Ontario, Canada. This technology is the most widely used collector of road

surface data collection (Roadware 2006). Auburn University is one of those whom use

this technology. Auburn's ARAN system, Figure 1.5, is outfitted to a van and contains

the ability to acquire data on a road's roughness, texture, rut depth, profile, and crack

count.

Figure 1.5 Auburn University's ARAN Van

The ARAN system includes a series of lasers as well as accelerometers used to

collect data at traveling speed. Technologies used to collect different data include the

following. An ARAN Smart Rutbar mounted to the front of the van uses up to 37 sensors

to measure the pavement profile to an accuracy of 1.5 mm. The laser transverse profiling

14

system, Laser XVP, employs a dual scanning laser technology to measure rut depth to an accuracy of 1 mm. This system can also be used to acquire crack count for a stretch of pavement. Texture data is gained through the use of 64 kHz high frequency lasers which measure the mean profile depth of a pavement's macrotexture. This can be done for speeds up to 60 mph (Roadware 2006). Lastly, the Laser South Dakota Profiler (SDP) system collects roughness index data. Lasers mounted over each wheel path measure the van's height over the ground while accelerometers mounted to the axles measure the vertical forces caused by the roughness. These measurements are then used to calculate the International Roughness Index (IRI) in real time (Shahin 1994).

The ARAN technology has been used in practice by various organizations within their pavement management systems. One such example is the Missouri Department of Transportation, MoDOT. This department performed a study on how pavement smoothness affects fuel efficiency. ARAN technology was used before and after an overlay to evaluate pavement smoothness by collecting IRI data at highway speeds. Through the use of this technology, MoDOT was able to conclude that driver comfort and ability to control a vehicle improved dramatically from driving on rougher pavement to driving on new, smoother pavements. Also, they found that smoother pavements produce better fuel economy and reduce vehicle maintenance costs (Amos 2006).

The Maryland State Highway Administration, MDSHA, purchased ARAN in 1995. This administration uses this technology to collect ride, rut, and cracking pavement performance data from the spring until the fall. After some synchronizing and development of the ARAN system into the current management system, MDSHA was able to produce an efficient, accurate, and repeatable process for gathering these data and

performing a network based analysis. The network based analysis being further

developed with the data from these automated condition surveys is based on an overall

condition index. This is an indicator value from 0 to 100 which has a weighting factor

for each performance variable; texture, IRI, and crack detection data (Groeger et al.

2002).

Section 1.6 GIS within Pavement Management Systems Background

Since this thesis deals with both PMS and GIS, it is important to understand both

and how they relate to each other. The following section is a literature review of the

current state of GIS within PMS. This provides an understanding of why GIS is

important to PMS and how it is currently being used in practice.

A PMS is an essential entity to any transportation department since the

implementation in the late 1960's (Kulkarni 2003). Agencies ranging in size from a state

department of transportation to local county engineering offices must have a system in

which to manage the road networks under their jurisdiction. Amir Tavakoli defines a

pavement management system as "an organizational and computational program to

catalog pavements, recognize their current condition, realize their deterioration rates, and

review various methods and degrees of maintenance and repair" (Tavakoli et al. 1992).

This is necessary since funding for road repair and maintenance is limited, and agencies

must be able to prioritize every project to optimize the 40% of public funds that are spent

nationally on pavements (Tavakoli et al. 1992). This is the role of the pavement

management system.

Since the early 1990's, GIS has been utilized in many fields that deal with information that contain a spatial entity. The use of this tool in PMS has been one application. For example, GIS provides the ability to visualize spatially related pavement data on a map to quickly assess the condition of a network. Due to the fact that transportation agencies have accumulated immense amounts of data concerning pavement condition, GIS has become a useful tool for these management systems. This has made it imperative for agencies to find a way to first store and manage such a large amount of data, and second have the ability to effectively use these data to make appropriate and cost effective decisions concerning pavement maintenance and rehabilitation.

The use of GIS in a PMS is first warranted by the amount and type of data being gathered under current systems. GIS is specifically designed to handle both large amounts of attribute data, as well as, data containing a spatial element (Sobanjo 2006). Road networks have such a spatial element. Networks of roads cover large areas of land and interact with various land types, rivers, populations, buildings, and other roads. These types of spatially relevant data should be considered in a PMS (Osman 1994, Flintsch 2004).

Along with spatial considerations, GIS has proven to be a useful tool in simply storing and managing the large datasets associated with some pavement management systems. Current pavement management systems for all sizes of agencies consist of the inventory and monitoring of road length, classification type, location, distresses, surface condition, construction history, speed limit, accident history, and condition ratings (Mastandrea 1995, Osman 1994, Tsai 2004). Many of these sets of data are comprised of

many subsets of data which are also large. All these types of data contain spatial information and are often relate to each other in some fashion. The management of this comprehensive dataset, therefore, should logically be handled under one system. GIS provides the capabilities to handle such a large amount of data in a logical fashion.

Currently, GIS is being used as a tool in PMS often times at the state level. Many agencies are using GIS in order to manage highway systems and have specific offices for GIS employees. For example, Georgia Department of Transportation (GDOT) uses GIS to manage and improve an 18,000 centerline-mile highway system since 2000. GDOT integrated GIS into an already functioning pavement condition survey system. This led to the ability of field engineers to obtain visual representation of project ratings and distress data in real-time. This system is also used to effectively produce information required by support maintenance and rehabilitation activities. GIS's query and analysis functions allow GDOT to access information on routes with abnormal distress conditions, projects under construction, and projects with different types of rehabilitation activities. GDOT even uses GIS for financial analysis purposes in displaying funding distribution in different jurisdictional boundaries (Tsai 2004). Overall, this has strengthened the agency's ability to properly manage assets.

Over the past 10 years, Texas Department of Transportation (TxDOT) has also conducted studies on the implementation of GIS as a tool in its pavement management information system (PMIS). This study on the use of GIS for roadways, airports, and urban infrastructure led the agency to develop a useful set of user requirements for a GIS-integrated system. These requirements include the following;

- A user-friendly interface and flexibility;

- Data integration, extraction, and database operations with various methods;

- Sophisticated query capabilities;

- Graphical display of various PMIS data;

- Trend analysis of data;

- Access through Intranet and Internet;

- Ability to integrate with various databases;

- Easy to understand and simple to use; and

- Presentation of information to administration in a more understandable format.

All of these requirements are a good outline for what GIS within pavement management should have. For GIS to be a useful tool, it must be easy to use and easily enhance the management of current and future data. This benefits both the agency itself and all those dealing with the agency that may not be accustomed to the PMS in place (Zhang 2001).

U.S. state agencies are not the only ones using GIS for pavement management. This concept has been implemented and studied in both Japan and India as well. The Aichi Region of central Japan, including the city of Nagoya, implemented GIS as a tool within their highway PMS. This GIS program was developed for its spatial analysis capabilities, which included GIS presentations of the selected road network and region boundaries. Attributes for the road sections within this region included route number, geometric data, pavement type, California bearing ratio, structural number, distress amounts, traffic data, construction history, and maintenance control index (MCI) which is much like the PASER ratings. This GIS program improved the quality and availability of such spatially related data and provided a platform to perform spatial analysis to further improve the decision making process in this region and make more cost effective

decisions on pavement maintenance. GIS maps from this system also make it possible to clearly comprehend the dataset and make sensible judgments and decisions about the network as a whole (Osman 1994). These conclusions are similar to the ones made in the Uttaranchal State and State of Uttar Pardesh in India. Similar practices as in Japan were implemented here to create a GIS supported PMS. Again, pavements containing specific attributes were easily identified both through the use of spatial maps and through a sophisticated query analysis leading to quicker, more precise decision making (Parida 2005).

All these examples show how GIS is a growing entity within the management of highway pavements. The implementation of such a tool at the county level is merely a beginning. PMS for low volume county roads and small communities have not been fully integrated with GIS to a large scale. One example of work was performed by the Michigan DOT. The study, that was performed using the PASER rating systems (Section 1.4), was presented through the use of GIS maps. Different values of PASER ratings were displayed for roads in Chippewa, Grand Traverse, Alcona, Genesee, and Kent counties. These ratings were performed on both urban and county roads, but the study does show that GIS can be applied to datasets concerning this type of road (CRAM 2007).

Section 1.7 GIS within PMS Structure

A PMS framework is that which outlines the components within the system and how each relates to the others is important to convey the flow of the entire process. Each framework is also unique to the individual system, with each agency potentially having

different inputs, processes, and results within their own PMS. One example of a PMS

framework is included in Figure 1.7-1. This PMS structure was developed for a proto-

type low volume county road PMS in Fountain Hills, Arizona (Medina et al 1999). It is a

generic PMS structure which could be considered a basic structure for all types of PMS.
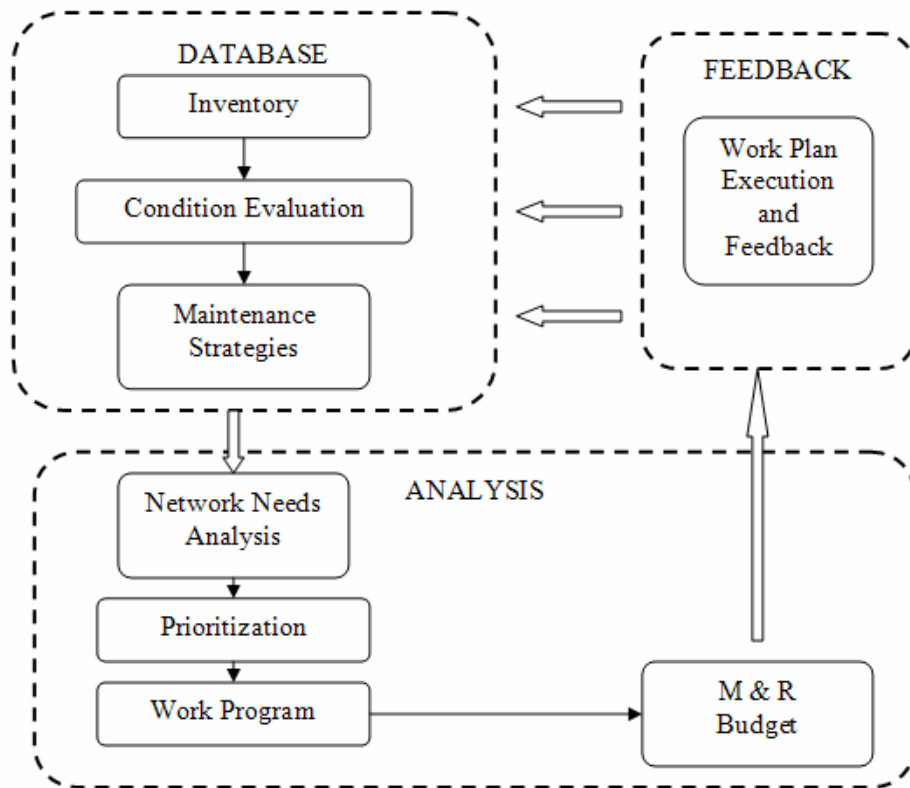
Figure 1.7 - 1 PMS Structure (Medina et al 1999)

The Figure 1.7-1, PMS structure, shows the essential elements that all systems

should possess: inventory, condition evaluation, network needs analysis, and maintenance

strategies and prioritization. These elements may also be integrated into a system

utilizing GIS as shown in Figure 1.7-2. Inventory in this framework is done within GIS

and includes three sources of data from the data collection section. Maintenance

inspection reports from the county, as well as, automated condition surveys and AU

windshield survey data from Auburn University research are all included within the

inventory. The data within this inventory as well as additional GIS layers are then used

in different analysis to compile a comprehensive pavement condition evaluation. This

then feeds into the decision making portion of the system in which key parameters, areas,

and relationships are used along with other inputs to make decisions concerning

maintenance strategies and prioritization. Note that the internal and external inputs listed

in the decision making sections are two input sources that were not within the scope of

this research, however, are important to the agency when making maintenance and

prioritization decisions.
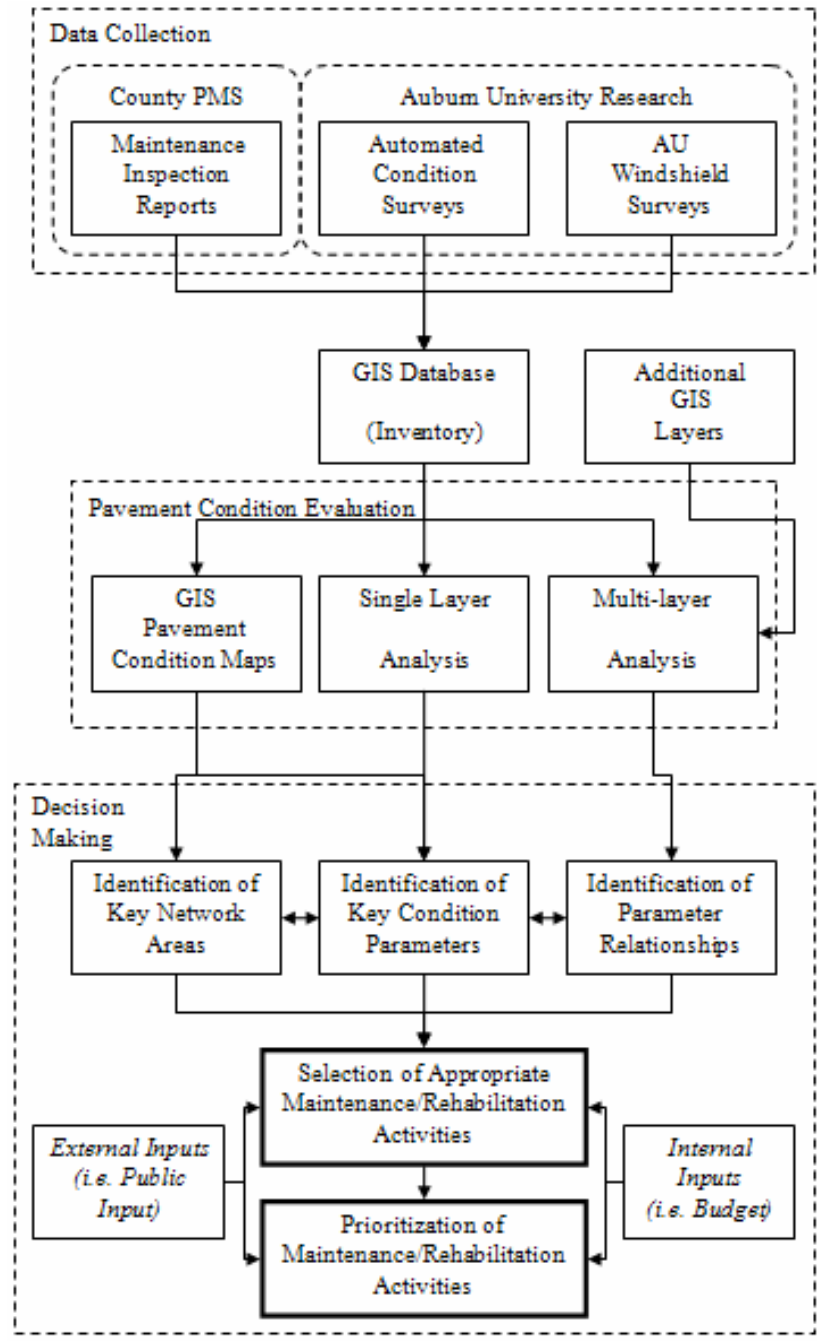
Figure 1.7 - 2 PMS Framework for Research

Using this framework as a basis, the following thesis explores all portions of this system and how they relate to each other and the current system in a pilot county in Alabama. This framework is provided as an outline to be used for better comprehension

of this research. The following section will outline the objectives of this research as well

as the scope of the work completed.

CHAPTER 2 PROJECT OBJECTIVES AND SCOPE OF RESEARCH

Section 2.1 Project Objectives

Three major objectives were set out at the beginning of this research:

- Develop a methodology for using public domain GIS products to display county roads.

- Create GIS presentations for a wide range of parameters used to indicate the condition of county roads.

- Explore different approaches of overlaying spatially represented pavement condition data for making network level decisions.

Section 2.2 Scope of Research

ESRI is the major provider of GIS software and products (ESRI$_a$ 2007, ESRI$_b$ 2007, ESRI$_c$ 2007, Ormsby 2004, and Parida 2005). The ESRI website contains a number of geospatially referenced data that is of particular interest in this study such as Topographically Integrated Geographic Encoding and Referencing (TIGER) files for all county roads, paved or unpaved, geological features (e.g., rivers, lakes), and population distribution based on data from the latest census (in this case, the 2000 data). TIGER files are a good source for free public domain GIS data. However, these types of files are known to be inaccurate at times. The particular files used for this research were examined and only two inconsistencies were observed. The first was that one road, which

was included in this study, was missing a segment of approximately one mile. The other

was that one road, which was not included in this study, was incorrectly placed and was

overlayed on top of water. These being the only two inconsistencies, it was determined

that these TIGER files were adequate for this research.

Three methods of collecting information for the county roadways were used in

this study:

- Traditional Alabama county windshield surveys,

- Automated pavement condition data collection,

- Auburn University windshield survey.

The condition of Alabama county roads are traditionally a windshield survey to

rate a range of components in four main categories: pavement surface, drainage, shoulder

condition, and traffic control features. Final annual reports are developed by the county

in conjunction with the Alabama Department of Transportation (ALDOT) and consist of

pavement history documentation as well as a windshield survey. The end result of the

ratings for these categories is a roadway total, which is used as a final grade for the

roadway.

Automated condition surveys served as another source of data for assessing

pavement conditions. These surveys are performed using Automated Road Analyzer

(ARAN) technology (Roadware 2006). This technology allows users to obtain objective

pavement condition data at travel speeds, i.e. 45 mph. Data obtained from these surveys

include parameters such as pavement macrotexture and the International Roughness

Index (IRI) which is automatically calculated by the system. These data can then be used

to learn more about a pavement's structural and functional condition, which leads to sound maintenance and rehabilitation decisions.

The third source of data was the Auburn University (AU) windshield survey, which was based on the PASER methodology (CRAM 2007, Mt. Pleasant 2007, Walker 2002). The Asphalt PASER Manual is used by a number of city and county transportation organizations as a way to evaluate a pavement's condition based on surface distresses. The AU windshield survey adopted this idea by recording distresses present on the road and the extent of each distress observed. These data were collected simultaneously along with the automated condition surveys; the survey crew consisted of the driver and computer system operator. Results from this project cover all objectives contained in Section 2.1 of this report. GIS was used to create a database and graphical representation of all sources of input data. These data were logically inventoried and displayed within the program. These databases and graphical presentations of data were then used in evaluating pavements and making proper decisions concerning appropriate maintenance and rehabilitation activities for the network of roads being studied.

CHAPTER 3 PROJECT DESCRIPTION AND DATA COLLECTION

Section 3.1 Tallapoosa County Project Description

Tallapoosa County was chosen as the example pilot project county for this project. It is located in the east-central part of Alabama, just northwest of Auburn University in Lee County. The county encompasses 701 square miles and has a population of 41,475 as of the year 2000. The two largest cities in Tallapoosa are Alexander City and Dadeville (county seat). The climate for this region is a moderate climate with average highs in the summer of 90°F and average lows of 30°F in the winters. Rainfall averages between 3" and 6" per month, with March being the wettest month on average.

The Tallapoosa County Engineer's Office is responsible for the 945 miles of county roads of which 520 miles are paved. For this pilot project, county roads under the engineer's office PMS were studied. The GIS map included in Figure 3.1 highlights roads maintained under the current system. All roads in the study are flexible pavement roads and fall into one of four roadway classifications: 1) local roads (approximately 100 ADT), 2) rural minor collectors (<2,000 ADT), 3) rural major collectors (2,000 – 8,000 ADT), and 4) rural arterials (>8,000 ADT). With over 2,000 roads in Tallapoosa, 83 projects of which were included in this study, 51 of these roads in the county fall under the rural minor collectors and local roads, with only 31 rural major collectors and only one rural arterial. Also, it should be noted that the common factor between these

particular 83 roadway projects is the fact that all were built using state or federal funds. This means that the county is contracted by the state to manage these roads using the inspection reports described within this thesis.

This figure shows the roads included in this research which are highlighted in red. These roads are divided into 83 road projects. These projects may include one road or multiple roads. Figure 3.1 also highlights multiple areas of the county which are important in the county. In the eastern part of the county, the green box includes Alexander City. The yellow box in the northern portion of the county includes the area

Figure 3.1 Roads in Project (Highlighted in Red)

referred to as New Site. Dadeville is included in the light blue box located in the center of the county. Lastly, Tallassee is highlighted by the orange box located in the southern portion of the county. Lake Martin is the body of water located in Tallapoosa County. These areas will be referred to through the rest of this research.

Since a PMS is currently being used by Tallapoosa County, it should be noted that this research is not meant to replace the current system. The methodology developed for the implementation of GIS into the PMS was developed with the intent of being

integrated into the current PMS in the county with little change to the current procedures.

Obviously GIS can be used to modify the system, but such an alteration would be better

developed in house by county engineers and staff. Also, the implementation of this

system is designed to be at minimal cost to the county. All GIS based data used in this

research is available for free download, Appendix A. The implementation and

maintenance of this GIS system is also designed to require minimal training at best. The

user guides included in the Appendices of this report give clear step by step instructions

on how a system can be developed for a county PMS and properly maintained. This

should eliminate either the extensive training for current staff or the addition of specific

GIS expert staff. This was done to keep the overall cost of using GIS for county agencies

at a minimum.

Section 3.2 Pavement Management System (PMS) for Tallapoosa County

The current PMS in Tallapoosa County has been in place for over 25 years. This

system is used by county engineers to maintain 520 miles of paved roads. One of the

main components in this PMS is the maintenance inspection reports developed by

ALDOT's County Transportation Bureau. These reports are used in conjunction with

constant monitoring by county employees, foremen, and engineering assistants to make

decisions on appropriate maintenance and rehabilitation activities for the county roads.

Public input is also considered when prioritizing activities.

Maintenance inspection reports are the type of pavement condition survey

currently used in Tallapoosa County and are performed annually. The inspection is done

in a windshield survey fashion by a county inspector, as well as an inspector from

ALDOT. The survey takes into consideration aspects relating to the pavement structure,

signage, markings, and surroundings. Each survey is then compiled into an annual

report. Figure 3.2 shows an example of a typical inspection report.

```
FORM BM-137              ALABAMA DEPARTMENT OF TRANSPORTATION        PAGE 002
REV. 1-1-1997               BUREAU OF COUNTY TRANSPORTATION

                          MAINTENANCE INSPECTION REPORT
                                  COUNTY ROADS

DIVISION  4     COUNTY  62     TALLAPOOSA                DATE  02-22-2006
LOC. AL.63 TO MARTIN LAKE WICKER POINT RD.              FAS NO.
                                                        SACP NO. 4425-C
                                                        STATE NO.
                *CONSTRUCTED*                         *RESURFACED*
    PROJECT    LENGTH    TYPE     YEAR  PROJECT      LENGTH      TYPE       YEAR
  4425-C       01.700 AKG         1969                    LS               1981



ELEMENTS*         DETAIL OF RATING - ROADWAY*            REMARKS*        RATING*
SURFACE           TREATMENT 13 PATCHING       4
                         (18)             (8)
ELEMENT    (40)   LEVELING   4 EDGE REPAIRS  6
                          (6)             (8)                              27
SHOULDER          HIGH       6
                          (8)
CONDITION (16)    LOW        8
                          (8)                                             14
DRAINAGE          DITCHES    7 PIPE/SIDE     2
                          (8) DRAINS        (2)
ELEMENT    (16)   EROSION    3 SETTLEMENT    2
                          (3)             (3)                             14
SHOULDER/         CLEARING   3
ROADSIDE                   (4)
ELEMENT    (14)   MOWING     4 ENCROACHMENTS 6
                          (4)             (6)                             13
TRAFFIC                       STRIPING/
CONTROL           SIGNS      5 PAVEMENT      1
ELEMENT    (14)           (8) MARKINGS      (6)                            6
                                          **ROADWAY TOTAL              74
BRIDGE CHECKLIST   (SEE NOTE2) GOOD COND FAIR COND POOR COND NOT PRSNT/MISG
1) GUARDRAIL/ATTACHMENT
2) HAZARD PANELS/SIGNING
3) ASSOCIATED ROADWAY/DECK
4) CHANNEL STABILITY
5) ABUTMENT EROSION

(1) A RATING OF LESS THAN 70 WILL BE CONSIDERED UNSATISFACTORY.
(2) SEE BI-ANNUAL BRIDGE INSPECTION REPORTS FOR STRUCTURAL DATA.

REMARKS:


ACCOMPANIED BY: DAVID MOORE          INSPECTED BY: JOHNNY INGRAM
TITLE: CO. ENGR.                     TITLE: CIVIL ENGINEER

ORIGINAL COPY TO BUREAU OF COUNTY TRANSPORTATION.
COPIES TO DIVISION ENGINEER AND COUNTY ENGINEER.
```

Figure 3.2 Example Maintenance Inspection Report for Tallapoosa County

The maintenance inspection report shown above has a number of key sections for data entry. First, the page number is a common way to identify a roadway when dealing with these reports. Since these surveys are kept in a comprehensive report, particular projects may be identified by page number along with name and project number. At the top of the form, the project is identified by division number, county number, county name, location, and road name. Beside this is the date for which the report was completed. The next section documents the project's construction and maintenance history. To the left, the year of original construction is noted along with project number, length, and type of construction. Additions to the roadway would be noted in this section. To the right, any resurfacing activity is noted. Project number, length, resurfacing type, and year of activity may be noted here. Below this section is the most important part of the survey, which is completed annually and indicates the condition of the roadway at the time of the survey.

The middle of the roadway condition information contains different categories for which the roadway is rated: surface element, shoulder condition, drainage element, shoulder/roadside element, and the traffic control element. Each category is then further broken down into specific areas (Table 3.1). This table provides descriptions on what is considered when rating the roadway. It should be noted that these ratings are very subjective and are the opinions of the particular inspector. Weather, time of day, and time of year may all affect how the condition of each road appears and therefore the rating received. Remarks can be noted beside each element section. These are often notes by the engineer or inspector commenting on a specific aspect of the project.

Table 3.1 Detailed Elements of Roadway Inspection

Element	Detailed Areas	Inspection Criteria	Total Points
Surface Element	Treatment, Leveling, Patching, Edge Repairs	Condition of Surface/Plant mix, ride quality, areas needing patching, and edge defects and failures.	40
Shoulder Condition	High and Low	Improper drainage due to deposits or vegetation on shoulder and shoulder drop off >2".	16
Drainage Element	Ditches, Erosion, Side Drains, Settlement	Proper amount of ditches, no erosion in ditches, proper side drains for driveways, no settlement of pipes/culverts	16
Roadside Element	Clearing, Mowing, Encroachments	Mowing and clearing of vegetation on right of ways and 6' clear zone from shoulder	14
Traffic Control Element	Signs, Pavement Markings	Proper signage (speed limit, curve ahead, stop signs, etc.) and adequate visibility of centerline and edge stripes, if present.	14

Once all areas are rated, the individual ratings are totaled to give a "Roadway Total" out of a possible 100. This value is often what is used to comment on the roadway project's condition. A Roadway Total of less than 70 for a given project is considered unsatisfactory. Also, county engineers prioritize attention to any pavement falling below a rating of 80.

The bottom of the report contains additional information. Any bridge inspections performed may be documented here. The names and job titles of each inspector are also listed at the bottom of the report.

Section 3.3 Automatic Road Analyzer (ARAN) Van Data

Auburn University's ARAN van was used to collect more objective data on the road projects within the Tallapoosa County pavement management system. The ARAN van was used to collect two main categories of data; macrotexture and International Roughness Index (IRI). These values were collected to create a database that was more

objective, i.e. quantitative, than the maintenance inspection reports currently used. These

objective data assist in making more sound engineering decisions on appropriate

maintenance and rehabilitation activities.

All ARAN data was gathered within the first week of June 2006 between 9:00 am

and 4:00 pm. Weather conditions were clear and moderately warm. More importantly

the weather conditions did not vary a great amount on any day of testing. Rain was not

an issue for gathering data. The ARAN van from Auburn University was used under the

direction of Dr. Mary Stroup-Gardiner. Data was gathered for all roads under study with

data being gathered in one lane only. No cases in which the lane being analyzed

possessing visible differences with the other lane were encountered.

Texture data is an important category of data to have when assessing pavements.

Texture is influential in factors such as skid resistance, drainage (i.e., hydroplaning), and

noise. For this project, texture data were recorded in millimeters. The texture was

recorded as a mean texture depth (MTD) for approximately 6.5 feet sections. Mean

texture depth is used as an indication of surface texture (ASTM E965 1996). Often times

this if found using a sand patch test, however, ARAN technology can compute the same

value at traveling speeds through the use of 64 kHz lasers, signal conditioning

electronics, and a computer. These macro-texture data were then extracted using the

Roadware ARAN View proprietary computer program; the results were then analyzed in

Microsoft Excel. In Microsoft Excel, a plot of texture versus chainage was examined for

any areas of erroneous data. Such areas could include bridges or a point at which the van

swerved off the road. Erroneous data was eliminated from the dataset. Appropriate

averages were then taken for each roadway projects. Projects which contained multiple

areas of different texture were given multiple texture averages with the corresponding

location within the project noted. These averages were the values used for this research.

An example of analyzed data is shown in Figure 3.3-1 with texture shown in mm and

chainage in miles. This figure also shows how one roadway project may possess more

than one texture value. The point, at which texture changes, was recorded for each file.

These points were then used as new divisions for road lengths in the GIS database and

used for texture, IRI, and distress data. This produced road segments which more

accurately described each length's pavement condition.
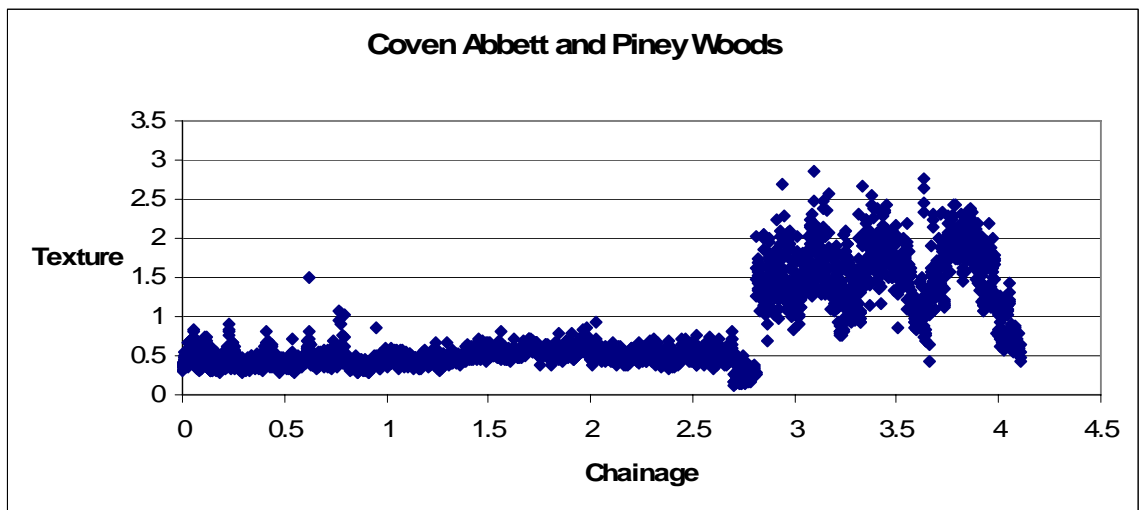
Figure 3.3-1 Analyzed Texture Data

The IRI is an internationally accepted value to evaluate roughness of a pavement

surface (Sayers 1998). The Federal Highway Administration (FHWA) Highway

Performance Monitoring System (HPMS) has even adopted this value as a standard for

its database (Huang 2004). The IRI is a mathematical model which computes the

suspension movement of a vehicle. This model simulates the cumulative movement of

the suspension based on a quarter-car system (QCS) traveling at 50 mph, and then divides

this by distance. Figure 3.3 shows a QCS model (Shahin 1994).
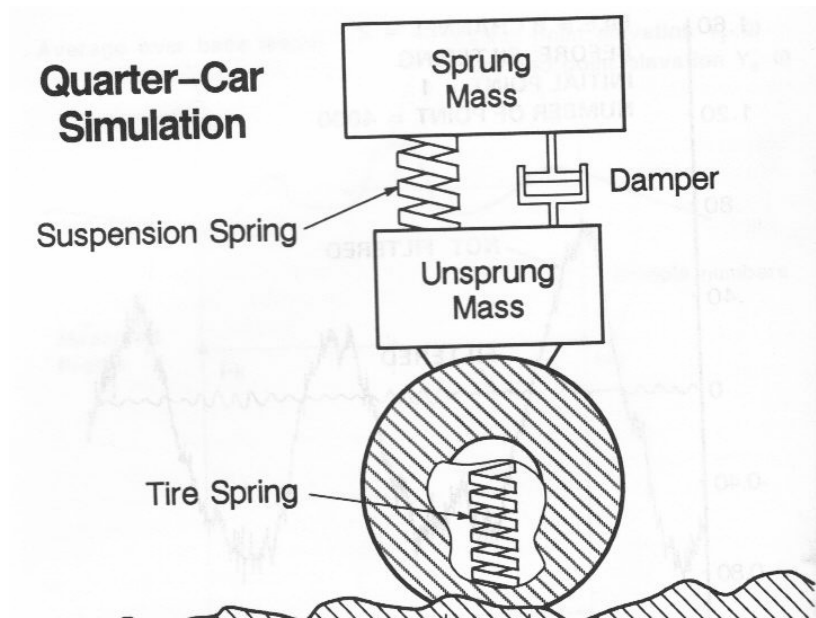
Figure 3.3-2 Quarter-car Model Used as Basis for IRI

Again, as described in Chapter 1, ARAN technology calculates this through the use of

lasers monitoring the vehicles height above the pavement and accelerometers mounted to

the axles to measure the vertical forces.

IRI can be used to describe roughness, and also is easily associated with ride

quality. For this project, IRI was collected in inches/mile units for each of the right and

left wheel path. IRI was computed for every 0.053 mile (538 feet) section of roadway.

These data were again taken from the van and extracted using the View program.

Microsoft Excel was used, in the same fashion as with the texture data, to compute

averages for both the right and left wheel paths. Also in Excel, the difference between

the two wheel paths was calculated to gain some information on if there is consistent

wearing between wheel paths.

Section 3.4 Auburn University Windshield Distress Survey

The third source of data for this project was a windshield survey conducted at the same time the ARAN data were collected. The AU windshield survey, unlike the standard county survey, was designed to document the pavement condition as a function of the general type and severity of distresses present. The format of this AU windshield survey was based on the PASER windshield survey technique used by some city and county agencies across the country (CRAM 2007, Mt. Pleasant 2007, and Sunset Hills 2007).

There are two reasons for this second type of windshield survey. First, a heavily distressed pavement is undesirable because it will perform poorly both functionally and structurally. Secondly, pavement distresses can often be used as an indicator of construction-related problems (e.g. poor compaction at the joints between lanes), environmental problems and/or aging of the binder. If the type and severity of pavement distresses are known, sound engineering decisions can be made for network management. It should be noted, however, that his is a source of subjective data. More research is needed to further develop this survey and its ability to accurately document pavement distresses and its repeatability. The purpose of inclusion in this research is to gain some extent of knowledge about pavement distresses within Tallapoosa County.

For this project, the AU windshield survey shown in Figure 3.4 was developed and utilized. A place for the "County Road Name" is located in the top left of the survey along with the road name, the page number corresponding to the page for the same road project in the Tallapoosa County Maintenance Inspection Report. The date of the survey,

name of technician completing survey, and name of the driver were recorded in the space

provided in the top right hand corner.

County Road Name	Date:
	Tech:
	Driver:

Locate Start of Run:

Start Chainage

End Chainage

Misc. Distresses	0%	<25%	<50%	<75%	100%
Shoving					
Polished Aggregate					
Pumping					
Bleeding					
Previous Construction Issues					
Long. Cracking, Non-WP					
Sealed Long. Cracking, Non-WP					
Environmental and/or Aging Issues					
Transverse Cracking					
Sealed Transverse Cracking					
Block Cracking					
Load- and Support-Related Distresses					
Long. Cracking, WP					
Alligator Cracking					
Sealed Long Cracking, WP					
Potholes					
More Potholes in Rt than Lft. WP?					
Patches					
Edge Cracking					

Figure 3.4 Windshield Survey for Pavement Distresses

The spaces labeled "Start Chainage" and "End Chainage" denotes the chainage

(i.e., length in miles) of data collection. These values were taken from the chainage

reading given by the ARAN van. Next is an area to note the location of the start of the

run for clarification on which end of a road project data collection began. This was done

by noting: 1) the intersecting road name, 2) the geographical location was noted such as "Southern end", or 3) specific landmarks were noted such as "County Line" or "Lake Martin". This also helped log which lane was being traveled. If the start point and direction of travel is known, then the lane of travel is also known.

The middle portion of the survey form was used to record the type and general level of severity of distresses present. The types of distresses were grouped according to the likely cause of each previous construction issues, environmental and/or aging issues, load and support-related issues, and miscellaneous distresses. While surveying the road, the distresses over the entire length of the project were noted. Once the entire project length had been traveled, the distresses present were noted along with an estimate of the severity of each. A rating of 0% signifies that the distress was not evident at 45 mph for the given roadway. A record of 100% means that particular distress was observed over the entire roadway length. Severity was noted in increments of 25%.

The Distress Identification Manual for the Long-Term Pavement Performance (LTPP) Program was used as the standard for defining each type of distress (Miller 2003). Each distress is defined in Table 3.2.

Table 3.2 Distress Identification Manual for the LTPP Program Definitions

Distress	Definition
Shoving	Longitudinal displacement of a localized area of pavement surface caused by breaking or accelerating.
Polished Aggregate	Surface binder worn away to expose coarse aggregate resulting in reduction of surface friction.
Pumping	Seeping/Ejection of water from beneath a pavement through cracks.
Bleeding	Excess bituminous binder occurring on pavement surface, usually in wheel paths.
Long. Cracking, Non-WP	Cracks predominantly parallel to pavement centerline located between the wheel paths.
Sealed Long. Cracking, Non-WP	Non-wheel path longitudinal cracks which have been sealed.
Transverse Cracking	Cracks those are predominantly perpendicular to pavement centerline.
Sealed Transverse Cracking	Transverse cracks which have been sealed.
Block Cracking	Cracks in a pattern which divides the pavement into rectangular blocks (0.1 m^2 to 10 m^2).
Long. Cracking, WP	Cracks predominantly parallel to pavement centerline located within the wheel paths.
Alligator (Fatigue) Cracking	A series of interconnected cracks which develop into many-sided, sharp-angled pieces occurring in areas subjected to repeated traffic loadings.
Sealed Long Crack, WP	Wheel path longitudinal cracks which have been sealed.
Potholes	Bowl-shaped holes of various sizes in the pavement surface with minimum 150 mm plan dimension.
Patches	Portion of pavement surface, greater than 0.1 m^2, which has been removed and replaced.
Edge Cracking	Crescent-shaped cracks or continuous cracks which intersect the pavement edge and located adjacent to shoulder.
Raveling	Wearing away of the pavement surface caused by the dislodging of aggregate and loss of binder.

One category that is contained in the survey yet not defined by LTPP standards is "More Potholes in Right than Left Wheelpath?" which was included to note the distribution of potholes.

Lastly, miscellaneous information was documented at the bottom of the AU windshield survey. GPS coordinates were noted for certain intersections in order to verify starting and stopping locations obtained from the ArcMap GIS Tiger files. Also

noted was any occurrence that would contribute to errors in the data. For example if the van's right wheel went off the road for a moment, this would signify an error in the data and the chainage of this event was noted. Bridge locations were noted using the appropriate chainage value. This was done so that distinct changes in texture and IRI due to these bridges could be eliminated from the data set. Finally, significant pavement surface changes were noted such as significant changes in surface texture, age of the pavement, or other noticeable differences in surface due to previous overlays or maintenance.

Since this windshield survey was based on the PASER windshield survey, the reliability of the data it produces should be similar. The PASER manual itself does not have any distinct comments on reliability. However, the study performed by the County Road Association of Michigan (CRAM) on the PASER rating system concludes that with some training, the rating manual, and just a little adjustment in the field, raters were able to become proficient with the system and produce reliable data. For this research, the AU windshield survey was based on clear distress definitions that were understood by both raters using the survey. Also, the final data for each road segment was agreed upon by two raters before recording. It should be noted that there was no occurrence for which a rating was not agreed upon. Lastly, both raters for this research, the author and Dr. Mary Stroup-Gardiner, became accustomed to the AU windshield survey through prior training and use in previous projects. Considering all this, these surveys were considered a reliable and repeatable source of data for this research.

CHAPTER 4 COLLECTED DATA

Section 4.1 Data Collected from Tallapoosa County PMS

All the data collected from the current PMS in Tallapoosa County came from the maintenance inspection reports; copies of the report for each roadway were provided by the county engineer. Table 4.1 displays a summary of rating data used in this project.

Table 4.1 Rating Data Collected from Maintenance Inspection Reports

| Road Name | Roadway Total (100) | Surface Element | | | | Shoulder Cond. | Drainage Element | | | | Shoulder/ Roadside Element | | Traffic Control Element | |
		Treatment (18)	Leveling (6)	Patching (8)	Edge Repairs (8)	High/Low (16)	Ditches (8)	Erosion (3)	Pipe/Side Drains (2)	Settlement (3)	Clear/Mow (8)	Encroachments (6)	Signs (8)	Striping (6)
Agricola	74	13	4	6	6	13	7	3	2	2	7	5	5	1
Ashurst Bar	78	15	4	7	7	14	7	3	2	2	7	5	5	0
Barrons Bridge	80	14	5	6	6	15	7	3	2	2	7	6	5	2
Bence	81	16	4	7	8	13	7	3	2	2	7	5	4	3
Blueberry Hill	72	13	4	6	5	14	7	3	2	2	7	5	4	0
Bluff Springs	75	13	4	6	6	12	7	3	2	2	8	6	6	0
Brazell	75	15	4	7	7	13	7	3	2	1	7	4	5	0
Buttston	77	14	4	7	6	13	7	3	2	2	7	5	5	2
Camp Ascca Rd	76	13	4	6	6	13	7	3	2	2	7	6	6	1
Campground	87	17	5	7	8	15	7	3	2	2	7	5	5	4
Carr	75	15	4	7	7	13	7	3	2	1	7	4	5	0
Central	69	13	4	3	6	12	7	3	2	2	7	4	6	0
Churchill	84	17	5	7	7	13	6	3	2	2	7	5	6	4
Cobb	86	17	5	8	8	13	6	2	2	3	7	5	6	4
Cold Creek	76	14	4	5	6	12	7	3	2	2	7	5	5	4
Coley Creek	70	12	3	4	6	13	7	3	2	2	7	5	5	1
Concord	86	17	4	8	8	14	7	3	2	2	7	5	6	3
County	72	14	4	5	6	13	6	3	2	3	6	5	5	0
Co. Highway 40	75	14	5	7	7	13	7	3	2	2	6	4	5	0
County Road 34	86	14	6	7	7	14	7	3	2	3	7	6	6	4
County Road 44	83	17	5	7	8	13	7	3	2	3	6	4	5	3

Road Name	Roadway Total (100)	Surface Element				Shoulder Cond.	Drainage Element				Shoulder/ Roadside Element		Traffic Control Element	
		Treatment (18)	Leveling (6)	Patching (8)	Edge Repairs (8)	High/Low (16)	Ditches (8)	Erosion (3)	Pipe/Side Drains (2)	Settlement (3)	Clear/Mow (8)	Encroachments (6)	Signs (8)	Striping (6)
County Road 89	86	17	4	8	8	14	7	3	2	2	7	5	5	4
Coven Abbett	75	14	6	6	5	12	7	3	2	3	7	5	4	1
Cowpens	72	13	3	5	6	12	7	3	2	2	7	5	6	1
Cowpens Cutoff	74	13	4	5	6	13	8	3	2	2	7	5	6	0
Cowpens West	80	15	5	7	7	14	7	3	2	2	6	4	5	3
Crowe	81	16	4	7	8	13	7	3	2	2	7	5	4	3
Davis	81	17	4	8	7	13	6	3	2	3	6	5	6	1
Denver	77	14	4	7	6	13	7	3	2	2	7	5	5	2
Drake	74	13	4	5	6	14	7	3	2	2	7	4	5	2
Dudleyville	94	17	6	8	8	15	7	3	2	3	7	6	6	6
Eagle Creek	83	17	5	7	8	13	7	3	2	3	6	4	5	3
Elder	80	15	4	7	7	15	6	3	2	2	6	5	5	3
Elkahatchee	95	18	6	8	8	16	7	3	2	3	7	6	5	6
Elkins	76	14	4	5	6	12	7	3	2	2	7	5	5	4
Ephesus	70	12	4	5	6	14	7	3	2	1	6	5	5	0
Gammil's Store	88	17	6	7	8	13	7	3	2	3	7	5	5	5
Gantt Mill	82	16	4	7	7	14	7	3	2	2	7	5	5	3
Germany's Ferry	72	13	3	5	6	14	7	3	2	1	7	6	5	0
Girls Ranch	80	14	5	6	7	14	6	3	2	3	7	5	5	3
Golden Pond	73	14	4	5	6	12	7	3	2	2	7	4	6	1
Goldville Cut Off	83	16	4	7	8	14	7	3	2	2	7	5	5	3
Goodwater	91	18	5	7	8	13	7	3	2	3	7	6	6	6
Greenwood	88	17	5	8	8	14	7	3	2	3	7	5	5	4
Happy Hollow	72	13	4	6	5	14	7	3	2	2	7	5	4	0
Harris	81	17	4	8	7	13	6	3	2	3	6	5	6	1
Hix	81	16	4	6	7	14	6	3	2	2	7	5	6	3
Horseshoe Bend	80	16	5	7	7	12	6	3	2	3	7	5	5	1
Jackson	76	13	5	7	6	14	7	3	2	2	7	5	5	0
Knight	72	13	3	4	6	13	7	3	2	2	7	5	5	2
Liberty Church	82	16	4	5	7	14	7	3	2	3	7	6	5	3
Lovelady	76	14	4	5	6	12	7	3	2	2	7	5	5	4
Lowe	91	17	5	8	8	15	7	3	2	3	7	6	6	4
Lower Tuskegee	71	13	4	5	6	11	7	3	2	2	7	5	5	1
Macedonia	88	18	6	8	8	13	7	3	2	2	6	5	5	6
Madwind	91	17	5	8	8	14	6	3	2	3	7	6	6	6
M.L. King	70	13	3	5	5	14	7	3	2	1	7	5	5	0
McCain Lane	76	14	4	7	7	12	6	3	2	2	7	5	4	3
Moose	73	14	4	5	6	12	7	3	2	2	7	4	6	1

Table 4.1 Rating Data Collected from Maintenance Inspection Reports (Continued)

Road Name	Roadway Total (100)	Surface Element				Shoulder Cond.	Drainage Element				Shoulder/ Roadside Element		Traffic Control Element	
		Treatment (18)	Leveling (6)	Patching (8)	Edge Repairs (8)	High/Low (16)	Ditches (8)	Erosion (3)	Pipe/Side Drains (2)	Settlement (3)	Clear/Mow (8)	Encroachments (6)	Signs (8)	Striping (6)
Motley	94	18	5	8	8	16	7	3	2	3	6	6	6	6
Mullican	79	13	5	7	7	15	6	3	2	3	7	5	5	1
Newman	73	14	4	5	6	12	7	3	2	2	7	4	6	1
Oak Heights	75	13	5	6	7	12	7	3	2	2	6	6	6	0
Old Dark	87	16	4	7	7	15	7	3	2	3	7	6	5	4
Old Providence	80	14	5	5	7	14	6	3	2	3	7	4	5	5
Old Susanna	76	14	5	6	6	13	7	3	2	2	6	5	5	2
Oz Hall	81	15	5	5	7	14	7	3	2	2	7	6	5	3
Paul Austin	73	14	4	5	6	12	7	3	2	2	7	4	6	1
Pearson Chapel	76	14	5	5	6	12	7	3	2	3	7	5	5	1
Peckerwood	75	14	5	7	7	13	7	3	2	2	6	4	5	0
Pine	81	16	4	8	8	12	7	3	2	2	7	5	5	2
Point Windy	80	15	5	8	8	14	6	3	2	2	6	4	5	2
Prospect	79	14	4	6	6	14	7	3	2	2	7	5	6	3
Robinson	72	14	4	5	6	13	6	3	2	3	6	5	5	0
Rock Springs	80	16	5	7	7	12	6	3	2	3	7	5	5	1
Sandy Creek	77	15	4	7	7	14	7	3	2	2	6	5	5	0
Sanford Rd	92	17	6	8	8	13	7	3	2	3	7	6	6	6
Seals	74	13	4	6	6	11	7	3	2	2	7	6	5	2
Simpson	81	16	4	8	7	13	7	3	2	2	6	5	5	3
South Tallasee	81	15	5	7	7	13	7	3	2	2	7	5	5	3
Sturdivant Rd	78	15	3	6	7	14	7	3	2	2	7	6	4	2
Sunny Level Cutoff	70	12	3	5	5	13	6	3	2	2	7	6	5	1
Tallasee	81	15	5	7	7	13	7	3	2	2	7	5	5	3
Tank	87	16	5	8	8	12	7	3	2	3	7	5	6	5
Town Creek	87	17	5	7	8	15	7	3	2	2	7	5	5	4
Walker Ferry	82	15	4	8	8	13	7	3	2	2	7	4	5	4
West Lafayette	88	17	5	8	8	13	7	3	2	3	7	5	5	5
Whaley Ferry	80	15	5	7	7	14	7	3	2	2	6	4	5	3
Wicker Point	74	13	4	4	6	14	7	3	2	2	7	6	5	1
Willow Point	83	16	5	4	6	13	7	3	2	3	7	6	6	5
Willow Point Cut-Off	85	16	5	7	7	13	7	3	2	3	7	5	5	5
Wind Creek Farm	83	15	4	7	8	14	7	3	2	2	7	5	6	3
Young's Ferry	76	13	4	7	7	13	7	3	2	2	6	5	5	2

Initial examination of this data displays a few interesting points. First, the average roadway total for the network is 80. This is the number used by the county engineer's office the point for which any project rating below this is considered for maintenance. Also, settlement is the only category which scores the maximum allotted points, 2 in this case for every project in the county. Lastly, pavement markings is the only category to score both a zero rating, in some instances, and contains scores covering the entire range of its rating scale, 0 to 6.

The other form of data collected from the maintenance inspection reports were information on pavement history. Table 4.2 displays data on a road's year of original construction, last year resurfaced (as of 2006), and number of times resurfaced.

Table 4.2 Pavement History Data from Maintenance Inspection Reports

Road Name	Year of Original Construction	Last Year Resurfaced	# of Times Resurfaced	Road Name	Year of Original Construction	Last Year Resurfaced	# of Times Resurfaced
Agricola	1956	1988	3	Jackson	1964	1983	1
Ashurst Bar	1964	2005	2	Knight	1952	1999	3
Barrons Bridge	1970	2005	1	Liberty Church	1962	2001	1
Bence	1966	2005	3	Lovelady	1956	2002	4
Blueberry Hill	1964	N/A	N/A	Lowe	1962	2005	2
Bluff Springs	1961	1981	2	Lower Tuskegee	1953	2004	4
Brazell	1965	2004	2	Macedonia	1965	2002	2
Buttston	1962	2000	3	Madwind	N/A	2003	1
Camp Ascca Rd	1970	1989	2	Martin Luther King	1960	1981	1
Campground	1956	2005	5	McCain Lane	1965	N/A	N/A
Carr	1965	2004	2	Moose	N/A	2005	2
Central	N/A	1981	1	Motley	1952	2005	4
Churchill	1960	2005	3	Mullican	1965	1998	4
Cobb	1965	2005	1	Newman	N/A	2005	2
Cold Creek	1956	2002	4	Oak Heights	1953	1970	2
Coley Creek	1961	1993	2	Old Dark	1963	2002	2
Concord	1952	2005	3	Old Providence Rd	1961	2001	3
County	1966	1998	2	Old Susanna	1954	1996	3

Table 4.2 Pavement History Data from Maintenance Inspection Reports (Continued)

Road Name	Year of Original Construction	Last Year Resurfaced	# of Times Resurfaced	Road Name	Year of Original Construction	Last Year Resurfaced	# of Times Resurfaced
County Highway 40	1960	1998	3	Oz Hall	1969	2001	2
County Road 34	1964	1998	3	Paul Austin	N/A	2005	2
County Road 44	1961	2004	2	Pearson Chapel	1961	1995	3
County Road 89	1962	2005	2	Peckerwood	1960	1998	3
Coven Abbett	1963	1985	1	Pine	1960	2005	3
Cowpens	1957	1989	2	Point Windy	1965	1998	2
Cowpens Cutoff	N/A	1983	1	Prospect	N/A	1994	2
Cowpens West	1951	2005	5	Robinson	1966	1998	2
Crowe	1966	2005	3	Rock Springs	1964	1997	2
Davis	1964	2005	3	Sandy Creek	1956	2004	1
Denver	1962	2000	3	Sanford Rd	N/A	2001	2
Drake	1963	1981	1	Seals	1959	1981	1
Dudleyville	1949	2000	4	Simpson	1952	2005	3
Eagle Creek	1961	2004	2	South Tallasee	1953	2004	3
Elder	1963	2005	3	Sturdivant Rd	1973	2004	3
Elkahatchee	1958	2005	4	Sunny Level Cutoff	1951	1974	3
Elkins	1956	2002	4	Tallasee	1953	2004	3
Ephesus	1953	1989	3	Tank	1959	2002	1
Gammil's Store	1956	2001	3	Town Creek	1956	2005	5
Gantt Mill	1965	2005	1	Town Creek	1956	2005	5
Germany's Ferry	1961	1964	1	Town Creek	1956	2005	5
Girls Ranch	1959	1995	2	Town Creek	1956	2005	5
Golden Pond	N/A	2005	2	Walker Ferry	N/A	2000	2
Goldville Cut Off	1956	2005	3	West Lafayette	1954	2003	5
Goodwater	N/A	2001	2	Whaley Ferry	1951	2005	5
Greenwood	1963	2005	3	Wicker Point	1969	1981	1
Happy Hollow	1964	N/A	N/A	Willow Point	1962	2002	2
Harris	1964	2005	3	Willow Point Cut-Off	1965	2002	2
Hix	1950	2005	2	Wind Creek Farm	1965	2005	3
Horseshoe Bend	1964	1997	2	Young's Ferry	1963	1998	3

It is important to note that certain roads within the network did not have this construction history data available. However, initial examination of available data in Table 4.2 shows that the average year of original construction for this network of county roads is 1960. This means that on average the roads are 46 years old. Also on average,

the roads have been resurfaced twice, some as many as 5 times, with resurfacing

occurring as early as 1964, and as recent as 2005.

Section 4.2 Data Collected from Automated Condition Surveys

The automated condition surveys performed using the ARAN technology yielded

texture and IRI data. These data are displayed in the Table 4.3. The IRI data were

collected for both the left and right wheel paths independently and the difference between

the two wheel paths was calculated. All three of these values, along with texture, are

included in this table.

Table 4.3 Data Collected from Automated Condition Surveys

Road Name	Texture (mm)	Right IRI (in/mile)	Left IRI (in/mile)	IRI Difference
Agricola	1.3043	245.4	160.5	84.9
Ashurst Bar	2.5378	329.7	252.2	77.5
Barrons Bridge	0.5997	204.2	116.5	87.7
Bence	3.1264	431.9	234.9	197.0
Blueberry Hill	2.3031	297.7	189.9	107.8
Bluff Springs	0.9021	246.3	170.2	76.0
Brazell	3.0007	258.8	238.0	20.8
Buttston	1.7502	204.6	153.2	51.4
Camp Ascca Rd	1.5374	326.1	240.6	85.5
Campground	0.4122	164.2	121.2	43.0
Carr	3.0007	258.8	238.0	20.8
Central	0.5813	138.3	106.7	31.6
Churchill	2.6960	304.5	197.4	107.1
Cobb	0.3607	132.1	88.7	43.4
Cold Creek	0.6861	127.4	101.0	26.4
Coley Creek	0.6442	126.8	105.0	21.8
Concord	0.6225	175.5	128.7	46.8
County	0.7933	193.6	151.2	42.4
County Highway 40	0.4623	144.4	119.4	25.1
County Road 34	0.6773	111.4	98.5	12.9
County Road 44	0.5023	169.1	106.1	63.1
County Road 89	0.3595	201.8	105.1	96.6
Coven Abbett	0.4908	111.5	95.9	15.6
Cowpens	1.2692	347.5	154.1	193.4
Cowpens Cutoff	1.3759	296.7	287.4	9.2

Table 4.3 Data Collected from Automated Condition Surveys (Continued)

Road Name	Texture (mm)	Right IRI (in/mile)	Left IRI (in/mile)	IRI Difference
Cowpens West	0.7372	178.7	99.1	79.6
Crowe	3.1264	431.9	234.9	197.0
Davis	2.6104	326.6	275.0	51.5
Denver	1.7502	204.6	153.2	51.4
Drake	1.4633	249.6	159.6	90.0
Dudleyville	0.4428	85.6	69.7	15.9
Eagle Creek	0.5023	169.1	106.1	63.1
Elder	2.5329	349.3	221.7	127.6
Elkahatchee	0.6952	93.4	76.1	17.3
Elkins	0.4779	88.8	90.0	-1.2
Ephesus	2.0702	282.1	208.0	74.0
Gammil's Store	0.4521	108.9	84.1	24.9
Gantt Mill	0.4759	132.1	111.9	20.1
Germany's Ferry	1.5119	249.4	194.8	54.6
Girls Ranch	0.7121	102.5	96.1	6.4
Golden Pond	1.1121	199.4	135.3	64.1
Goldville Cut Off	2.0139	346.3	159.5	186.8
Goodwater	0.5131	109.4	77.0	32.5
Greenwood	0.3488	123.8	91.8	32.0
Happy Hollow	2.6226	250.5	186.6	63.9
Harris	2.6104	326.6	275.0	51.5
Hix	2.3244	294.1	165.8	128.3
Horseshoe Bend	0.6974	100.5	84.1	16.4
Jackson	1.2065	196.4	174.5	22.0
Knight	0.5909	265.5	148.0	117.5
Liberty Church	1.8035	297.0	132.8	164.2
Lovelady	0.2781	73.8	69.6	4.2
Lowe	0.3497	129.8	90.3	39.4
Lower Tuskegee	1.2617	115.4	102.7	12.7
Macedonia	0.4607	80.2	72.1	8.0
Madwind	0.3349	125.5	107.3	18.1
Martin Luther King	1.8677	331.9	281.7	50.2
McCain Lane	1.4928	302.3	220.8	81.5
Moose	1.5908	246.2	175.3	70.9
Motley	0.3108	131.8	84.4	47.4
Mullican	1.0327	297.2	195.0	102.3
Newman	1.1121	199.4	135.3	64.1
Oak Heights	1.0627	152.5	100.9	51.6
Old Dark	0.8144	302.3	189.2	113.1
Old Providence Rd	0.8448	140.3	143.7	-3.3
Old Susanna	1.0327	297.2	195.0	102.3
Oz Hall	2.3475	229.5	201.8	27.7
Paul Austin	0.8657	274.0	120.1	153.8
Pearson Chapel	2.4266	281.3	192.0	89.2

Table 4.3 Data Collected from Automated Condition Surveys (Continued)

Road Name	Texture (mm)	Right IRI (in/mile)	Left IRI (in/mile)	IRI Difference
Peckerwood	0.7811	166.5	108.3	58.1
Pine	2.3453	343.9	196.6	147.3
Point Windy	0.5685	145.6	134.3	11.2
Prospect	2.0114	238.6	189.4	49.2
Robinson	0.7933	193.6	151.2	42.4
Rock Springs	0.6974	100.5	84.1	16.4
Sandy Creek	2.6261	278.9	248.8	30.1
Sanford Rd	0.4866	99.5	77.6	21.9
Seals	1.6233	293.4	192.5	100.8
Simpson	2.6409	375.2	218.9	156.3
South Tallasee	0.7112	136.7	105.8	30.8
Sturdivant Rd	2.4629	356.0	290.3	65.7
Sunny Level Cutoff	1.2902	272.6	189.6	83.0
Tallasee	0.7112	136.7	105.8	30.8
Tank	0.7515	149.7	134.5	15.2
Town Creek	0.4122	164.2	121.2	43.0
Walker Ferry	0.4983	166.0	113.3	52.7
West Lafayette	0.6513	146.2	112.2	34.0
Whaley Ferry	2.2905	399.2	212.3	186.9
Wicker Point	1.4884	264.6	201.4	63.2
Willow Point	0.5462	148.9	85.5	63.4
Willow Point Cut-Off	0.4559	99.9	91.5	8.3
Wind Creek Farm	0.3313	149.4	145.0	4.5
Young's Ferry	0.5469	120.3	109.8	10.6

A few interesting points on this data are that all texture data is within the range of 0.28 and 3.12 mm with a network average of 1.21 mm. IRI ranged between 69.9 and 432 in/mile with the network average being 211.0 and 150.3 for the right and left wheel paths, respectively. IRI difference was mostly positive, with only 2 roads having a negative reading, which signals more wearing in the right wheel path which is appropriate.

Section 4.3 Data Collected from AU Windshield Surveys

Table 4.4 displays the distress data collected for each road project. The data displayed in the table is in terms of percentages of roadway, meaning a value of 50 represents 50%. This data was recorded at the same time the data in the previous section. It was collected by Dr. Mary Stroup-Gardiner and David Grass. Details concerning the collection of this data are outlined in the previous chapter.

Table 4.4 Data Collected from AU Windshield Surveys

Road Name	Long. Cracking (Non Wheel Path), %	Transverse Cracking, %	Block Cracking, %	Long. Cracking (Wheel Path), %	Alligator Cracking, %	Potholes, &	Patches, %	Edge Cracks, %	Raveling, %
Agricola	50	75	50	75	50	0	25	25	0
Ashurst Bar	50	0	0	50	50	0	0	100	100
Barrons Bridge	0	0	0	25	0	0	0	0	0
Bence	0	25	0	25	0	0	0	0	100
Blueberry Hill	50	50	0	50	50	25	25	0	100
Bluff Springs	25	25	0	100	50	0	100	25	25
Brazell	25	25	0	25	0	0	0	25	100
Buttston	25	25	0	50	0	0	0	25	0
Camp Ascca Rd	25	25	25	75	50	0	0	25	100
Campground	0	0	0	25	0	0	25	0	0
Carr	25	25	0	25	0	0	0	25	100
Central	25	25	0	75	50	0	25	0	0
Churchill	75	75	50	75	25	25	50	25	100
Cobb	0	25	0	25	0	0	0	0	0
Cold Creek	50	50	50	75	50	0	0	0	50
Coley Creek	50	25	50	50	50	0	50	25	0
Concord	25	25	0	25	0	0	0	0	0
County	50	50	25	25	50	0	25	25	0
County Highway 40	25	25	0	25	0	0	0	0	0
County Road 34	0	0	0	0	0	0	0	0	0
County Road 44	25	25	0	25	0	0	0	0	0
County Road 89	0	25	0	25	0	0	0	0	0
Coven Abbett	75	50	100	75	0	0	0	25	0
Cowpens	50	25	25	75	25	0	0	25	0

Table 4.4 Data Collected from AU Windshield Surveys (Continued)

Road Name	Long. Cracking (Non Wheel Path), %	Transverse Cracking, %	Block Cracking, %	Long. Cracking (Wheel Path), %	Alligator Cracking, %	Potholes, &	Patches, %	Edge Cracks, %	Raveling, %
Cowpens Cutoff	75	75	75	100	50	0	0	0	0
Cowpens West	25	25	0	25	0	0	0	0	0
Crowe	0	25	0	25	0	0	0	0	100
Davis	25	50	0	50	0	0	0	0	100
Denver	25	25	0	50	0	0	0	25	0
Drake	50	50	0	75	50	0	0	50	50
Dudleyville	25	25	75	75	50	0	0	50	0
Eagle Creek	25	25	0	25	0	0	0	0	0
Elder	25	50	0	50	0	0	0	50	100
Elkahatchee	0	0	0	25	0	0	0	0	0
Elkins	0	0	0	25	0	0	0	0	0
Ephesus	25	25	100	75	25	0	25	25	75
Gammil's Store	0	25	0	0	0	0	25	0	0
Gantt Mill	25	0	0	25	0	0	0	0	0
Germany's Ferry	50	25	0	50	0	0	50	0	100
Girls Ranch	0	75	0	75	75	0	25	0	100
Golden Pond	0	0	0	50	0	0	0	0	100
Goldville Cut Off	0	0	0	25	0	0	25	0	75
Goodwater	0	0	0	25	0	0	0	0	0
Greenwood	0	25	0	25	0	0	0	0	0
Happy Hollow	50	50	0	50	75	25	25	0	100
Harris	25	50	0	50	0	0	0	0	100
Hix	0	25	0	25	0	0	0	25	100
Horseshoe Bend	0	0	0	25	0	0	0	0	0
Jackson	75	25	0	75	75	50	25	0	100
Knight	0	0	0	25	50	0	75	25	0
Liberty Church	25	25	0	25	0	0	0	25	0
Lovelady	0	0	0	0	0	0	0	0	0
Lowe	0	25	0	25	0	0	0	0	0
Lower Tuskegee	75	50	100	75	75	0	25	0	100
Macedonia	25	0	0	25	0	0	0	0	0
Madwind	25	25	0	25	0	0	0	0	0
ML King	50	50	50	75	0	50	25	0	0
McCain Lane	25	25	25	25	0	0	0	50	0
Moose	50	25	25	50	25	0	50	50	0
Motley	0	25	0	25	0	0	0	0	0
Mullican	25	25	0	50	25	0	25	50	0

Table 4.4 Data Collected from AU Windshield Surveys (Continued)

Road Name	Long. Cracking (Non Wheel Path), %	Transverse Cracking, %	Block Cracking, %	Long. Cracking (Wheel Path), %	Alligator Cracking, %	Potholes, &	Patches, %	Edge Cracks, %	Raveling, %
Newman	0	0	0	50	0	0	0	0	100
Oak Heights	0	0	0	75	25	0	25	25	0
Old Dark	25	0	0	25	0	0	0	0	0
Old Providence Rd	0	0	0	25	25	0	50	25	0
Old Susanna	25	25	0	50	25	0	25	50	0
Oz Hall	0	0	0	0	0	0	0	0	100
Paul Austin	0	0	0	50	0	0	0	0	100
Pearson Chapel	0	25	0	25	25	0	0	25	0
Peckerwood	25	0	0	25	0	0	25	25	0
Pine	0	0	0	25	0	0	0	50	0
Point Windy	25	0	0	25	0	0	0	25	0
Prospect	50	75	75	75	50	0	25	25	100
Robinson	50	50	75	50	75	0	25	25	0
Rock Springs	0	0	0	25	0	0	0	0	0
Sandy Creek	50	25	0	50	0	0	0	0	100
Sanford Rd	0	0	0	25	0	0	0	0	0
Seals	75	25	25	75	0	0	0	25	50
Simpson	0	0	0	25	0	0	0	0	100
South Tallasee	75	50	75	75	50	0	0	0	75
Sturdivant Rd	50	25	0	50	0	0	0	25	100
Sunny Level Cutoff	50	50	75	50	75	0	25	0	0
Tallasee	75	50	75	75	50	0	0	0	75
Tank	25	0	0	25	0	0	0	0	0
Town Creek	0	0	0	25	0	0	25	0	0
Walker Ferry	25	25	75	25	0	0	0	25	0
West Lafayette	50	50	25	50	25	0	0	0	0
Whaley Ferry	0	0	0	25	0	0	0	25	75
Wicker Point	25	0	0	50	25	0	25	0	100
Willow Point	25	0	0	25	0	0	50	0	0
Willow Point Cut-Off	25	25	0	25	0	0	50	0	0
Wind Creek Farm	0	0	0	25	0	0	0	0	0
Young's Ferry	25	25	0	50	25	0	0	50	0

52

Table 4.4 contains a few interesting points. The first being that four distresses were not seen over 100% of one road segment; potholes, alligator cracking, non-wheel path longitudinal cracking, and transverse cracking. The other distresses were seen over 100% of a road segment at least once. Also, the most prevalent distress in the county was wheel path longitudinal cracking, with potholes being the least seen distress of those recorded.

Section 4.4 GIS Attribute Table

All of the data in the previous three sections was entered into ArcGIS to create a comprehensive inventory of roads and their pavement condition. The methodology that was used to do this is outlined in detail in Appendix C of this thesis. The area of GIS which holds these data is an attribute table. For this research, all data was stored in the attribute table associated with the road network shapefile. Each column shown in the previous Chapter 4 tables was added to one comprehensive attribute table as new feature classes in addition to the pre-existing features, present in all TIGER files of road layers. The attribute table for this research is shown in Figure 4.1. This particular figure does not show all features within the table, but does show how these features such as road name, pavement rating, texture, right wheel path IRI, and left wheel path IRI are contained within the table.

Figure 4.1 GIS Roads Attribute Table

The following chapter shows how this information contained within the attribute table is manipulated and displayed in GIS. It also shows how to use GIS maps in network analysis with both single variable and multi-variable analysis.

CHAPTER 5 GIS DISPLAYED DATA

Section 5.1 Maintenance Inspection Report Data Displayed in GIS

Data collected from the maintenance inspection reports were all entered into

ArcGIS^{TM}. An overlay of each dataset was created and displayed on top of

Topographically Integrated Geographic and Referencing system files (TIGER Files).

The process, with which these data were entered and displayed in ArcGIS^{TM}, is covered,

in detail, within the following Appendices.

- Appendix A: Creating ArcGIS^{TM} Maps Using TIGER Files

- Appendix B: Managing TIGER Files Road Networks

- Appendix C: Adding and Editing Data in ArcGIS^{TM}

- Appendix D: Displaying Data in ArcGIS^{TM}

The following figures are the results of these processes. Each figure displays one

variable from the maintenance inspection report; the discussion highlights the important

information that can be obtained from each GIS generated map. These presentations are

meant for single variable analysis only. The following sections will include both single

and multiple variable analyses. Each map contains a legend showing the levels of that

particular parameter, as well as, the percentage of the network at that level located in

parenthesis to the right of each level. Section 5.4 and the following chapter will discuss

comparisons and relationships of these parameters.
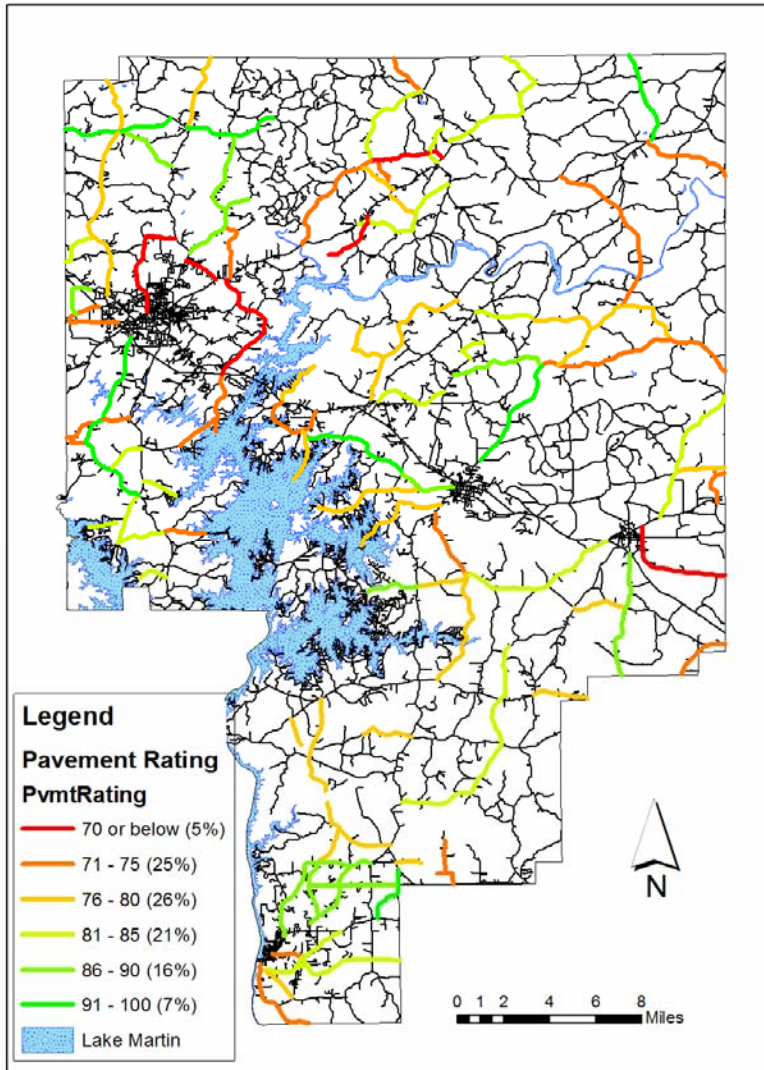
Figure 5.1- 1. Pavement Rating

Roadway total, also referred to as the pavement rating, is displayed in Figure 5.1-1. Red and orange lines signify a rating lower than 80 out of 100 and signal some maintenance or rehabilitation will be needed in the near future. Projects located northeast of Alexander City (concentration of roadways at the northwestern tip of Lake Martin) and in the eastern part of the county generally show lower pavement ratings compared to the rest of the county. The grouping of roads highlighted in red and orange north of Alexander City are of particular concern since these colors indicate values close to 70, the minimum allowable condition for a roadway.

56
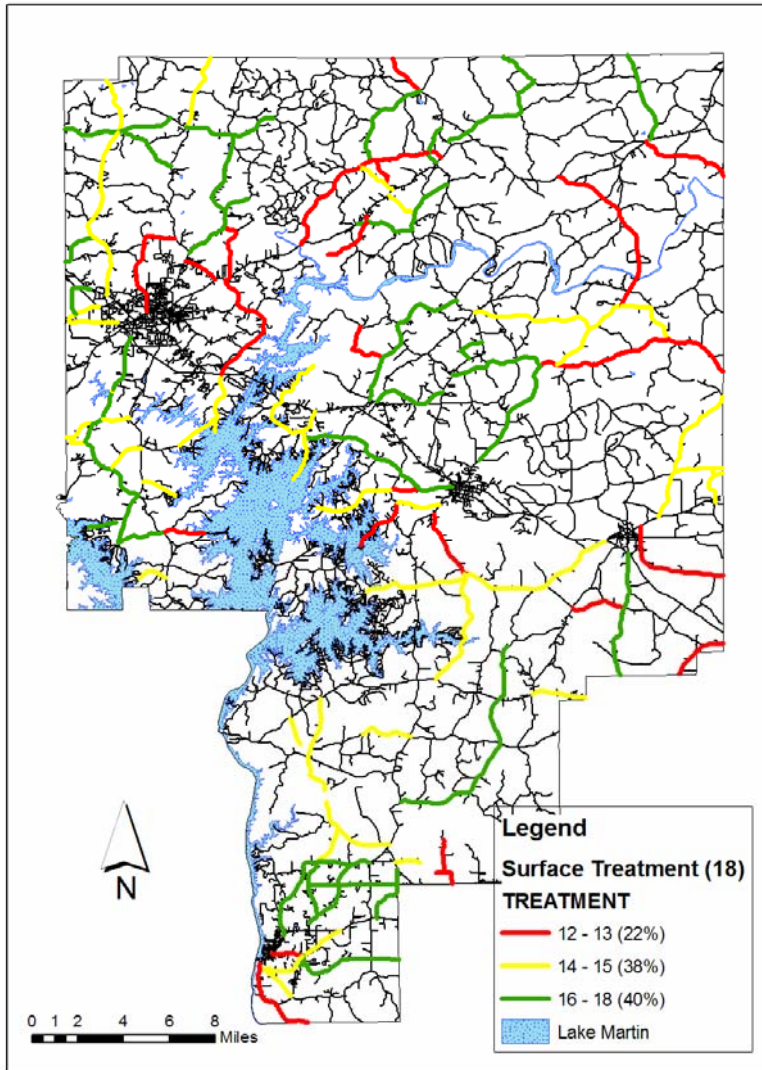
Figure 5.1- 2. Surface Treatment GIS Map

Surface treatment is important because it is one of the only areas, in the maintenance inspection reports, which takes into consideration the surface of the pavement. This area is rated on gradation and surface condition. Almost 50% of the county has a surface treatment rating below 16 (maximum of 18 allowable for this factor), shown by yellow and red lines. A number of county roads in the northern third of the county are rated 13 and below (red lines). The majority of roads with ratings between 14 and 15 are present on the eastern side of Lake Martin. The area surrounding Tallassee (concentration of roads in the extreme south of the county), have surface treatment ratings consistently above 14.

57
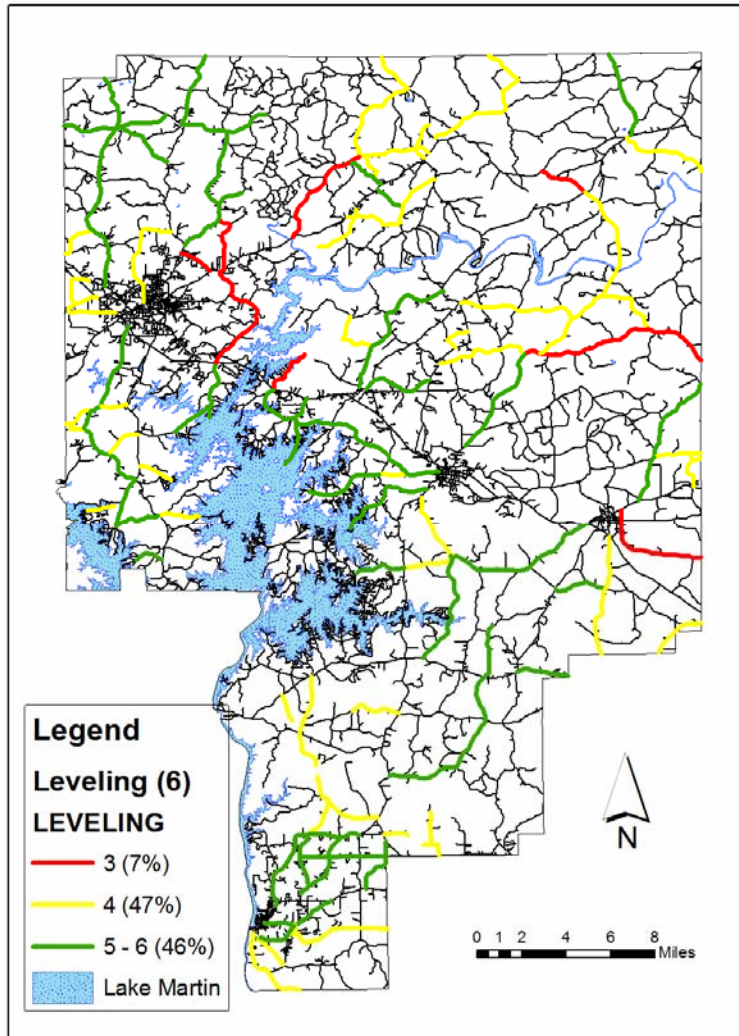
Figure 5.1- 3. Leveling GIS Map

The leveling rating is shown in Figure 5.1-3. There is a maximum possible score of 6 for this element. Leveling is generally rated high across the county with 46% rating 5 or better. Specific areas of concern are in the northern section of the county. Many of the roadways in this area have ratings of 3 to 4, or about half of the maximum value, 6.
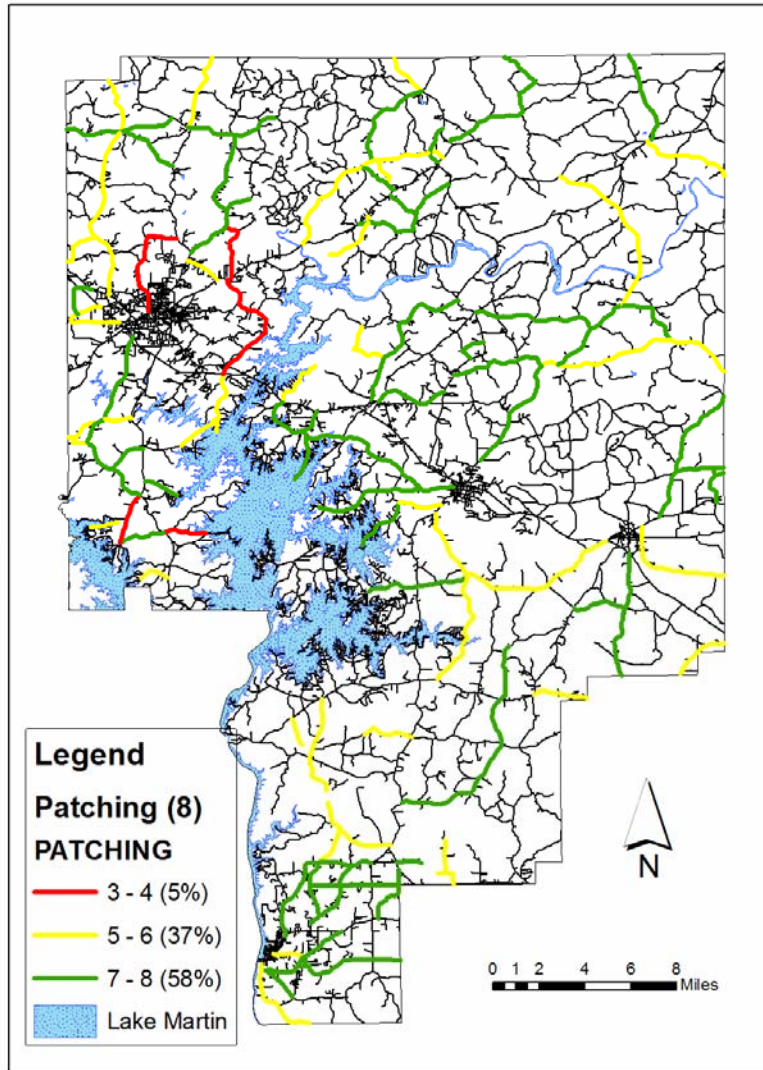
Figure 5.1- 4. Patching GIS Map

Patching is an area which rates the extent that patching is seen on a roadway project. This includes patches covering potholes and other defects, as well as, patching over utility repairs. Patching seems to be of moderate concern county wide (Figure 5.1-4). Most roads score below 6 out of 8. Roads north of Alexander City are again an area of consistently low ratings. Patching was expected county wide due to the fact that one of the most common maintenance undertaken by the Tallapoosa County Engineer's Office is that of patching defects. However, scoring half of the possible 8 points indicates further attention is likely needed for the road around Alexander City.

59
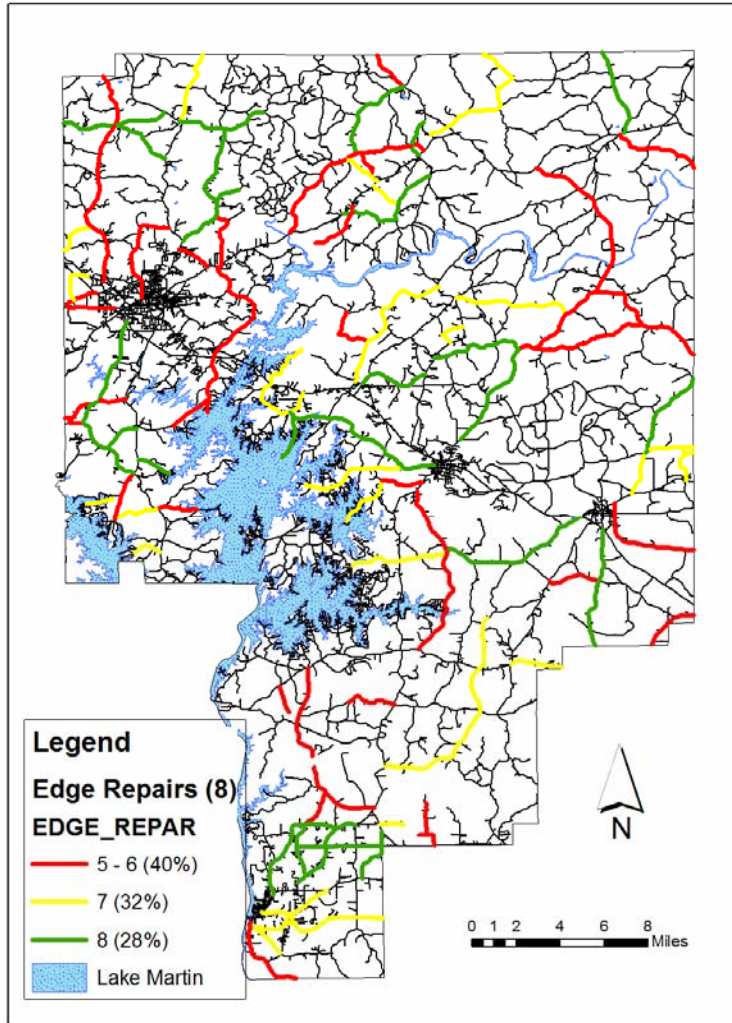
Figure 5.1- 5. Edge Repairs GIS Map

Edge Repairs is an area which rates the amount of repair needed to the edge of the pavement. This area also consistently rate low throughout the entire county (Figure 5.1-5). This is expected due to the lack of proper structural support historically given to road edges when widening lanes. Red lines display roads with a rating below 6 out of 8. Many projects across the county display this score or lower. Edge repair is a variable which should be focused upon to upgrade the pavement ratings of the entire network. The area in and around Alexander City is again highlighted with low variable ratings.

60

The shoulder high/low variable rates the edge of each pavement. A shoulder would be considered high if build up due to vegetation and sediment is present which may cause pooling of water. Low rated when a shoulder has eroded. This variable shows that many shoulders across the county are
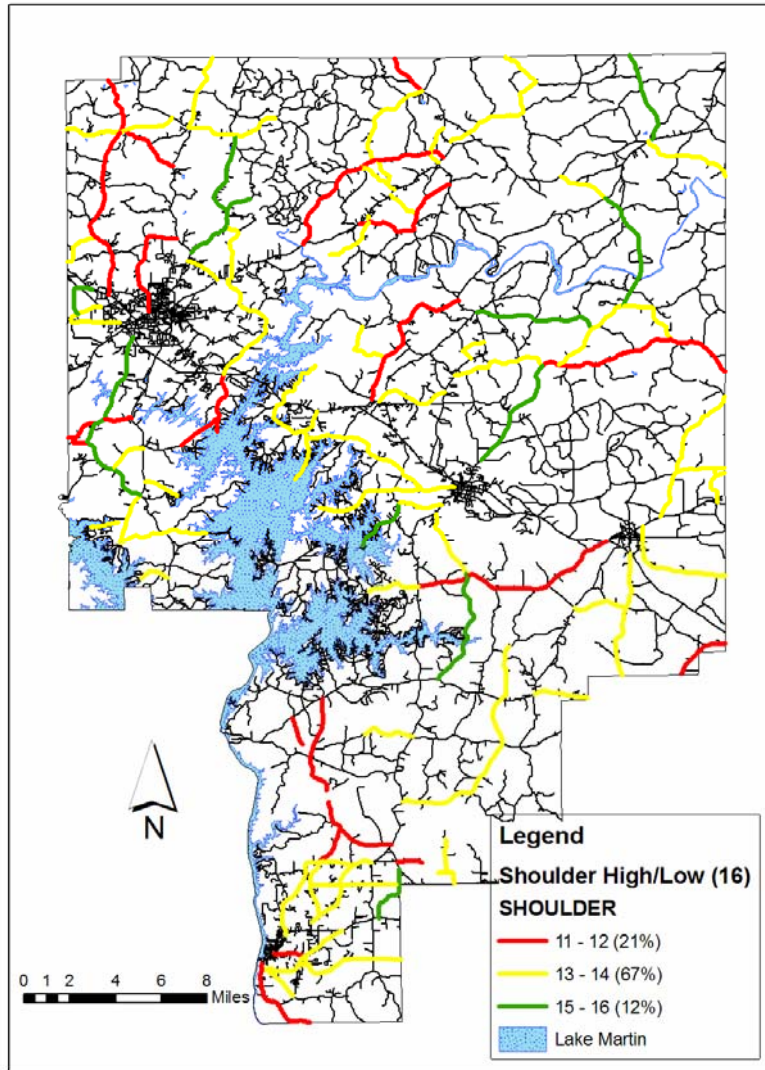
Figure 5.1- 6. Shoulder High/Low GIS Map

not maintained at a proper height (Figure 5.1-6). Very few roads are rated 15 or higher. Roads highlighted in red are of particular concern scoring 12 or below out of a possible 16. No one specific area of the county contains a large grouping of these lower- rated roads. It should be noted that most of these low scores are due to the shoulder being too high due to vegetation or sediment build up.

61

Ditches scores reflect the condition of drainage on the side of the road. Ditches contain objects which would impede drainage rate low. Only one road in the county scored the maximum rating of 8 in the ditches area (Figure 5.1-7). A select few roads, 17%, possessed ditches scoring 6 out of 8, but this is the lowest any projects scored, and is shown to be an uncommon occurrence since 81% of the county did score 7 out of 8.

Figure 5.1- 7. Ditches GIS Map
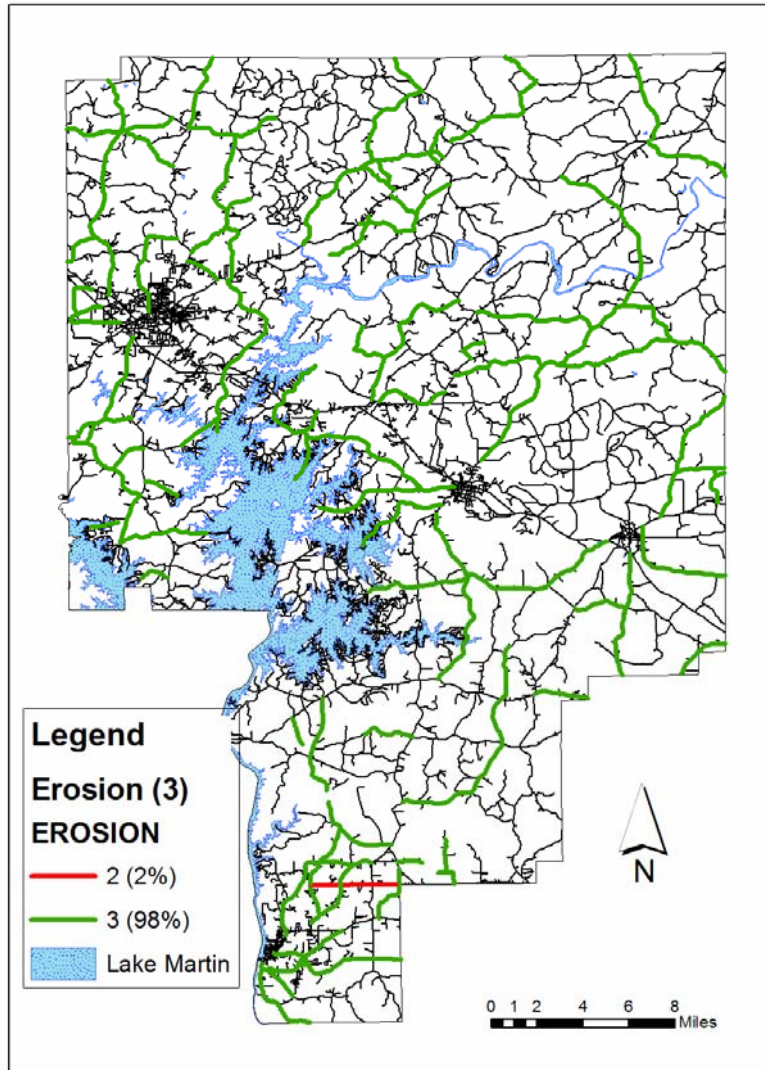
Figure 5.1- 8. Erosion GIS Map

All projects in the county, except one just north of Tallassee, scored the maximum 3 out of 3 for the erosion element (Figure 5.1-8). This element considers how much erosion is present on the sides of the roadway. Erosion is obviously not a problem for this network of roads, with 98% of the roads scoring the maximum 3, and would not be significant in further evaluation of immediate necessary maintenance and rehabilitation activities.
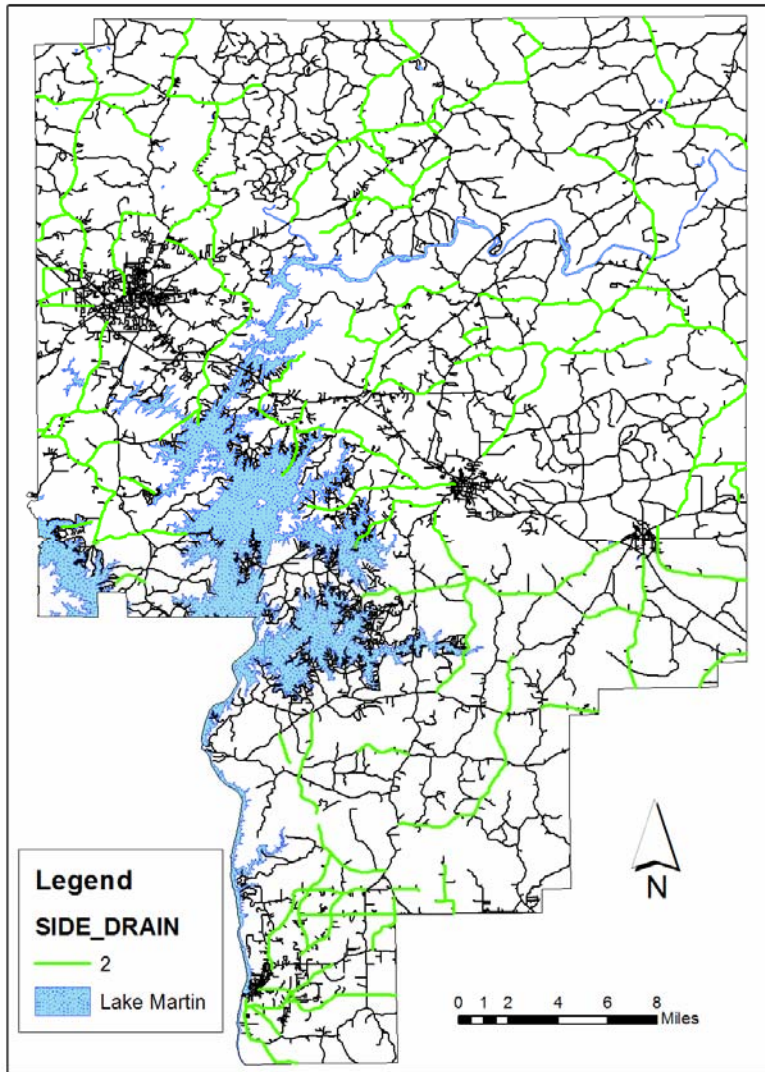
Figure 5.1- 9. Pipe/Side Drains GIS Map

Pipe/side drains are also in excellent condition county wide (Figure 5.1-9). This rating shows that appropriate drainage in the form of pipes under driveways and culverts are present throughout the county. The entire county scores the maximum rating of 2 out of 2, shown by the green highlighted roads. This signifies that pipe/side drains are not an area needing immediate maintenance activities to improve the overall network rating.
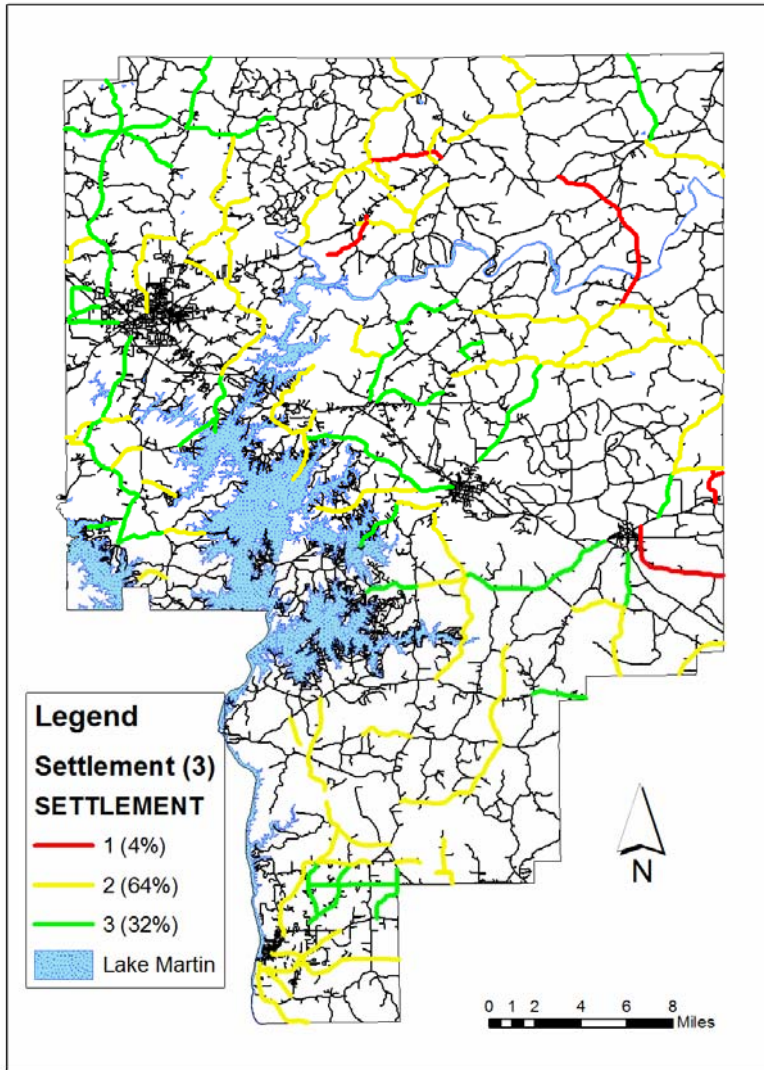
Figure 5.1- 10. Settlement GIS Map

Settlement is an area dealing with any noticeable settlement over underground utilities or drains. Some settlement is noticeable in the northeastern and southern section of the county (Figure 5.1-10). Overall 96% of the county scored either a perfect 3 or one less, 2, rating. A handful of roads on the eastern side of the county have the lowest rating of 1. Settlement may be a variable that is important in decision making for spending funds on repairing these roadways.

Clearing and mowing rating throughout the county with the most common rating of 7 out of 8 is displayed here (Figure 5.1-11). This rating is based on the need for the clear zone on the sides of a road to be cleared of vegetation or mowed. A few projects, 20% of the network, rated a 6; however, this variable can be deceiving. Clearing and mowing ratings are influenced by scheduling of mowing at the time the ratings were taken. This variable is easily improved county wide as needed, and should be monitored.

Figure 5.1- 11. Clearing/Mowing GIS Map
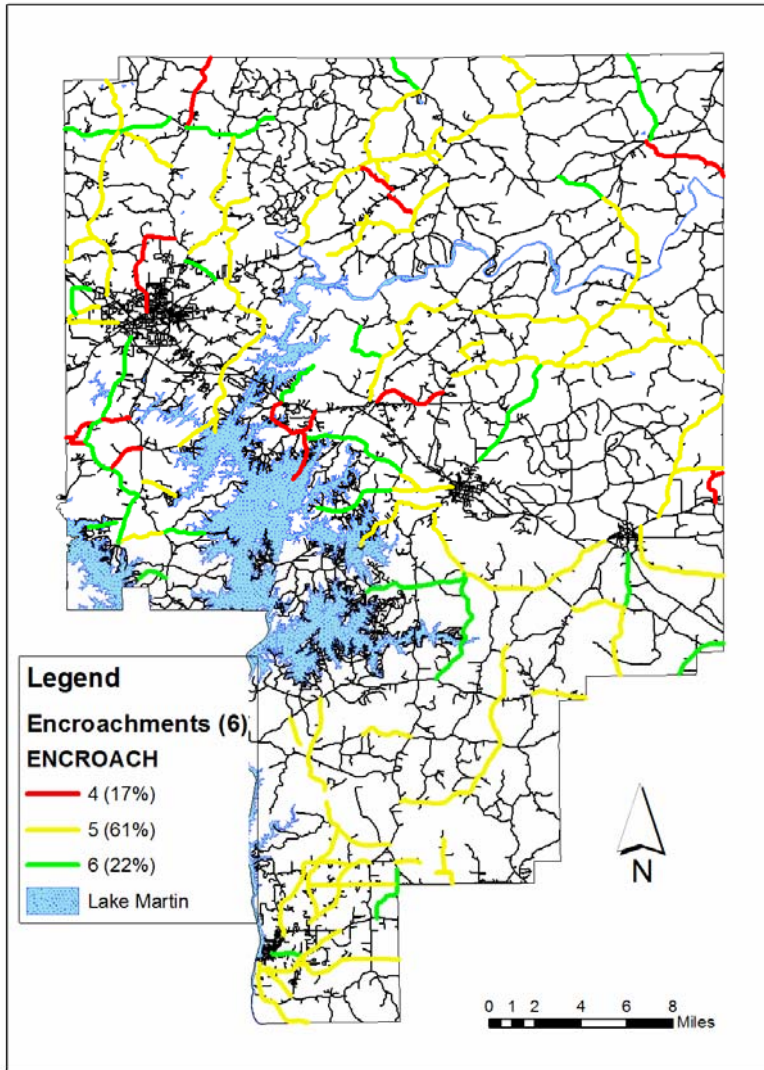
Figure 5.1- 12. Encroachments GIS Map

The most common encroachment rating is 5 out of 6 with 61% of the network at this level (Figure 5.1-12). The area north of Alexander City again shows the lower rating for this parameter (4 out of 6). This variable is constantly monitored by the county in the form of the removing of rigid encroachments such as brick mailboxes, and the map shows that the county is doing an adequate job of maintaining the clear zones. The handful of roads highlighted in red should still be noted, however.

Signage is an area which rates the placement of proper signage, such as stop and speed limit signs, and the ability to clearly see these signs. The signage legend shows that the highest score in the county is 6 out of 8, with the more common rating being 5 out of 8, 64% of the network (Figure 5.1-13). Improvement in the signage rating would consistently improve the overall pavement rating score of the entire network of roads within Tallapoosa County. Roads scoring 4 out of 8 should be paid particular attention being that they only scored half of the possible allotted points. There is not a single area with lower ratings than another.

Figure 5.1- 13. Signs GIS Map

Striping and pavement markings are a concern for this network of roads with 86% of the network scoring at most a 4 out of 6 (Figure 5.1-14). This element rates the visibility and condition of centerline, edge stripes, and all other pertinent pavement markings which is an important for driver safety. The GIS presentation shows that the northern half of the county has a number of roadways with ratings of 1 or 0 out of a possible 6. Areas around Alexander City tend to have this lower rating as well. The northern and northeastern part of the county and to some degree the southern half of the county roads, score between 2 and 4. Striping is an important factor to consider when making future maintenance decisions since this is a key driver safety factor.

Figure 5.1- 14. Striping/Pavement Markings GIS Map

Figure 5.1- 15. Year of Original Construction GIS Map

Looking at the original age of the roadway network within the Tallapoosa network, it can be seen that most roads were originally constructed more than 30 years ago (Figure 5.1-15). Roads older than 40 years are common in the Alexander City and Dadeville area. The rest of the county seems to have a mix of newer and older roads. The roads highlighted in red and orange are those for which age should be considered in the evaluation since these roads were constructed over 35 years ago. No distinct pattern is visible within this variable, which is expected. An interesting note is, of the roads within this study, all were constructed before the year 1973 according to maintenance inspection reports.

Figure 5.1-16 shows many of the roads in the network have been resurfaced within the last 5 years. This map will be useful in prioritizing maintenance and resurfacing activities; the roads which have not been resurfaced recently will likely also be those roads with lower ratings for other parameters.
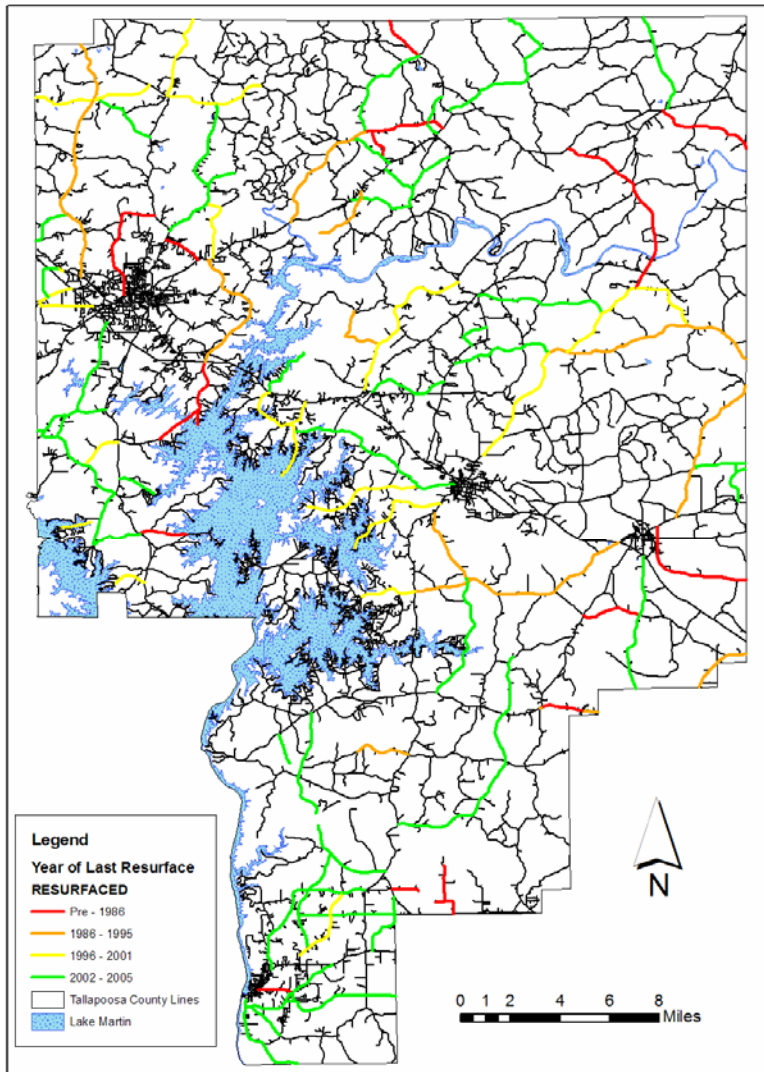
Figure 5.1- 16. Last Year Resurfaced GIS Map
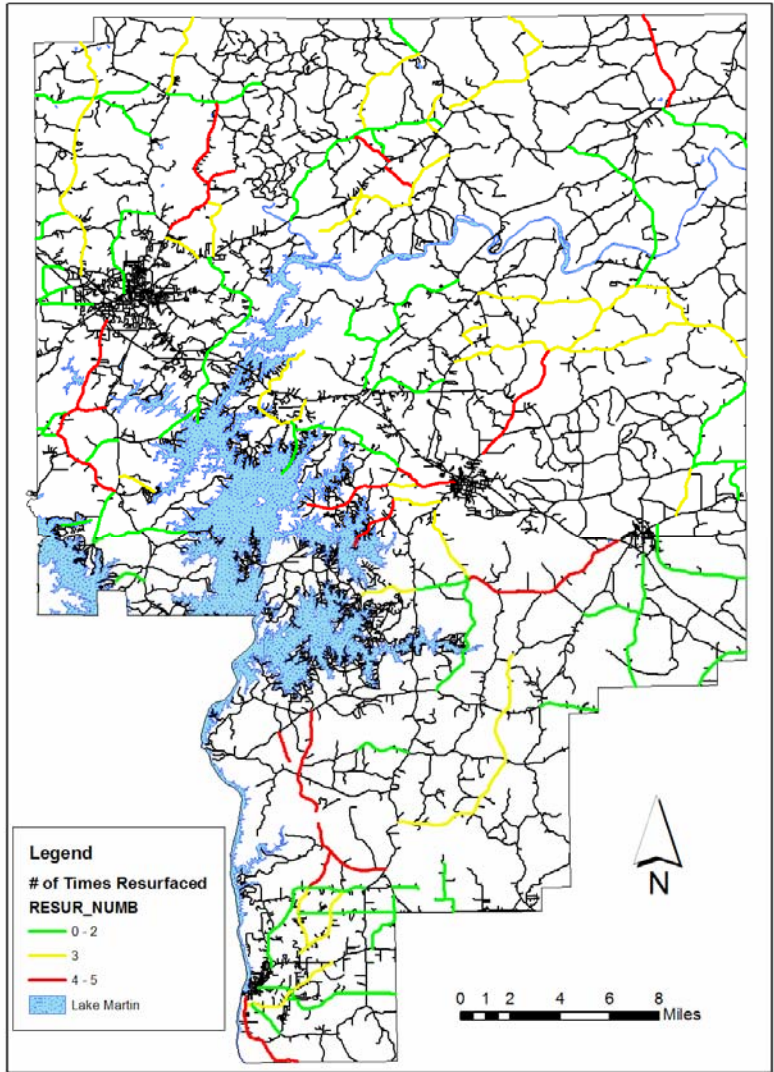
Figure 5.1- 17. Number of Times Resurfaced

The number of times a roadway has been resurfaced is important in visualizing which areas of the county that may be in need of more substantial rehabilitation work, rather than frequent maintenance activities (Figure 5.1-17). Projects around Alexander City and on the eastern shore of Lake Martin have had the most resurfacing projects; these are also the roadways with the oldest dates of original construction.

72

Section 5.2 Automated Condition Survey Data Displayed in GIS

Automated condition survey data were entered into and displayed with ArcGIS in the same manner as described in the beginning of Section 5.1. However the extraction and analysis of these data did require extra methods. The step by step methodology for extracting the survey data and analyzing it are detailed in Appendix E: Extracting ARAN Van Data and Preparing for ArcGIS. The following figures display texture and IRI data.

Discussion again highlights important points of each GIS presentation. The percentage of the network displaying each parameter level is again displayed in to the right of each level.

Most county roads register below 1.0 mm in texture (Figure 5.2-1) which indicates a pavement surface of generally less than 15 to 20 years old (Stroup-Gardiner et al 2001). The area around New Site (north central rural

Figure 5.2 - 1. Texture GIS Map

73

area) displays higher texture which may signal cracking in the pavement surface; these roads should be listed as in need of further investigation

The texture measurement is the first parameter in which a multi-layer analysis was found to be useful. Figure 5.2-2 shows the texture layer overlayed over the last year resurfaced GIS layer, which, indicates the pavement surface age rather than structure age.
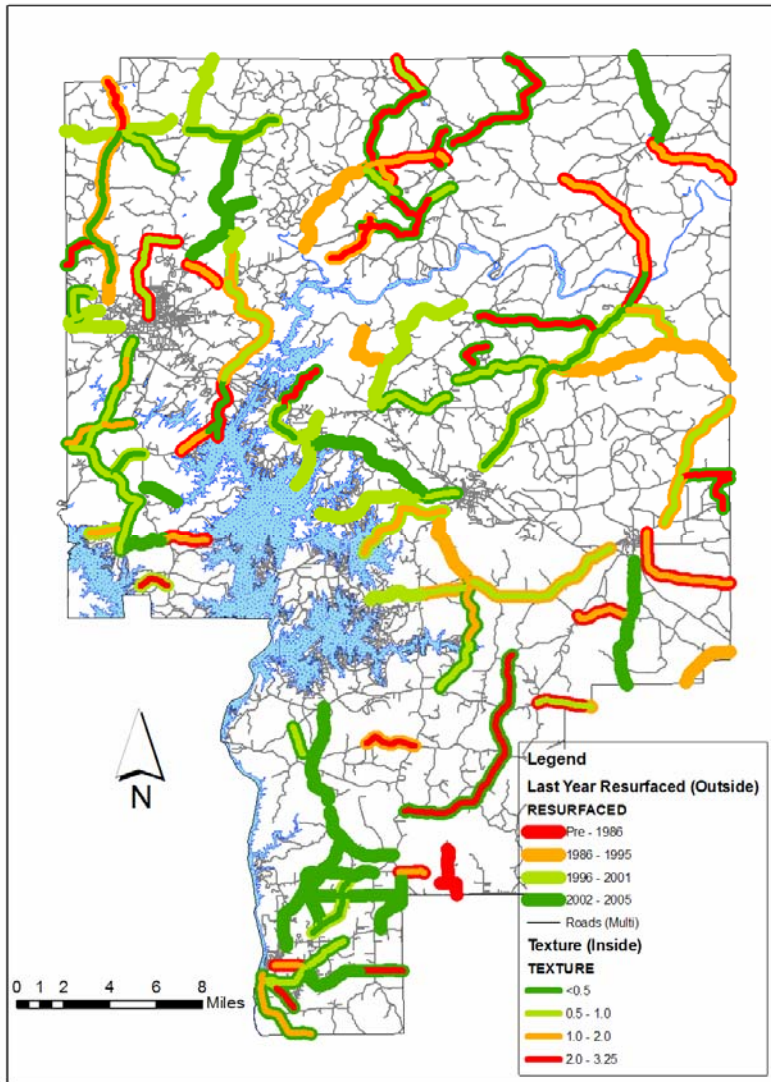
As the legend shows, the color representing texture is the interior color (narrow lines), while the exterior or outside color is that of the last year resurfaced (wide lines). Here the network was examined for road segments containing less than 1.0 mm of texture and a last year resurfaced of no later than 1986 signifying a 20 year old pavement surface. These

Figure 5.2 - 2. Texture vs. Pavement Surface Age

74

pavements would be shown with a green (light or dark) interior and anything but a red exterior.

Only five segments do not meet these criteria. Two of these cases are located around Alexander City. Looking at the network as a whole, of the 20 year old or younger pavements, 96% of these possess a texture value of less than 1.0 mm. Although this finding does not fully develop an explanatory relationship between the two variables, it does show that texture maybe a good indicator for pavement surface age. Exceptions to this may be examples such as those pavements which have recently been resurfaced and still have a higher texture, shown in Figure 5.2 -2 by red or orange interiors with green borders. These road segments are likely new seal coats containing coarse aggregates. Further study in this area would be beneficial, especially including information on how gradation factors into this relationship.
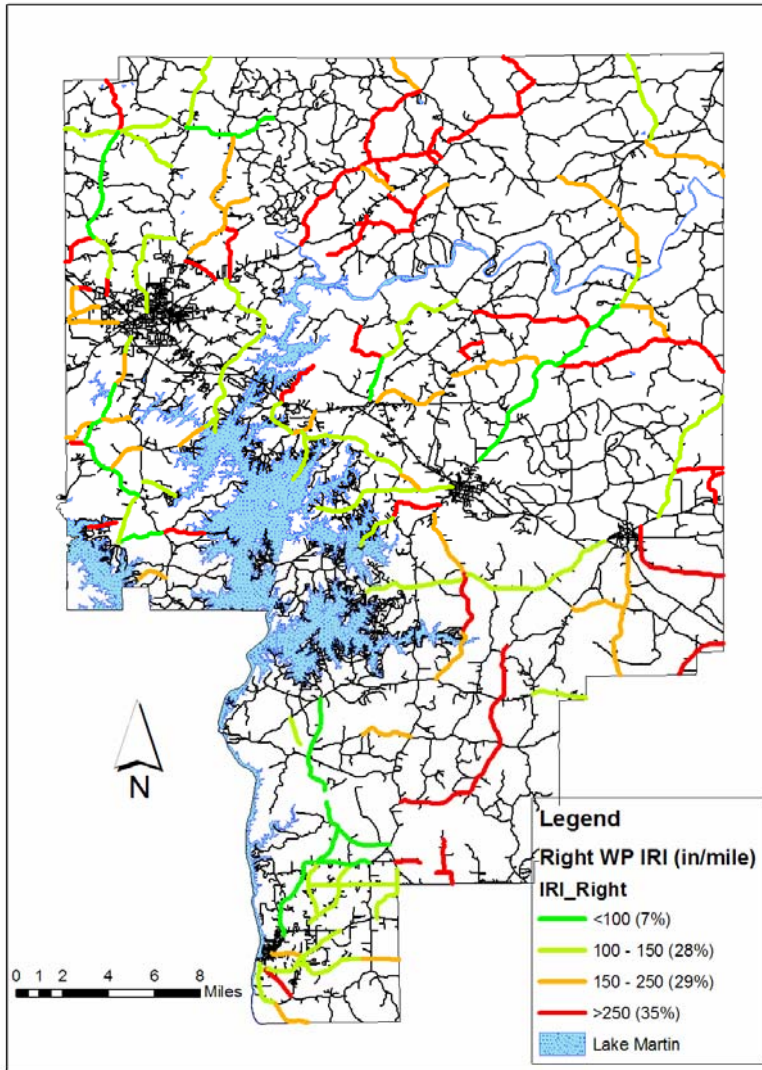
Figure 5.2 - 3. Right Wheel Path IRI GIS Map

The area of New Site shows that the right wheel path IRI typically exceed values of 250 in/mile (Figure 5.2-2). This high IRI indicates a rough ride quality and possible structural support issues under the upper pavement layer. High IRI values are generally dispersed, rather than concentrated, in other portions of the county. However, it should be noted that 35% of the network possess a high value of IRI of over 250 in/mile.

The IRI for the left wheel path shows simlar trends (Figure 5.2- 2); however the left wheel path is generally smoother than the right (i.e., lower IRI values) shown by only 6% having over 250 in/mile in the left wheel path and 35% over 250 in/mile in the right wheel path. Roads in the New Site area again have the higher IRI compared to rest of the county. Still, most are contained within

Figure 5.2 - 4. Left Wheel Path IRI GIS Map

the 150 to 250 in/mile range. One possible reason that left wheel path IRI were generally higher is due to the state of the shoulder and edge of pavement. Roads in this study often times had essentially no shoulders, with the right wheel path very close to the edge of the pavement. This would suggest that the right wheel path may be more susceptible to load related damage. This may account for why the left shows a consistently lower IRI.

To explore this hypothesis, a multi-layered analysis of right wheel path IRI and the condition of the edge of the pavement was performed to evaluate the possibility of a relationship between a high right wheel path IRI and a low scoring edge condition (figure 5.2-5). The parameter used for to rate edge condition was edge repairs from the county Maintenance Inspection Reports.

This multi-layer analysis produced interesting results. As shown, there is no clear, distinguishable relationship between pavements with an IRI over 250 in/mile and those whose edge repair rating fell below 7. Only 41% of the network containing a right IRI over 250 in/mile rated below 7 in the edge repair category. There are some suggestions of a correlation, however. Rather than examining those with an IRI over 250, road segments with less than 250 in/mile were examined. Of these road segments, two-thirds were pavements with an edge repair rating of at least 7 out of 8.

Figure 5.2 - 5 Right IRI vs. Edge Repair

Judging from these results, more analysis is needed to draw any type of conclusion concerning the relationship between right wheel path IRI and edge condition. This wasn't unexpected considering the edge repair rating is a subjective one. Further examination of this was conducted with right wheel path IRI and edge cracking values, which is further discussed in the next section.
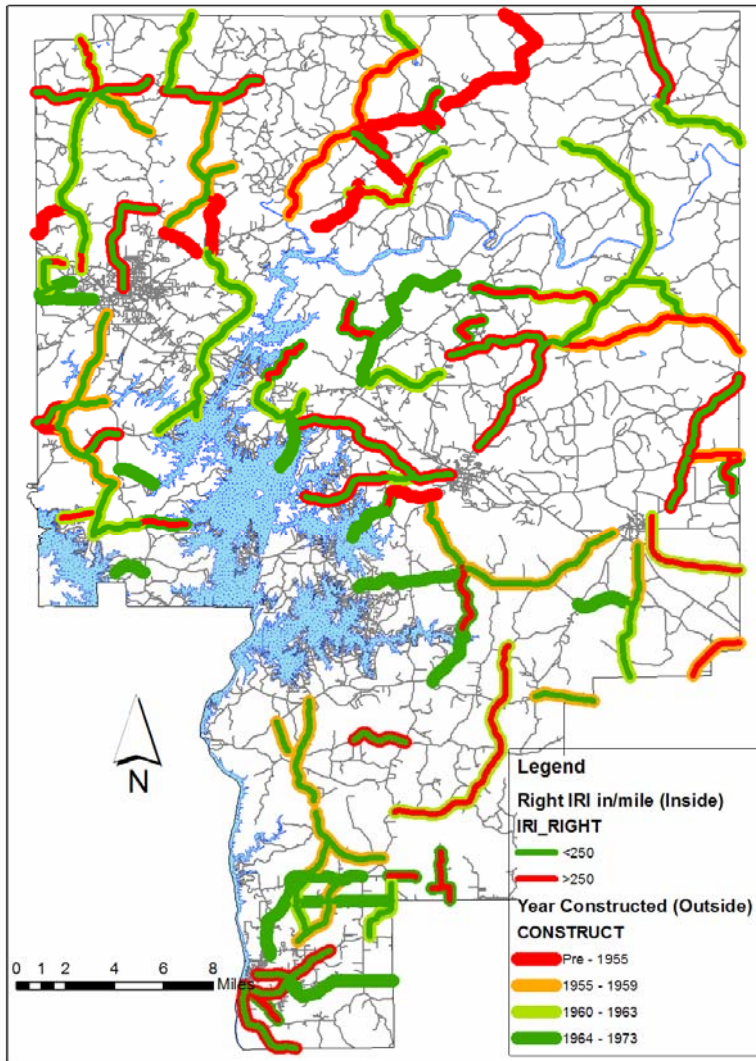
Figure 5.2 - 6. Right IRI vs. Year Constructed

Another variable which may affect IRI is the age of the pavement structure. These two variables are overlaid in Figure 5.2 – 6. This figure shows there are no distinct patterns between the two variables, except in the New Site region, where IRI values of 250 in/mile or greater are seen consistently with pavements constructed before 1960. For the rest of the network, old pavements with high IRI values are seen randomly. Overall, pavements in this network with an IRI over 250 in/mile are on average 46 years old, which is the average age of all pavements. This

79

suggests that, for this network of roads, older pavements do not necessarily have higher

IRI values as would be expected.
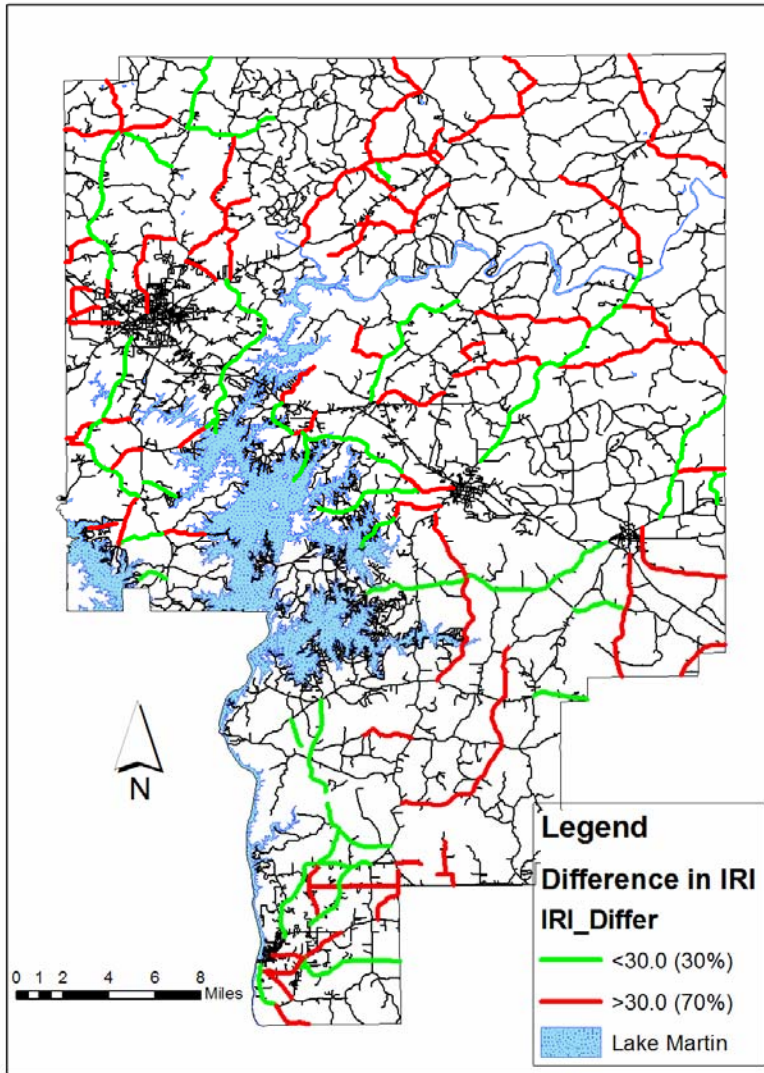
Figure 5.2 - 7. Difference in Wheel Path IRI GIS Map

The difference in IRI between the wheel paths illustrates possible structural damage by highlighting uneven wear of the roadway (Figure 5.2-7). With over 50% of the county displaying a greater than 30 in/mile difference (Stroup Gardiner 2004), it can be said that the network of roads as a whole is wearing unevenly. The age of the roadways, on average 46 years old, indicate that it is a possibility that current traffic levels exceed the original design, or that the pavements have reached the end of their design life.

Section 5.3 AU Windshield Survey Data Displayed in GIS

The data compiled from the AU windshield survey was entered into ArcGIS and displayed within the program in the same fashion as data from the traditional maintenance inspection reports. The process for entering and displaying this data is the same as discussed in Section 5.1. The following GIS presentations are the results from this data and each includes discussion highlighting the key points for each. These maps display two sets of percentages in the legend. The first percentage is the extent each road segment displayed that particular distress. The second is the percentage of the network at this extent of distress.

Longitudinal cracking (between the wheel paths and between lanes) was present for road segments east of Lake Martin (Figure 5.3-1). Here roads display
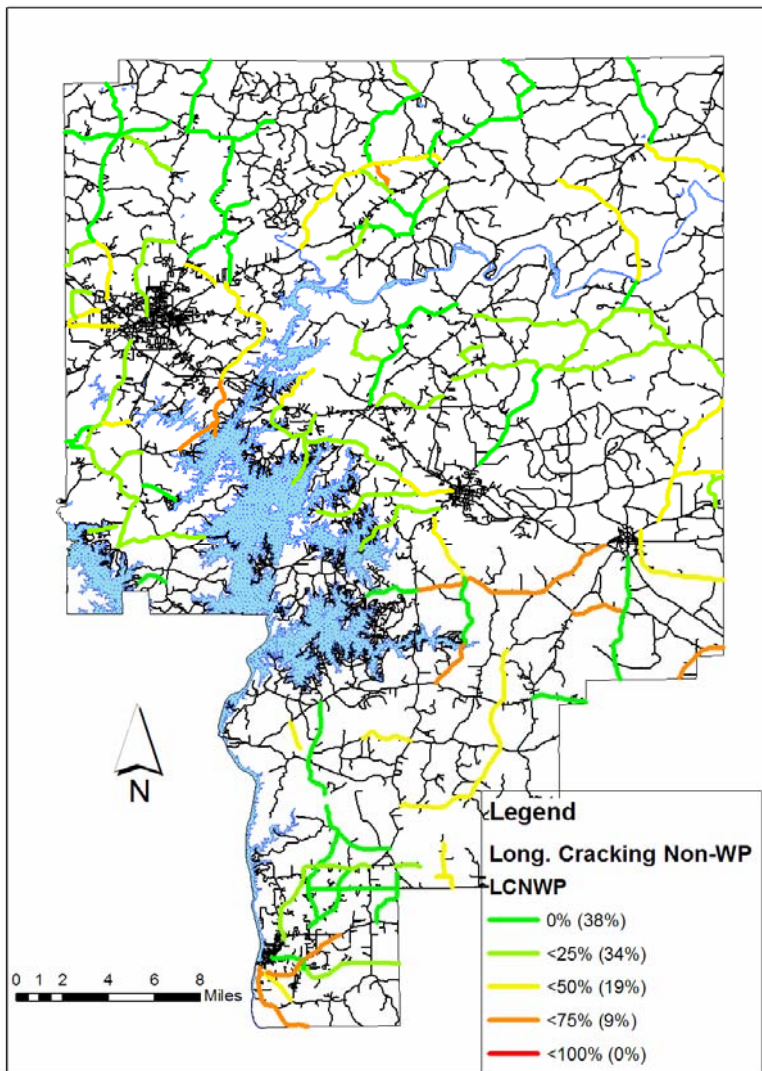
Figure 5.3 - 1. Longitudinal Cracking (Non Wheel Path)

50% to 75% cracking along the roadway length. Roads surrounding Alexander City and

located in the very southern portion of the county also show this extent of cracking. Sealing these cracks might be a good option for these roadways. This will keep water from entering the base layer or from generating potholes. Longitudinal cracking (non wheel path) is rated as having an extent below 25% for the remainder of the county.

Transverse cracking issues are most predominant southeast of Lake Martin (Figure 5.3-2). Here roads are exhibiting up to 75% extent of cracking. This is a sign of possible environmental or aging issues in this section of the county. The rest of the county shows little transverse cracking with 78% of the county displaying this distress to 25% or less of the segment lengths. These also are

Figure 5.3 - 2. Transverse Cracking

candidates for a surface seal if load support is not also an issue.
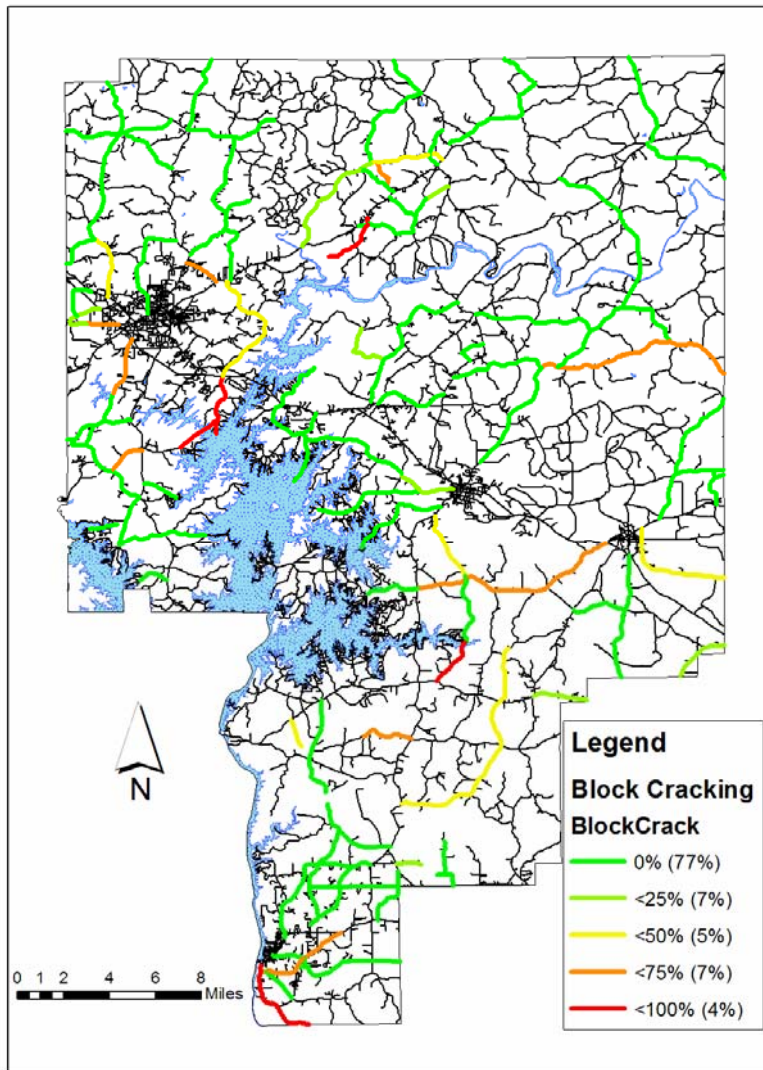
Figure 5.3 - 3. Block Cracking

Large extents of block cracking are not present in one particular area of the county with 77% of the network not possessing this distress (Figure 5.3-3). Again, areas surrounding Alexander City and located southeast of Lake Martin show higher extents (50% to 75%) than the rest of the county. Network wide however, block cracking seems to be limited.

To analyze roads in the network containing environmental/aging problems, the three previous discussed distresses, block, transverse, and longitudinal non-wheel path cracking, were all overlayed on a GIS presentation. Figure 5.3 -4 highlights road segments possessing a 50% extent of these distresses. This was done to show where extensive amounts of these distresses exist, and which projects contain multiple environmental/aging distresses. As the figure shows, these types of distresses are seen in all parts of the county. Alexander City, New Site, Dadeville, and Tallassee areas all have

roads that are over 50% distressed with these distresses. This figure also displays which

roads possess all three distresses. These roads are of particular interest since half of the

segment length displays all three types of environmental/aging distress and would probably be first in line for maintenance dealing with these issues when prioritization is being done. It is also of interest to see that, when 50% extent of block cracking is present, it is associated with 50% of some one of the other two distresses; either non-wheel path longitudinal cracking or transverse cracking.

Figure 5.3 - 4. Environmental/Aging Distresses

This is not the case for the other two distresses which are present in other segments as the

sole distress. This could suggest that block cracking is a progressed state of previously

environmental or age distressed roads.

84
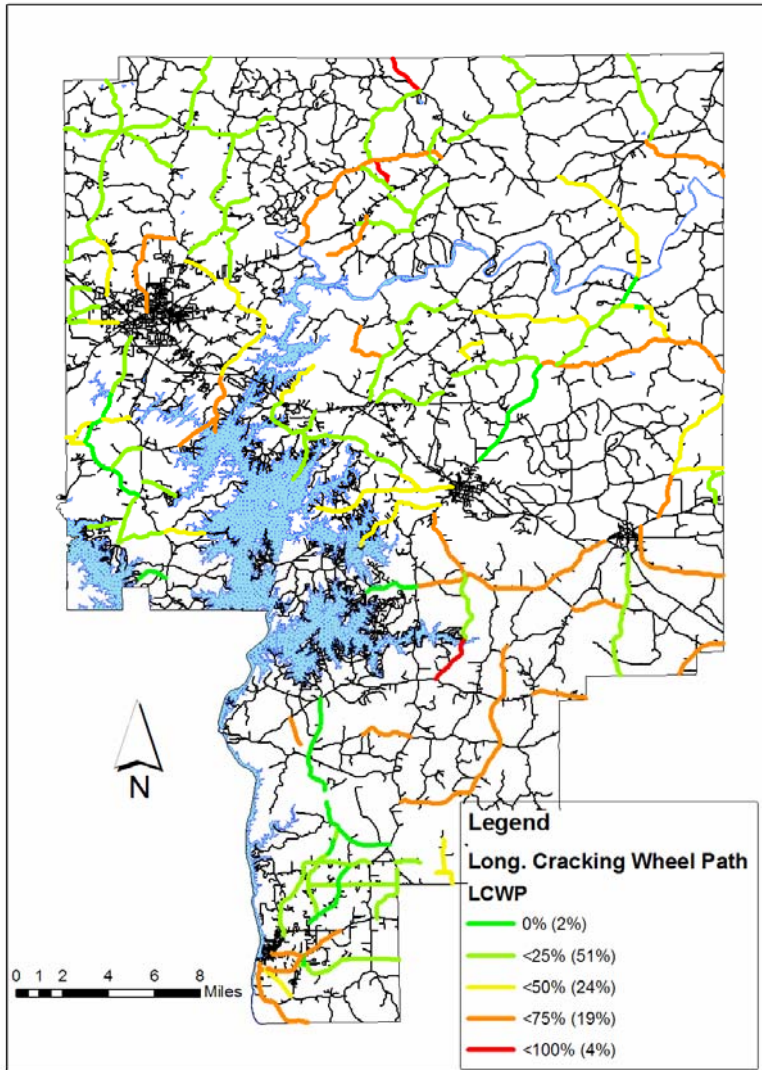
Figure 5.3 - 5. Longitudinal Cracking (Wheel Path)

Longitudinal cracking in the wheel paths is present in all parts of the county with 98% of the network roads exhibiting at least 25% extent (Figure 5.3-5). Higher extents, 50 to 100%, are visible in the area between Dadeville and Tallassee, in the southern half of the county. Longitudinal cracking in the wheel paths is often the first load/support related distress present in flexible pavements. It is also a point of pothole generation after a rain event.

Alligator cracking, also referred to as fatigue cracking, is shown in this GIS presentation and is often the result of the progression of longitudinal wheel path cracking (Figure 5.3-6) (Huang 2004, Shahin 1994, and Miller 2003). The highest concentration of roads containing 50% or greater extent of this distress is located in and around Alexander City.
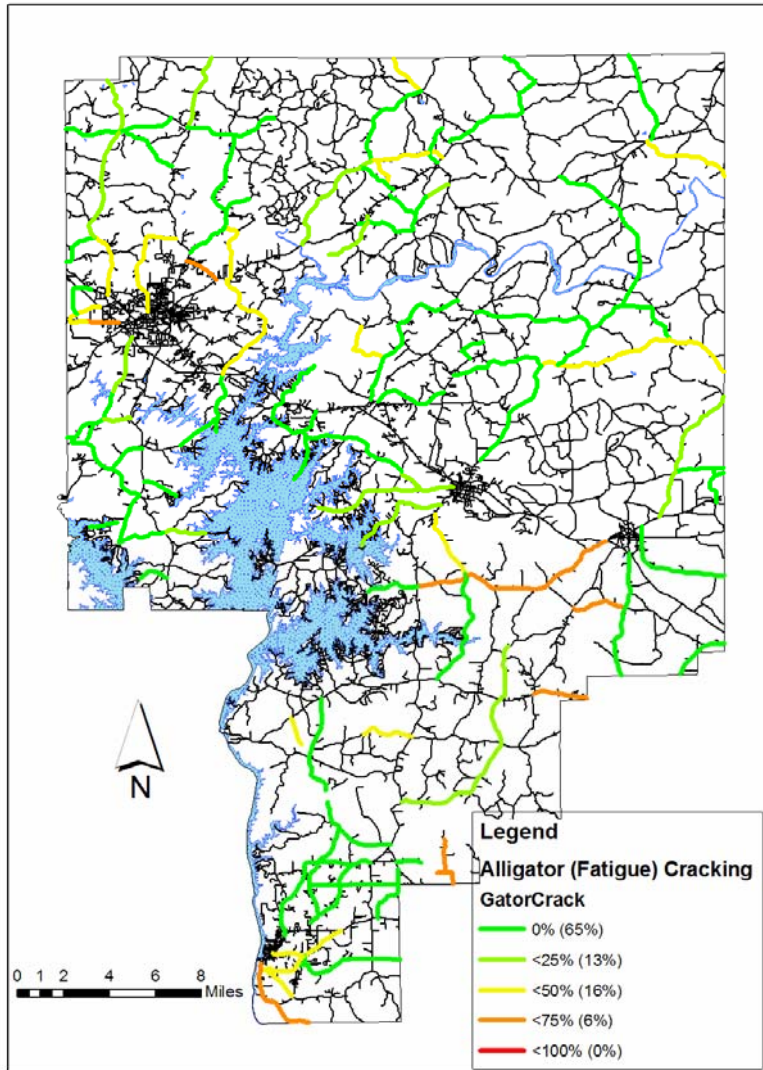
Figure 5.3 - 6. Alligator (Fatigue) Cracking

High extents are seen to some degree south of Tallassee and sporadically south of Dadeville. Otherwise, 78% of the county roads in the county contain 25% or less extent of alligator cracking.

Areas containing alligator cracking and longitudinal cracking in the wheel path were also examined in a multi-layer GIS presentation. This was to identify roads within the network with one or both of these types of load/support related distresses. This was done by creating layers displaying over 50% longitudinal cracking in the wheel path, as well as, alligator cracking of any severity. The results are shown in Figure 5.3-7. Here

86

we can see the roads with over 50% of the length possessing longitudinal cracking in the wheel paths, highlighted in green. All but two of these are located in the northern half of the county. Areas containing alligator cracking are mostly seen around Alexander City and Lake Martin. This display also shows 6 road segments containing both distresses. These are seen in the middle third of the county. These roads are likely in the need of the most immediate attention out
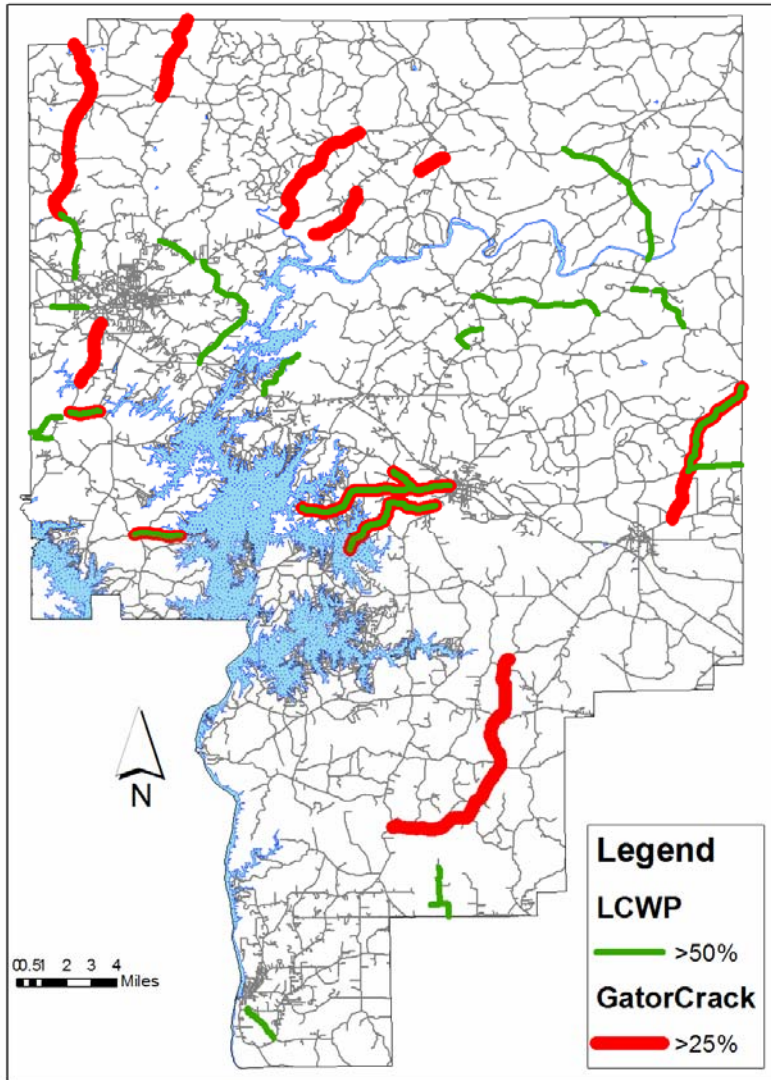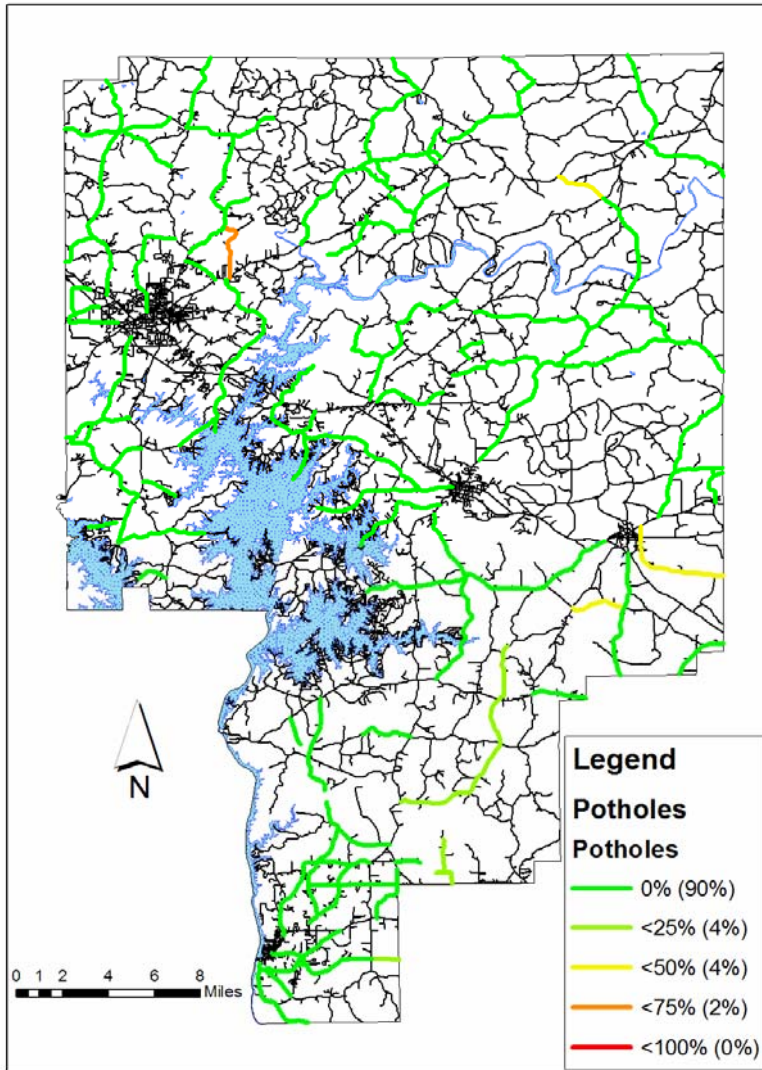

Figure 5.3 - 7. Support/Load Related Distresses

of this network subset because they would probably be the most vulnerable to water infiltrating the pavement substructure. This is particularly important since these are load/support related distresses, and water infiltration will further weaken the support of the pavement structure thus possibly magnifying the distress issue.

Figure 5.3 - 8. Potholes

Potholes are not observed to any great extent throughout the entire county (Figure 5.3-8). This is expected because one of the most common maintenance activities undertaken by Tallapoosa County is patching, which would include the repair of potholes. A greater extent of patching is expected since any potholes that are present are readily repaired. The figure shows that 90% of the network has no potholes. This suggests that this distress is readily maintained.
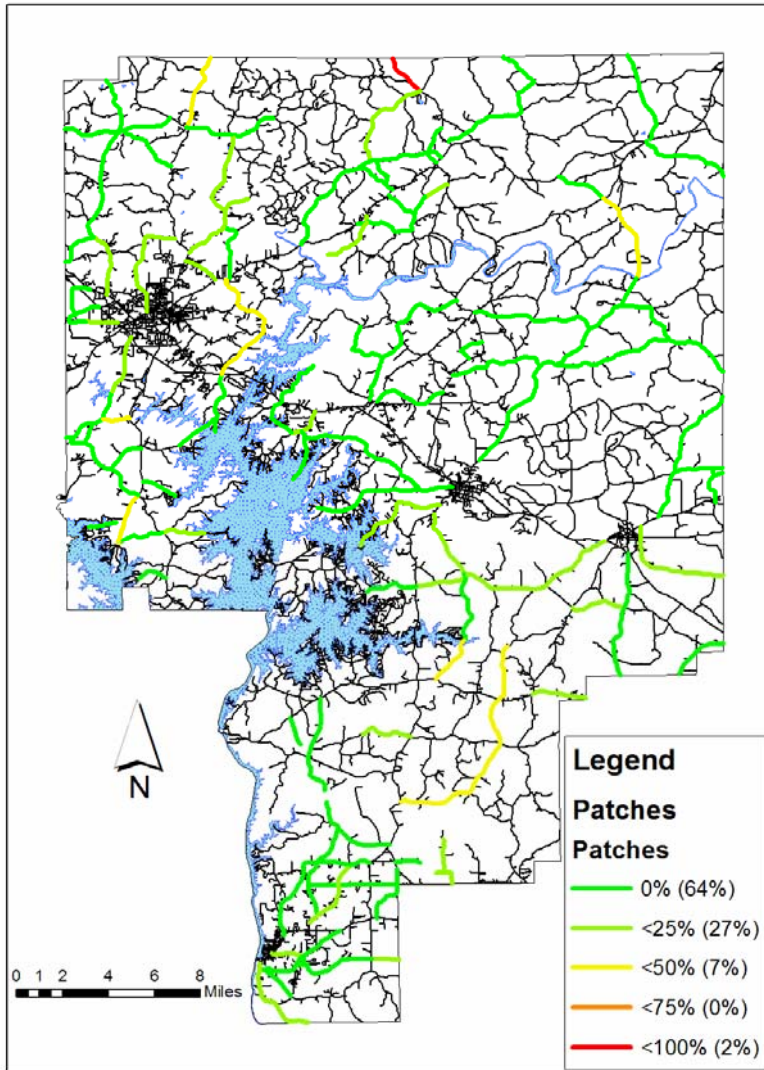
Patches are not present to a great extent in this GIS map with 64% of the network not possessing this distress (Figure 5.3-9). Other than one road in the north central part of the county, the entire county shows 50% or less of patching. The 100% extent for the one red road is due to the presence of a half lane full depth patch the entire length of the road segment. The rest of the patches in the county were relatively rare and often just isolated repaired potholes. This also agrees with the county windshield survey data (Figure 5.1-4).

Figure 5.3 - 9. Patches

Most (98%) of the county exhibits 50% or less extent of edge cracking, according to Figure 5.3-10. This is somewhat unexpected since other factors, which are influenced by support on the outer edge of a lane, displayed less desirable results. However, edge cracking may have simply been repaired recently before the time the AU windshield surveys were recorded. It can be seen that an extent of 50% seems to be common for roads extending to the eastern county line.

Figure 5.3 - 10. Edge Cracking

90
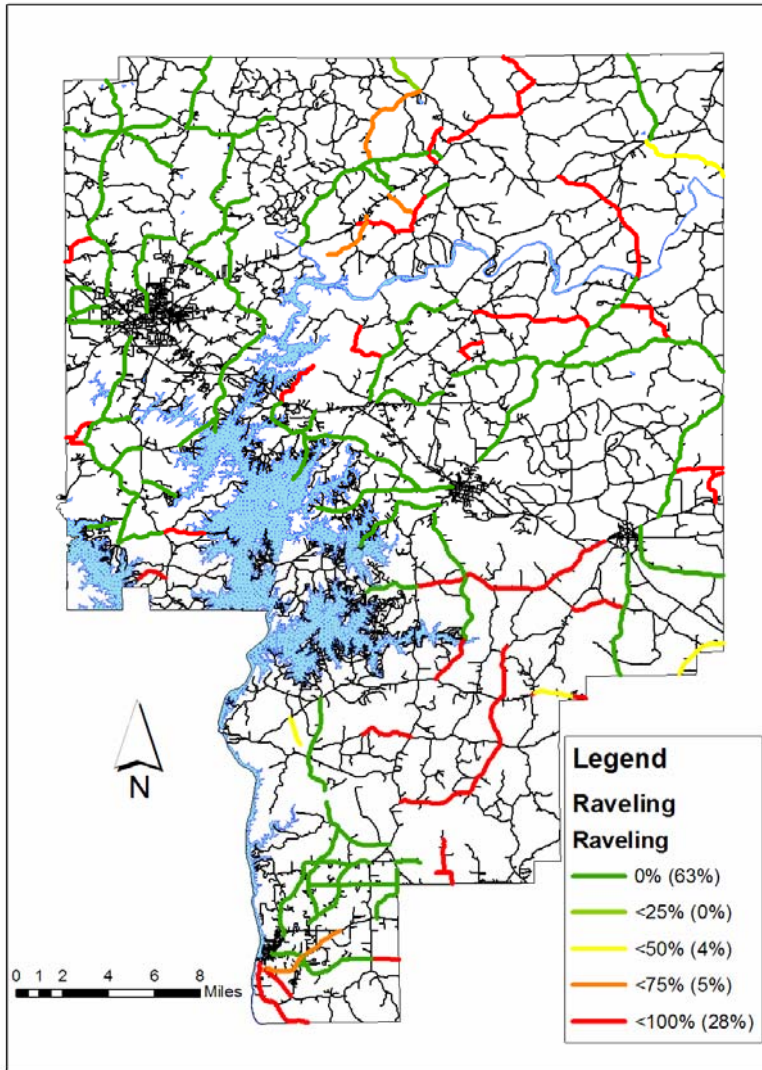
Figure 5.3 - 11. Raveling

A large number of roads in the eastern half of the county possess 100% raveling (Figure 5.3-11). Network wide this distress is present to 100% extent in a quarter of the road segments. These roads were often constructed with an old large stone chip seal. This result suggests a surface treatment such as a slurry seal might help reduce the extent of this distress within the network and at the same time improve both the surface texture and reduction of moisture infiltration.

It was also of interest to see if these road segments which possess 100% extent raveling correspond to any other pavement condition parameters. A multi-layered analysis was performed to see if these heavily raveled pavements corresponded to those pavements having a high texture value. Figure 5.4 – 12 shows just those road segments which possessed over 50% raveling overlayed on the texture values. It can be seen here that in most all cases pavements with at least

Figure 5.4 - 12. Raveling (50%) vs. Texture

50% raveling extent have an associated texture of around 2.0 mm. It is also of interest very few raveled pavements exist in and around Alexander City, with the highest concentration being closer to New Site and south of Dadeville.

92

Section 5.4 Areas of Interest Displayed in GIS Presentations

The collection of GIS presentations compiled in this study highlight different areas of common pavement condition throughout the county. These areas are of interest due to their observed conditions displayed by their values of the various condition parameters collected. Roads grouped in these areas display similar values and therefore may all need a similar type of maintenance or rehabilitation activity. These areas of interest are listed in Table 5.1 along with which parameters were observed to distinguish these areas. Each parameter, used to distinguish a general area of the county, was observed in the GIS presentation as an area that may call for maintenance to upgrade the quality of that rating.

Table 5.1 Areas of Interest within Tallapoosa County Road Network

Area of Interest	Parameters	Area of Interest	Parameters
North of and surrounding Alexander City	Pavement Rating	South of Dadeville and Southeast of Lake Martin	Edge Repairs
	Surface Treatment		Settlement
	Patching		Pavement Markings
	Edge Repairs		# Times Resurfaced
	Pavement Markings		IRI
	Year Constructed		Difference in IRI
	Difference in IRI		Transverse Cracking
	Longitudinal Cracking		Longitudinal Cracking
	Block Cracking		
	Alligator Cracking		Raveling
New Site Area/North Central/North Eastern portion of county	Pavement Rating	Southern portion of county and Tallassee	Edge Repairs
	Surface Treatment		Pavement Markings
	Edge Repairs		Difference in IRI
	Settlement		Longitudinal Cracking
	Pavement Markings		
	Year Constructed		
	Texture		
	IRI		
	Difference in IRI		
	Longitudinal Cracking		
	Raveling		

Each area of the county presented in the previous table has its own set of

parameters which likely need to be considered when making network level maintenance

and rehabilitation decisions. Some of these parameters are common in the four areas

while some are specific to a given area. This suggests that some parameters may be more

important than others in improving the overall pavement ratings for the county network.

This hypothesis will be explored further in the following chapter.

The other interesting question arising from these groupings of roads displaying

similar properties is "Why do these roads display these conditions?" Also, is it possible

that another parameter can be used to at least partially explain these observations?

Pavement condition is obviously a function of a number of different variables such as

traffic, weather, soil conditions, poor joint density achieved during construction, and

individual layer material properties.

With all these variables affecting pavement condition, it is important to explore

how GIS layers can be used to study these within a network of county roads. Traffic is

one of the most important variables, especially when dealing with load related types of

distress. However for low volume county roads, this information is not available in either

GIS or non-GIS form. This is the case for Tallapoosa County. With the lack of this

information, some type of alternative could still be useful. Being that traffic is not

available, population overlays could be used as another option. This research is not to

suggest that traffic counts are not needed, or that population and traffic have a proven

relationship. The use of a population layer is developed primarily to show the usefulness

of alternative GIS layers. Where as population may not be a surrogate for traffic, it can,

however, be used to examine some about pavement usage. Areas of high population may

experience higher usage. Where this suggestion lacks is the percent trucks factor. This

being true, it is possible that high population areas experience some heavy traffic such as

school buses, garbage trucks, and delivery trucks to grocery stores for example. The

amount of this type of traffic may not be present in areas of very low population. That is

not to say that heavy traffic does not exist on roads within a low population area.

Logging trucks for example may cause damage on these roads, but it is expected that if

this is the case these roads will display some type of signal within pavement condition

GIS layers.
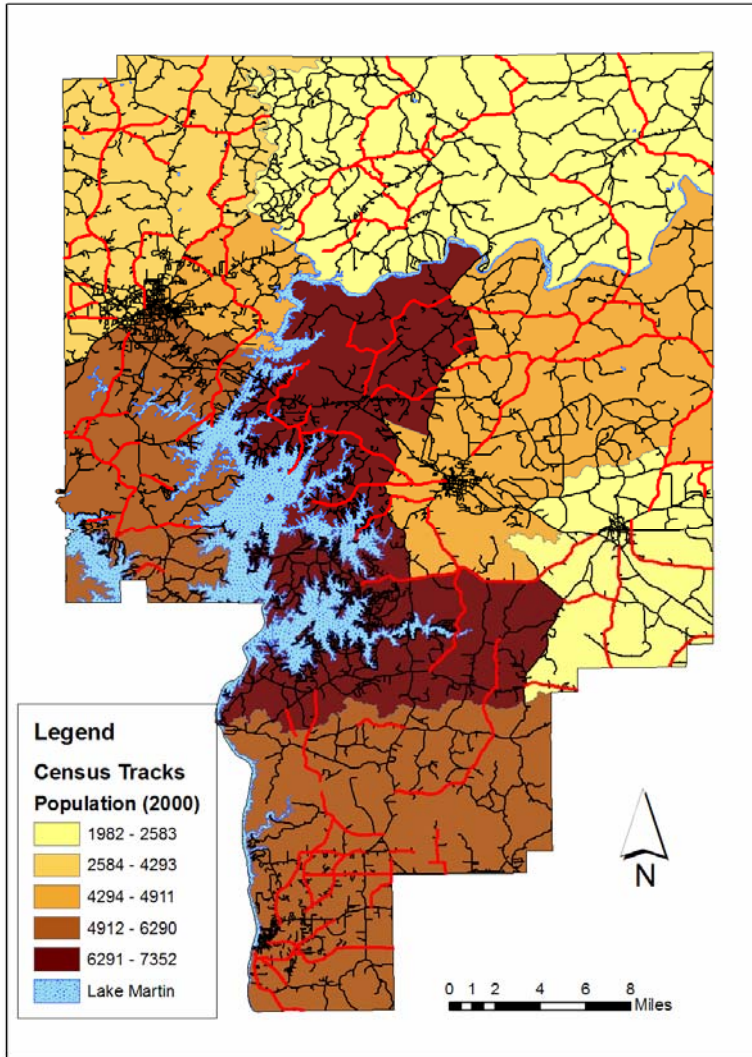
Figure 5.4 Census Tracks

Population data are obtained from the most currently available census records, in this case, the 2000 national census database. While population is not an exact traffic count for a given road, the population of the area in which a road is located does suggest a certain level of usage and public input to the county engineering office, which is a variable that should be considered when making maintenance decisions. The population overlay was created for Tallapoosa County from ESRI TIGER files, and is displayed in Figure 5.4 -1. The roads within the study are highlighted in red on this GIS presentation. Areas of higher population are shown in a darker shade of brown; higher population areas are located around Alexander City, Lake Martin, and the southern portion of the county near Tallassee. The area around New Site and the eastern portion of the county are less populated areas. These populations and census tracks in some cases closely relate to the areas containing common roadway

condition parameters. For example, the New Site area and northeastern corner of the

county is an area of similar low population. Likewise, the Tallassee area is one certain

population level. This suggests that population may have some degree of influence on

the condition of the pavement. In the next section, population overlays, in addition to

Chapter 5 analysis of pavement condition will be used to show the usefulness of

alternative GIS layers.

CHAPTER 6 MAKING DECISIONS USING GIS PRESENTATIONS

Section 6.1 Key Variables in Improving Roadway Total Rating

A main objective for a county PMS is to provide key condition information that can be used to optimize the overall quality and condition of a network of roads while minimizing cost, time, and disruption to traffic flows. For Tallapoosa County, this improvement would be reflected in an increase in roadway total scores (pavement rating). It is important, then, to understand what types of maintenance activities will have the greatest effect on the overall pavement rating. To better quantify any moderate to strong single variable correlations between category and pavement rating, a Pearson's coefficient matrix, also known as sample correlation coefficient, R, was developed. A sample correlation coefficient is used to describe the degree of linear association between two variables. It is also related to R^2 which is the measure of how much variance between the actual and predicted value within a linear regression can be explained by the relationship between the two variables (Ramsey 2002). For this research, moderate to strong correlations were defined as any relationship having an R greater than 0.7 (i.e., R^2 >0.49). This means that in a simple linear regression 50% of the variance between the actual and predicted value due to the model. Four variables were found to have a 0.7 or better correlation with pavement rating (Table 6.1).

Table 6.1 Pearson's Coefficients in Relation to Pavement Rating

Parameter	Pearson's Coefficient	R^2
Surface Treatment	0.89	0.79
Patching	0.73	0.53
Edge Repairs	0.83	0.69
Pavement Markings	0.86	0.73

Three of the four best single correlations with the pavement rating are categories in the Surface Element section of the county windshield rating form. Pavement marking, a key safety factor, is the fourth category that has a reasonable impact on the overall pavement condition rating.

It should be noted that the calculation of Pearson's coefficient and R^2 values assumes that both variables have a normal distribution. Each parameter was tested for normality using a Chi-squared test for normality which tests the null hypothesis that the distribution is normal. This is done to a significance level of 5%. Pavement rating was the only parameter tested which did not reject the null hypothesis of a normal distribution. This means that the normality assumption is not met. However, this does not mean the sample correlation coefficients and R^2 are not valid due to the fact that the statistical tools are robust to non-normal distributions. The only time this normality assumption is critical is when creating confidence intervals for simple linear regression which is not within the interest of this research. Other assumptions were linearity, constant variance, and independence. The data was plotted and linearity was observed with a constant variance presence so these assumptions were met. This is seen in Figure 6.1.
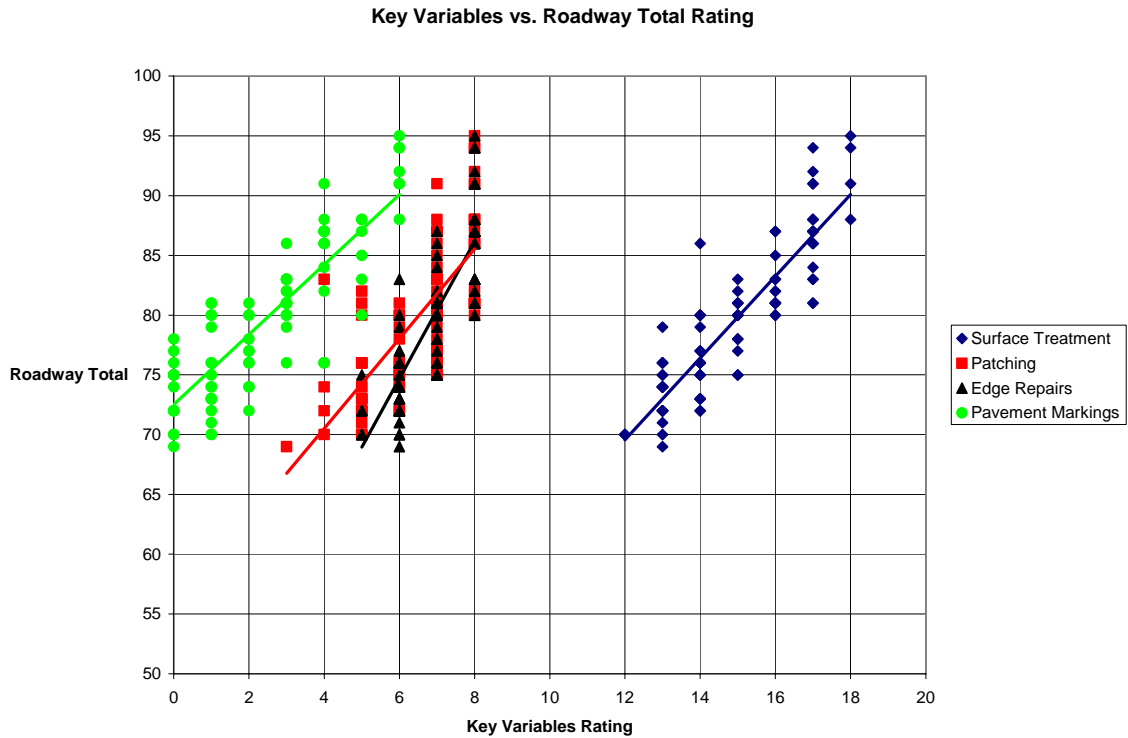
Key Variables vs. Roadway Total Rating

Figure 6.1 Key Variables' Rating vs. Roadway Total

Referring back to Table 5.1, each area in which the overall pavement rating was a

concern also included, at a minimum, these four categories based on visual observations

from the GIS presentations. This was the case for the area surrounding Alexander City.

The areas around New Site/Northeastern portion of the county contained three out of four

of these parameters. The other two areas noted contained pavement markings and edge

repairs, but not surface treatment and patches. In these two areas which contained only

half of the four key categories, pavement ratings were not seen as an issue.

A study of GIS presentations, and supported by the Pearson's coefficient matrix,

suggest that the overall pavement condition rating are likely a function of surface

treatment, patching, edge repairs, and pavement markings more than any other variable.

Therefore when making decisions on maintenance and rehabilitation, these four variables

should be focused upon since they have the most influence on the roadway's total rating. This is not to discount the necessity of properly maintaining all other areas, but does suggest that focusing funds on these areas could prove to be more cost effective.

Taking this result into consideration is simply a part of the decision making process. Distresses present, automated condition survey results and other available GIS layers, such as population, also have their place in the decision making process. The next sections study each area of interest, as set forth by Table 5.1, and show how each variable plays a role within the process of developing a maintenance plan for the upkeep of the network's total ratings.

Section 6.2 Decision Making for Areas Surrounding Alexander City

The first section of interest to be studied is the area surrounding Alexander City and north of the city to the county line. This area is shown within the boxed area in Figure 6.2-1 along with the overall county rating for the roadways in this area. This figure shows that the overall rating does not effectively highlight the key sections of the county that may need to be addressed by the county engineer.
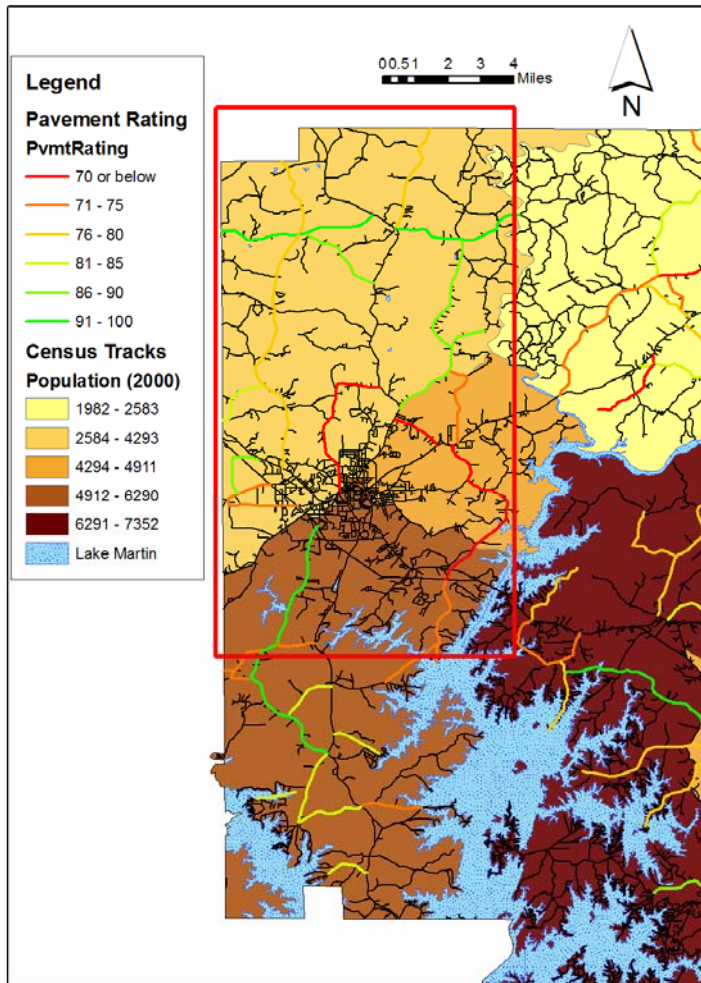
Figure 6.2 Roads Surrounding Alexander City (Boxed)

For this area, the previous GIS presentations (Chapter 5) showed that pavement rating, surface treatment, patching, edge repairs, and pavement markings all have low ratings according to the traditional county maintenance inspection reports. In addition, other parameters that can be used as tools for decision making for this region of the county are construction history, original year of construction, difference in IRI, longitudinal cracking, block cracking, and alligator (fatigue) cracking.

First, it is important to develop an understanding of possible reasons why these particular roads are in their current condition. A better understanding of this will lead to more logical and sound engineering decisions concerning maintenance and rehabilitation. Pavement history is a reasonable place to start this investigation. All the roads in this area (Red Box on Figure 6.2-1), except one, were constructed before the year 1963. Of these approximately 40 year old roads, half of these have only been resurfaced a maximum of 2 times (Figure 5.1- 17 in previous chapter) with many of these resurfacing activities having been performed before the year 2000. This suggests that on average these roads are resurfaced approximately every 20 years. This pavement history suggests that age and maintenance history may be a factor in why these roads are in their current state. Relating this information to a particular section of the maintenance inspection reports, the low rating of pavement markings may be contributing to the current ratings.

Next, distress and automated condition survey data are used to further study the condition of the pavement. Block cracking was one type of distress that was observed for this area of roads. Along the lines of pavement aging issues, block cracking is a type of distress which signals age- and environmentally-related material problems. Figure 5.3- 3 shows that block cracking extents of 50% to 100% exist on the roads directly surrounding Alexander City; this is also an area of the county with pavement ages over 40 years.

Longitudinal cracking and alligator crack were two other distresses that were present in this area as well. These types of distresses are caused by load or support related issues, which seems to be the case for these set of roads. Figure 6.2 - 1 shows that this area around Alexander City is one of a high population compared to the rest of the county. Also, Alexander City is one of the largest cities in the county and attracts traffic

from surrounding areas. These two facts suggest that traffic levels in this part of the county may be higher than other portions of Tallapoosa. This higher traffic and possible heavy traffic, such as delivery trucks, would lead to more load-related pavement distresses present on the older roadways that were likely not designed, given the age of original construction, to carry the current levels of traffic. The loss of support for traffic can be represented by both the loss of ride quality (IRI) and differential loss of ride quality (IRI difference between wheel paths). Levels of difference in this area often exceed 30 in/mile (Figure 5.2- 7). This suggests that structural issues within the pavement may exist and will become increasingly more important in both the functional and structural condition of the network. This structural issue may also be highlighted by the area's low patching ratings (Figure 5.1- 4) since patches are a result of pothole repair, which is sign that structural issues may be present.

Highlighting the above issues through the use of data displayed within GIS now lends a stronger platform for making pavement maintenance and rehabilitation decisions. For example, improvement of pavement markings in the area would increase the roadway total. This type of maintenance is also relatively inexpensive. However, judging by the rest of the factors, the area of roads may be a candidate for structural rehabilitation or at least resurfacing in the near future. Therefore, performing striping maintenance to the roads may not be cost effective due to the fact that these new markings would covered by an overlay of surface seal, then have to be re-striped. Performing an overlay or structural maintenance activity could be beneficial since it would address all four key variables that affect roadway total. Such an activity would increase the ratings of surface treatment, patching, and edge repair. The new striping that follows the overlay would in turn

104

increase the pavement markings rating. The increase of all four of these would have a

potential substantial increase for the roadway totals in this area. An increase of 6 is

possible for striping, 2 for edge repairs, 5 for patching, and 5 for surface treatment. This

means that the roadway total of 69 could be increased by 18 points to 87. This would

also address the distress issues present in the road.

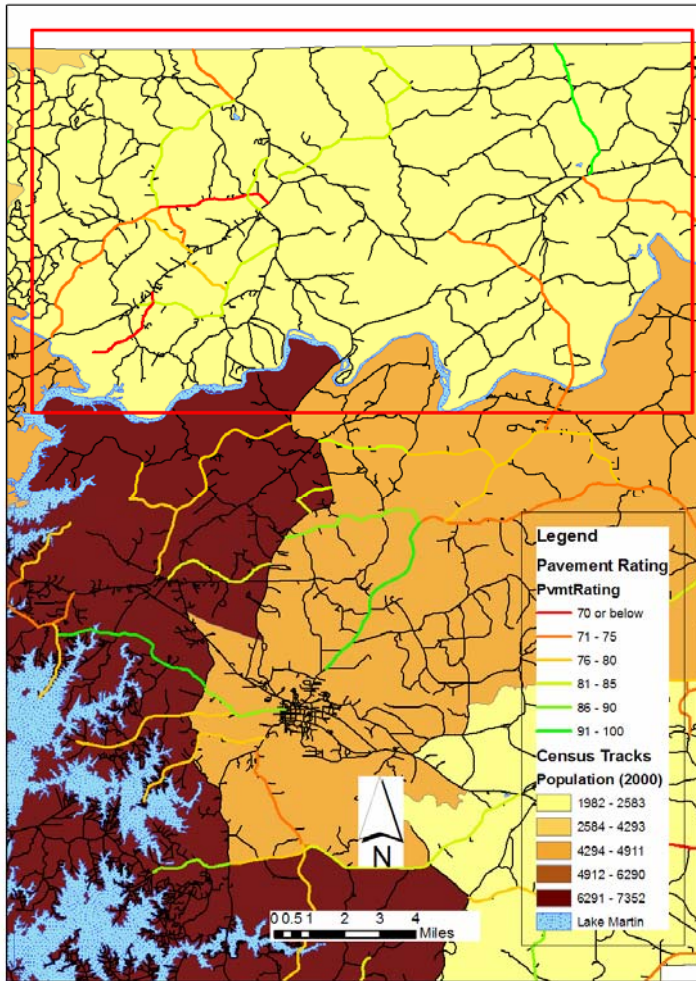**Section 6.3 Decision Making for New Site Area and Northeastern Tallapoosa**

Figure 6.3 Roads Surrounding New Site/Northeastern Area (Boxed)

The area boxed in red in Figure 6.3- 1 is the New Site area in the west and the northeastern corner of Tallapoosa County in the east. This is the second area of interest as indicated in Table 5.1. In this figure, the area is shown with both the pavement ratings and population overlays. Again, the key survey areas that may need attention are not fully highlighted by the overall pavement condition rating. Further examination is required.

Low scoring parameters for this region of the county are similar to those for the area around Alexander City. Again several pavement ratings for this area fall below 80, with two projects rating below 70. As was the case with in the Alexander City area, this occurrence, of low pavement ratings, is accompanied by low levels of the key survey areas; surface treatment, edge repairs and pavement markings. These parameters each fall around 50% of their respective maximum score in this area.

Texture, IRI, and difference in IRI values for New Site indicate poor ride quality. Also, the distresses present are not the same for as around Alexander City. Here longitudinal cracking and raveling are the most common distresses with considerable extent. Seeing these different parameters of interest suggest that the appropriate type of maintenance activities for this region will not be the same as in Section 6.2. While the Alexander City area may need overlays to increase structural capacity, the New Site area may only need surface seals.

Again, a better understanding of the current pavement condition can be gained through the examination of GIS presentations. For this area, the original year of construction is generally before 1963 (Figure 5.1- 12). So again, this area is comprised of mostly older pavements. About half of these pavements were resurfaced in the past 10 years, with most of these being resurfaced about 3 times over the life of the pavement. This suggests that maintenance activities have been used to upgrade the pavements throughout the years, but these activities have been somewhat scattered around the area. This could signify that certain roads around New Site may be due for some overlay activity. This also suggests that pavement markings may have been graded low due to lack of recent re-striping, which accompanies resurfacing activities.

Considering the data from the automated condition surveys and the AU windshield survey for distresses, ride quality seems to be the main issue in this portion of the county. Texture, IRI, differential in IRI between wheel paths, and raveling all signal a loss in ride quality. The ratings for IRI in this area would suggest that some structural support issues may be present; however, the fact that the only pavement distress that is predominantly seen in this area is longitudinal cracking in the wheel paths suggests that

107

the structural integrity of the pavements is starting to deteriorate, but is still not showing signs of advanced failure. The real issue seems to lie more within the wearing course itself. Texture above 1.0 mm (Figure 5.2- 1) and raveling of over 50% (Figure 5.3- 11) both suggest that pavement macrotexture is one of the main reasons for this poor ride quality.

The reason for this degradation in ride quality does not seem to be related to population, since Figure 6.3- 1 shows that this area of the county is one of the least populated. Maintenance activities in this region might be best directed toward distresses as a function of aging and/or water intrusion into the subgrade rather than structural inadequacy. The data collected and displayed in GIS presentations in Chapter 5 do not show the need for a structural fix. Patching is not an issue and all the distresses associated with support related issues except longitudinal cracking are not present to a great extent. Therefore, funding would be more effectively spent in improving the ride quality through a thin overlay or surface treatment. This would address the issues of surface treatment, as well as, pavement markings since the road would need to be re-striped after the overlay. For example, Cowpens Rd. currently has a roadway total of 70 which is the limit for being considered satisfactory by the state; even though any project in Tallapoosa County rating below 80 is given attention. An overlay to this project could potentially bring the surface treatment rating from a 13 to possibly 17 out of 18 in the surface treatment category. The pavement markings rating would also increase from the current score of 0 to possible 5 or 6 out of 6. This would bring the roadway total from a 70 to 80. Other factors for this project that an overlay would improve are the 5 to 8

patching score and a 6 to 8 edge repair score. This could increase the roadway total even further.

Structural rehabilitation in this region of the country would not be cost effective since the pavements do not show signs of needing such an activity and appear to be supporting the low traffic load adequately already. As seen in the Cowpens Rd. example, a simple surface treatment (e.g., thin overlay, microsurfacing) could be the most advisable use of funding for this area to improve network roadway total scoring around the New Site area. Life cycle cost comparison is needed, but is beyond the scope of this research.

Section 6.4 Decision Making for Dadeville and Southeast of Lake Martin
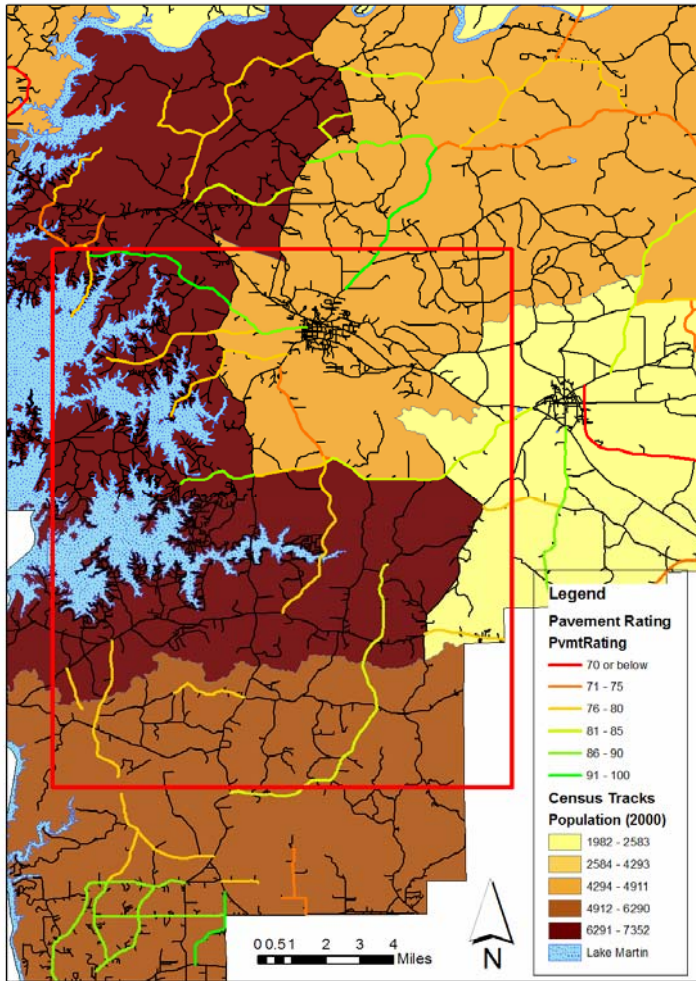
Figure 6.4 Dadeville and Area Southeast of Lake Martin (Boxed)

The area around Dadeville and the southeast shore of Lake Martin is shown here in Figure 6.4- 1 along with population and pavement ratings for the area. As shown, pavement ratings for the area are not particularly low. However, this does not mean that certain areas of pavement condition do not need to be addressed.

GIS presentations, in Chapter 5, show that edge repairs, pavement markings, and settlement all rate low in this area. Along with these traditional county survey areas, high IRI values, transverse cracking, longitudinal cracking, and raveling are all present through this area. These suggest that ride quality may be an issue and that both aging and environmental issues could be present.

Construction history GIS presentations in Section 5.1 show that the roads in this area were mostly constructed before 1960 and have been resurfaced three to as many as five times since their original construction. A number of these resurfacing occurred after

110

the year 1995. This suggests that even though the original pavements are around 40 years old, constant monitoring and resurfacing activities have been performed. This would explain why pavement ratings are above 70 and generally above 80 out of 100 for this portion of the county.

Population for this area seems to be high relative to the rest of the county and similar to the Alexander City area. This area around Lake Martin is highly residential with many people owning lake houses. This suggests that usage of these roads could be moderate and possibly seasonal, with more people traveling on the roads during the spring and summer. Longitudinal cracking and the high IRI values may be a result of a prolonged periods between maintenance coupled with high usage. This particular population would suggest more possible public input, as well, and could explain why this area has had more activity may need to be dedicated to it.

The distresses and other data for this area do not signal specific maintenance or rehabilitation activities since pavement ratings are not an issue and parameters in need of attention do not signal one specific type of issue within the region. Therefore, it can be said that the most cost effective type of maintenance in this area would more than likely focus on each survey area or distress individually. Pavement markings could be improved throughout the region with re-striping which would also improve safety on the roads. In relation to distresses, the progression of cracking, both longitudinal and transverse, could be addressed by crack sealing maintenance. A chip seal or slurry seal may also be appropriate for this region. This, along with crack sealing, could slow the progression of surface distresses along with possibly improve the ride quality of the roads by lowering the levels of IRI. Whichever type of maintenance for this area is decided

upon, constant monitoring and maintenance activities should continue for this area since it is highly populated, and more substantial structural issues could arise if such traveled roads are left unattended.

Section 6.5 Decision Making for Areas Surrounding Tallassee
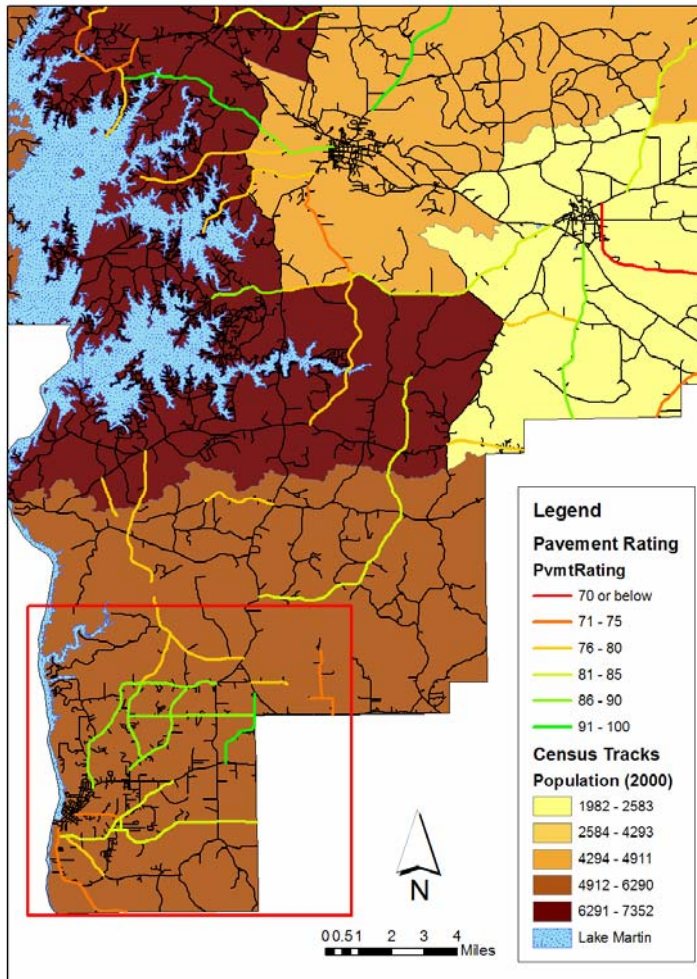

Figure 6.5 Area Surrounding Tallassee (Boxed)

The pavement ratings for the roads in and around Tallassee score above 80, except for four roads. This is shown, along with population in the boxed portion of Figure 6.5-1. This is an area in which most roads are in fairly good condition. GIS presentations in Chapter 5 do show that there are still some areas in need of attention even for roads having a high overall pavement rating on traditional county surveys.

The parameters in need of attention and present distresses for this area tend to be the ones that are observed for the entire county network. Edge repairs, pavement markings, differential in IRI between the wheel paths, and longitudinal cracking are seen in this region to some extent as they are

112

throughout the entire county. This suggests that the pavement condition in this region may not be as sensitive to things such as population since population varies throughout the county and these types of deficiencies are still present. For this region, simple construction practices may be the cause of a low edge repair rating. If roads in this area have been widened from their original state, the construction practices of this activity may have resulted in the premature deterioration of the edge of the pavement. Often time's county engineers have experienced situations in which inadequate support has been given to the edge of a pavement. Further study of this phenomenon would be useful. For example, lane width could explain the deterioration on the edge of the pavement. Wider lane widths may correspond with the driving public staying closer to the center of the pavement and more towards where wheel path distress should occur, instead of wheel paths being the edge of the pavement. This could be the case for this region's low edge repairs score, as well as, could be the case county wide since this area of the maintenance inspection reports score low throughout the county.

Pavement markings rate low around Tallassee, as they do for the rest of the county. This too suggests that, perhaps, attention should be given to this parameter county-wide. Striping or re-striping a road is a relatively inexpensive maintenance activity which could have a noticeable improvement to the network's overall roadway totals. The average pavement markings score for the entire county is only 2 out of 6. As Section 6.1 explains, this low score has a noteworthy effect the roadway total rating for the network roads. Improvement in this area would not only help roadway total, it would also increase the safety of the roads which is important to county engineers and the general public alike.

Lastly, differential in IRI values between wheel paths and longitudinal cracking are issues around Tallassee. These two parameters are again seen throughout the county. This is expected with longitudinal cracking in the wheel path since it is often one of the first distresses to appear in flexible pavements. This along with difference in IRI does suggest, however, that certain attention should be paid network wide in controlling the appearance of surface distresses. Longitudinal cracking paired with an uneven wearing of the pavement, shown by a high difference in IRI values between wheel paths, may suggest that more advanced types of distresses such as fatigue cracking or potholes may develop in the near future. Maintenance activities such as crack sealing as well as upkeep of proper drainage effects will help protect the pavement and slow this progression of distress.

This section and the previous three have shown that GIS presentations are a useful tool in analyzing data for a network of roads. The examination of different regions using this GIS data shows different ways to help determine the most appropriate activities for that particular region. This emphasizes how important having a geographic reference for pavement condition data can be to network analysis.

CHAPTER 7 SUMMARY OF WORK, CONCLUSIONS, AND FUTURE WORK

Section 7.1 Summary of Work and Conclusions

The following section is a summary of work that was performed during this research followed by conclusions that are based on the objectives in Section 2.1 of this report. This summary is given to highlight important points of the work completed.

- Public domain GIS products such as ArcGIS^{TM} and TIGER files are available, and GIS maps of county roads, boundaries, bodies of water, etc. are able to be constructed by completing the step-by-step methodology developed for this thesis. This process provides the base layer information for entering any type of county-developed condition information into a GIS interface, and displaying it as a county-wide GIS presentation.

- The creation of a subset of roads to be managed by the agency is created within GIS using TIGER files by selecting the roads of interest and labeling them in some fashion, for example by county maintenance report page number. This allows the organization of attribute tables so that all roads not being managed are moved to the bottom of the table while data manipulation is being performed.

- GIS files may be edited to include a variety of different data for each roadway. Data from traditional county surveys, automated condition surveys, and the AU windshield survey for distresses were successfully added into the ArcGIS shapefile's attribute table.

- Addition of data to attribute tables may be accomplished with ArcGIS or Microsoft Excel computer packages. One roadway project may include one datum value for a certain variable, or it may be appropriate to add different values for different parts of one project.

- Pavement condition data may be displayed using different overlays upon a base map of roads within ArcGIS. Different values for one pavement condition variable can be displayed through the use of highlighting these different values with a gradient of colors.

- Each area of traditional county maintenance inspection reports can be individually displayed in GIS presentations. These presentations give an understanding of how certain areas, such as surface treatment or patching, are rated across the entire network of roads.

- Displaying a network's construction history within GIS highlights areas of older pavements, higher maintenance activity frequency, and age of current overlays.

- Automated survey condition data can be displayed within GIS for a network of roads. This information is a source of objective data for observing pavement condition and is a good supplement to traditional county surveys.

- GIS presentations for automated survey condition data for Tallapoosa County highlight IRI and the difference in IRI between wheel paths as an area which may require attention.

- Distress data from the AU windshield surveys, displayed in GIS presentations, show how and to what extent the network of roads in Tallapoosa County are deteriorating. Examining these presentations give insight into what type of issues,

such as aging, environmental, load, or support-related issues may exist within a collection of roads.

- Additional GIS overlays, such as population, soil conditions, land use, and industry locations may give important insight into possible causes of a pavement's condition, and also allow for further analysis of how a county's road network performs and interacts with its surroundings.

- Different combinations of GIS overlay presentations may lead to more cost effective decisions on maintenance and rehabilitations activities for a network of roads.

- Population may suggest the level of pubic input and subsequent prioritization in some areas. Lower frequency of certain maintenance activities in areas of low population may explain lower condition ratings of roads in those areas. It may also give some indication of pavement usage.

- Cost effective decisions may be made for different areas of a network by the examination of all three types of pavement condition data. For example, striping would not be cost effective in an area that will soon need an overlay or other surface treatment since these roadways would have to be re-striped after this work. Similarly it would not be wise use of funds to overlay an area which may simply call for re-striping and signage improvement to increase the overall pavement rating.

The following items are the conclusions from this research. Based on the research objectives, the following conclusions on the research can be made.

- Displaying network data in GIS presentations highlight issues that exists network wide.

- GIS presentations of Tallapoosa traditional county maintenance inspection reports show that four areas consistently score low throughout the entire county. These areas are surface treatment, patching, edge repairs, and pavement markings.

- Different areas in Tallapoosa County display different types and extents of distresses. This suggests that different areas of the county are differentially influenced by environmental factors, available materials, or traffic-related issues and should be considered individually.

- Based on all three sources of data, the network of roads in Tallapoosa County can be separated into four main areas which are listed below. Roads in each geographic area display similar values for a set condition parameters, which differentiates one area from another.
    o North of and surrounding Alexander City
    o New Site Area and northeastern portion of Tallapoosa County
    o South of Dadeville and southeast of Lake Martin
    o Tallassee and southern portion of Tallapoosa County

- Surface treatment, patching, edge repairs, and pavement markings were determined to be the four areas of traditional maintenance inspection reports in Tallapoosa County which have a reasonable effect on the overall roadway total. This fact was confirmed by both GIS presentations and Pearson's correlation coefficient (R) values of over 0.7.

Section 7.2 Future Research

This research was a pilot study of how this system can be used by Alabama county engineers. From this research, more ideas and questions concerning future research have been developed which are discussed in this section. This is presented in order to promote and guide future work within this area of study.

First, the GIS database which has been created should be further expanded to include other counties in Alabama. The reason for this is to ensure that the current system is applicable to different counties. This would ensure that issues that may not be present in Tallapoosa County are considered and that there are not discrepancies in the usefulness of this system between counties. Ideally, the same type of data for other counties should be added to the system. This will both show that GIS is applicable in the same fashion to different county, and hopefully, support some of the preliminary findings of the current Auburn University research for simplified low volume county road pavement condition surveys. Relationships between pavement performance variables developed in this research should be further explored with data from different counties.

Additionally, more work should be done to explore additional uses of GIS within the framework of a county PMS. Sophisticated queries and spatial analysis are two of the many tools available within GIS. These types of analysis should be further developed to increase the usefulness of this tool to county engineers. Some examples of possible studies include; the effect of soil type and water table height on pavement condition, the relationship between pavement condition and surrounding land usage, studies on the affect of different weather parameters, and the study of the relationship between topography/ground slope and pavement condition. Analysis of all these types of

variables can be performed within GIS. Future research should be considered in studying

how these types of analysis could be useful to a county engineer, as well as, how to best

implement them into the current PMS.

BIBLIOGRAPHY

AAG, Association of American Geographers, http://www.aag.org/tomlinson, Retrieved January 2007.

Aber, J., "Brief History of Maps and Cartography", http://academic.emporia.edu/aberjame/map/h_map/h_map.htm, Retrieved February 2007.

Amos, D. "Pavement Smoothness and Fuel Efficiency: An Analysis of the Economic Dimensions of the Missouri Smooth Road Initiative" Report No. OR07-005. 2006.

ASTM E965, Measuring Pavement Macrotexture Depth Using a Volumetric Technique, Subcommittee E17.23, American Society for Testing and Materials, 1996.

ASTM STP 1433, Constructing Smooth Hot Mix Asphalt Pavements, M. Stroup-Gardiner, Ed., American Society for Testing and Materials, 2003.

CRAM, County Road Association of Michigan, "PASER Cooperative Road Condition Survey: Demonstration Project" http://www.michiganltap.org/pubs/paser.pdf, Retrieved January 2007.

ESRI$_a$, "Desktop GIS", http://www.esri.com/software/arcgis/about/desktop.html, Retrieved February 2007.

ESRI$_b$, "Implementing GIS", http://www.gis.com/implementing_gis, Retrieved January 2007.

ESRI$_c$, "What is GIS?", http://www.gis.com/whatisgis/index.html, Retrieved January 2007.

Flintsch, G., Dymond, R., and Collura, J. "Pavement Management Applications Using Geographic Information Systems: A Synthesis of Highway Practice", Transportation Research Board, Washington D.C, 2004.

GIS Development, http://www.gisdevelopment.net/history/index.htm, Retrieved February 2007.

Groeger, J. et al. (2002). "Implementation of Automated Network Level Crack Detection Processes in the State of Maryland", http://pms.nevadadot.com/2002presentations/36.pdf. Retrieved January 2007.

Hill, Liz "GIS Support in DRL" SSC Network Update, Volume 9, Issue 1, Winter 2006

Huang, Y. "Pavement Analysis and Design" Upper Saddle River, NJ: Pearson Education Inc. 2004.

James, N. "Mapping the Sense of Place", http://envstudies.brown.edu/Thesis/2001/james/index.html, Retrieved January 2007.

Kulkarni, Ram B. and Richard W. Miller. "Pavement Management Systems: Past, Present, and Future." Transportation Research Record 1853, TRB, National Research Council, Washington D.C., 2003, pp. 65-71.

Mastandrea, Angela, Bill Swindall, and Gary Klassen. "Development and Implementation of an Automated Facility Inventory System", Transportation Research Record 1500, 1995, pp 127-133.

Medina, M., Flintsch, G., and Zaniewski, J. "Geographic Information Systems-Based Pavement Management System: A Case Study", Transportation Research Record 1652, 1999, pp 151-157

Miller, J. and Bellinger, W. "Distress Identification Manual for the Long-Term Pavement Performance Program", Report No. FHWA-RD-03-031. 2003.

Mt. Pleasant, City of. "Summary of Projects: Major Street Funds", http://www.mt-pleasant.org/depts/finance/capitalimprovement/majorstreet.pdf, Retrieved January 2007.

Ocean Teacher, http://ioc.unesco.org/oceanteacher/OceanTeacher2/02_InfTchSciCmm/ 01_CmpTch/03_GIS&SDI/02_AdvancedGIS/Projection.html, Retrieved March 2007.

Ormsby, T. et al. "Getting to Know ArcGIS Desktop: Basics of ArcView, Arc Editor, and ArcInfo", Redlands, CA: ESRI Press. 2004.

Osman, Omar and Yoshitsugu Hayashi. "Geographic Information Systems as Platform for Highway Pavement Management Systems", Transportation Research Record 1442, TRB, National Research Council, Washington D.C., 1994, pp. 19-30.

Parida, M., S. Aggarwal, and S.S. Jain. "Enhancing pavement management systems using GIS", Proceedings of the Institution of Civil Engineers: Transport 158, May 2005, pp. 107-113.

Partnerships for Change. "Mayville Area Joint Planning Commission Comprehensive Plan" Section 5, http://www.partnershipsforchange.cc/mayville/, Retrieved February 2007.

Ramsey, F. and Schafer, D. "The Statistical Sleuth; A Course in Methods of Data Analysis" Pacific Grove, CA: Duxbury and Thomson Learning, 2002.

Roadware, www.roadware.com, Retrieved December 2006.

Sayers, M. and Karamihas, S., "The Little Book of Profiling", September 1998.

Shahin, M.Y. "Pavement Management for Airports, Roads, and Parking Lots" New York, NY: Chapman & Hall. 1994.

Sobanjo, J. "GPS/GIS Inspection and Analysis Tools for Highway Construction", Contract No. BC 542-8, July 2006.

Stroup Gardiner, M., Carter, A., Das, P., and Bowman, B., "Development of a Ride Quality Specification Using an Inertial Profiler", Transportation Research Boards Transportation Research Board, TRR 1900 pp. 41-49. Jan 2004.

Stroup-Gardiner, M., Studdard, J., and Wagner, C., "Influence of Hot Mix Asphalt Macrotexture on Skid Resistance," Highway Research Center, April 2001.

Sunset Hills, City of. "Pavement Management History" http://www.sunset-hills.com/Publicworks/pavehist.html., Retrieved January 2007.

Tavakoli, Amir, Mitchell S. Lapin, and J. Ludwig Figueroa. "PMSC: Pavement Management System for Small Communities", Journal of Transportation Engineering 118, 1992, pp 270-280.

Tsai, Yichang and Buddy Gratton. "Successful implementation of a GIS-based pavement management system", Proceedings of the International Conference on Applications of Advanced Technologies in Transportation Engineering; Proceedings of the Eighth International Conference on Applications of Advanced Technologies in Transportation Engineering, 2004, pp. 513-518.

U.S. Census Bureau, http://www.census.gov/geo/www/tiger, Retrieved December 2006.

U.S. Geological Survey, USGS, http://erg.usgs.gov/isb/pubs/gis_poster, Retrieved February 2007.

Walker, D., Kummer, S., and Entine, L., "Pavement Surface Evaluation and Rating; PASER Asphalt Roads Manual", Transportation Information Center University of Wisconsin-Madison, 2002.

Zhang, Zhanmin, Stephen Smith, and W. Ronald Hudson. "Geographic information system implementation plan for pavement management information system: Texas department of transportation", Transportation Research Record 1769, TRB, National Research Council, Washington D.C., 2001, pp. 46-50.

APPENDICES

Appendix A Guide to Creating ArcGIS Maps using TIGER Files

Often times when creating an ArcGIS map, the area and features that are of

interest have already been created into ArcGIS layers for you. It is just a matter of

finding them. TIGER files are shapefiles created from the Topologically Integrated

Geographic Encoding and Referencing (TIGER) database of the United States Census

Bureau. These files contain data pertaining to roads, hydrography, utility lines, census

tracts, school districts, churches, parks, etc. This information is available for counties in

every state.

For this guide, the example that will be used is how to create a map of Tallapoosa

County in Alabama. The map will consist of county lines, roads, and bodies of water.

Obtaining the TIGER Files

1. Go to the ESRI homepage at www.esri.com shown in Figure A-1.
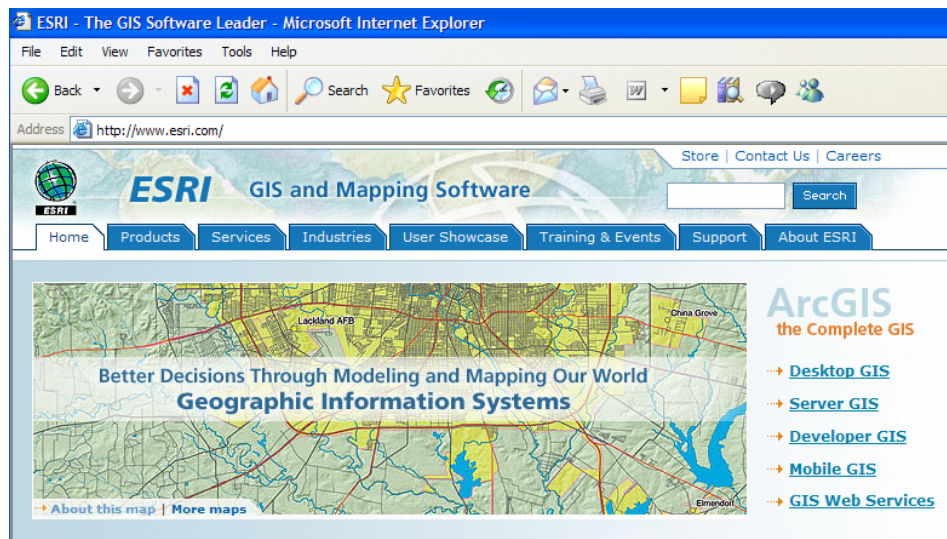
Figure A-1 ESRI Homepage

2. Under the Products tab, select "ESRI Data". The page shown in Figure A-2 should

appear.
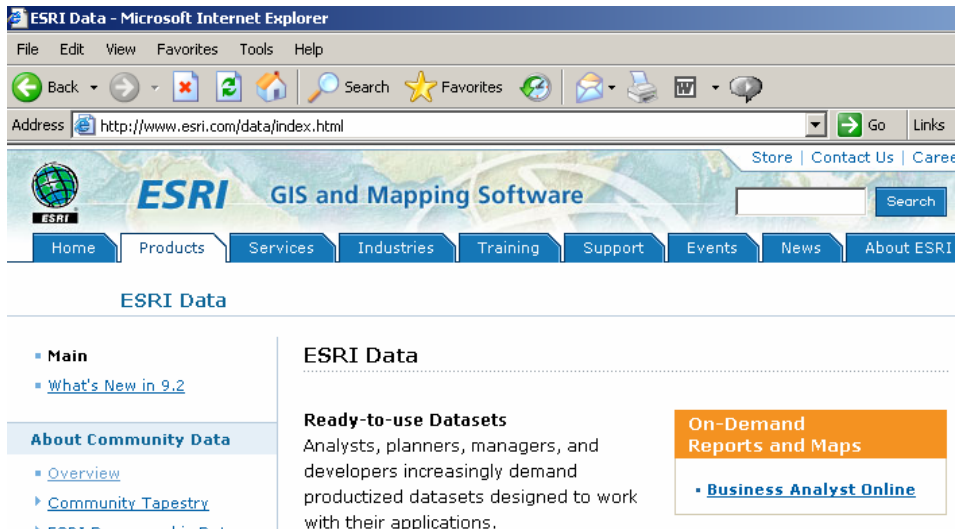
Figure A-2 ESRI Data Page

3. On the left of the page under the "Resources" section, select "Geographic Data

Portals". Within this new page, in the center, select "Census 2000 TIGER/Line Data"

under the Featured Downloadable Data section. This leads to Figure A-3.
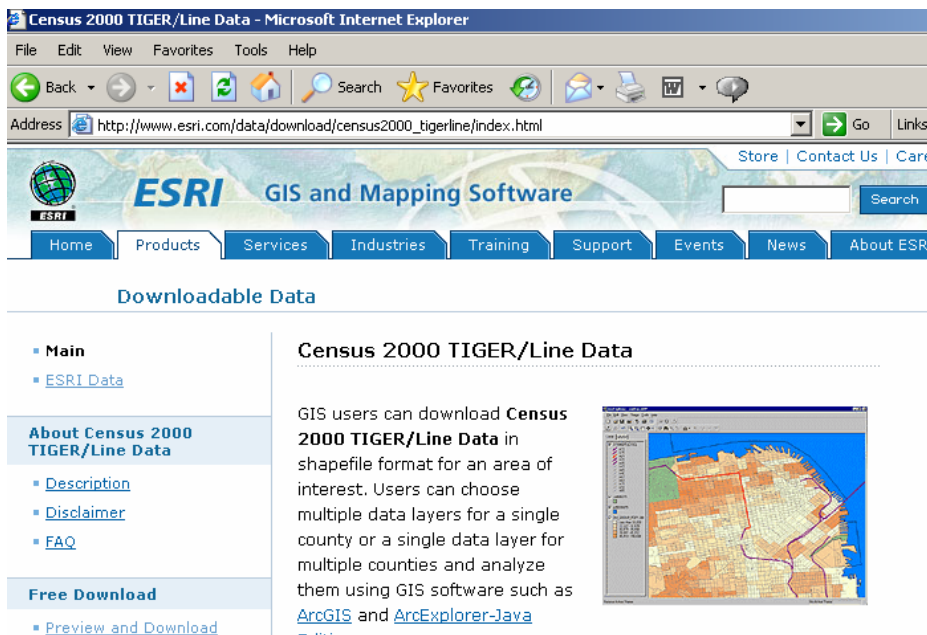
Figure A-3 ESRI Downloadable Data Page

4. Select "Preview and Download" under the Free Download section. This will open a

new page shown in Figure A-4.
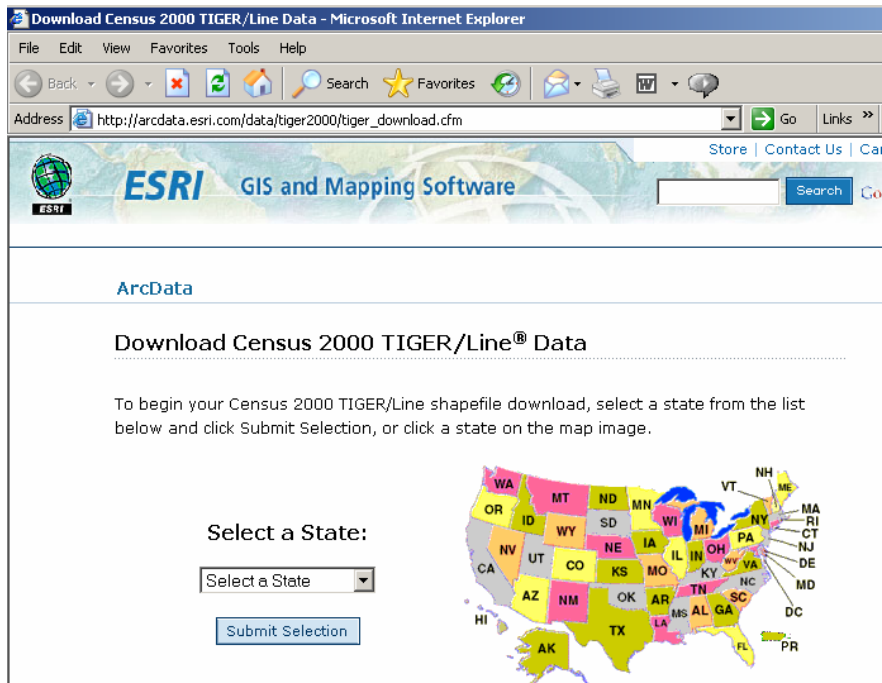
Figure A-4 ESRI Data Portals Webpage

*Note: At this point the Tallapoosa County example will be used.

5. Select the appropriate state either by using the drop down menu or by selecting the

state within the map on the right. For example select Alabama. The page in Figure A-5

should appear.
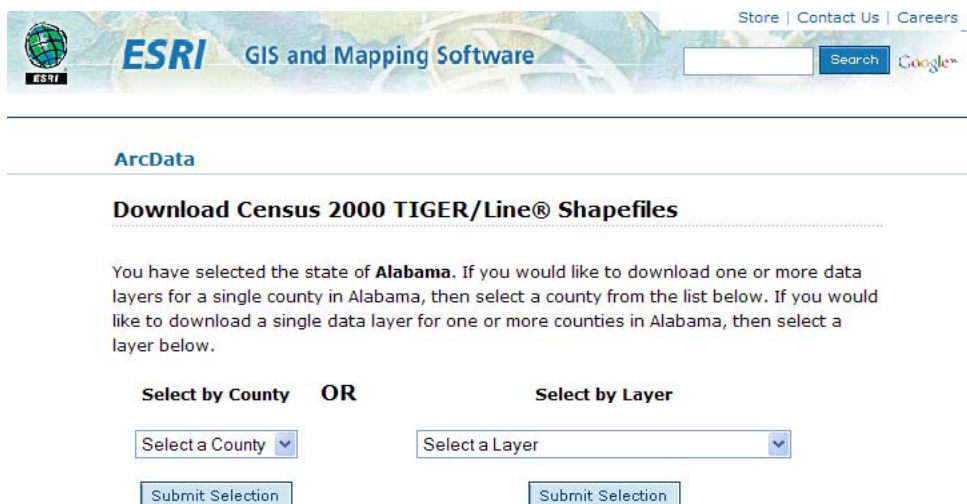
Figure A-5 ArcData State Specific Page

6. Now select either the county of interest of layer of interest. When selecting multiple layers for one county, selecting the county is a more direct approach. For this example, choose Tallapoosa County.

7. A list of all the available shapefiles will appear. To start a basic map of a county, select County 2000 (this is the county lines), Line Features – Roads, and Water Polygons. This will be enough to create a road map of the entire county including any major lakes, rivers, or streams. Once selected, click "Proceed to Download" at the bottom of the list.

8. Click Download File. Save files in a place where you plan to keep them. Once a project file is created in ArcMap, moving the shapefiles can disassemble the project.

9. The data is downloaded in zipped file folders. Find these folders and extract all files from them, saving them in an easily accessible location.

*Note: Do not change the name of the files. This will create an error when using them in ArcMap.

Creating the Map in ArcMap

Now that the appropriate layers have been downloaded, these are the steps to creating the map in ArcMap.

1. Open ArcMap. In the interface shown in Figure A-6 select "A new empty map" and then OK.
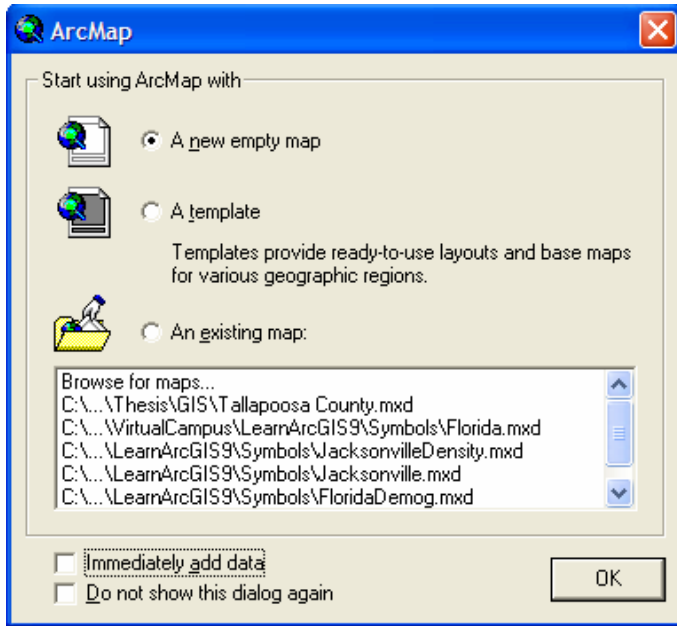
Figure A-6 ArcMap Startup Interface

2. Located in the top toolbar, click the Add Data Button (see Figure A-7) to add the

previously download shapefiles.
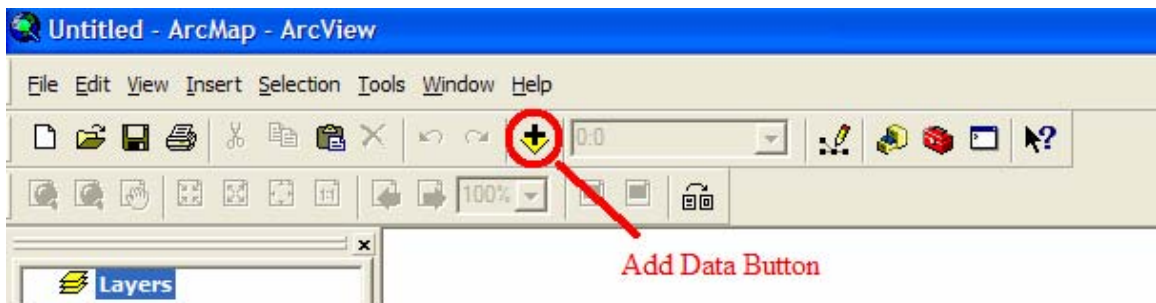
Figure A-7 Add Data Button in ArcMap

3. Navigate to the location of the saved shapefiles and select the layer to be added. For

example, select the roads layer and click add. Repeat this step with the other layers that

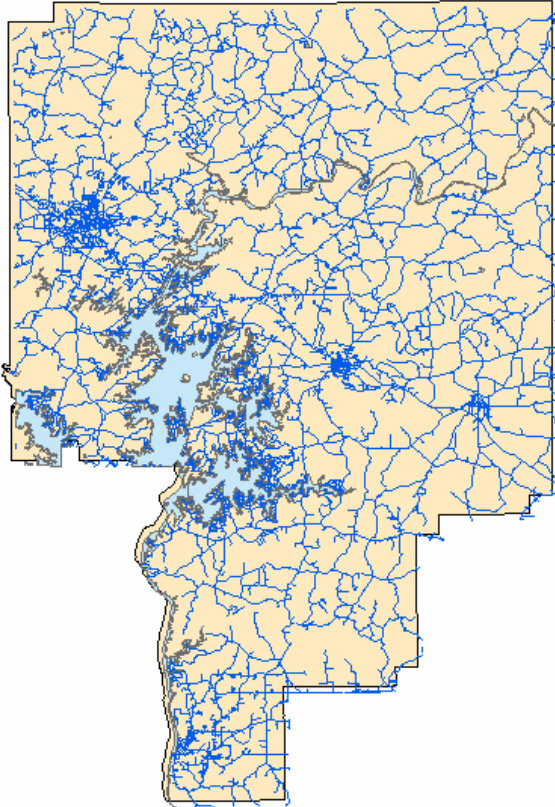were downloaded. The finished product should look like Figure A-8.

Figure A-8 Tallapoosa County Map

10. To change the properties of the symbol, double click the symbol located under the title of the roads layer in the pane on the left. The box shown in Figure A-9 should be opened. This is the editor for the line features. The interface for editing the polygon or point features is very similar.
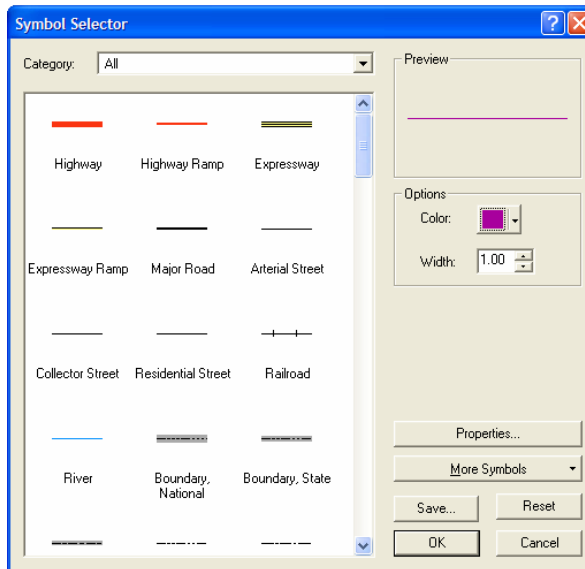
Figure A-9 Symbol Editor

11. The name of each layer can be changed by highlighting the layer name by clicking it once. Then clicking another time and changing the text.

12. Lastly, TIGER files often have useful data stored within them. To access the data, right click on the layer name and select Open Attribute Table. This will display the table containing all of the data used to create the layer.

13. To label the roads, right click the roads layer and select Label Features. This will display the road names on the map

14. To zoom in and out on the map, use the magnifying glass buttons located in the top tool bars.

15. Save the project file when finished.

The finished product should resemble the following figures. Figure A-10 is the map at full extent.
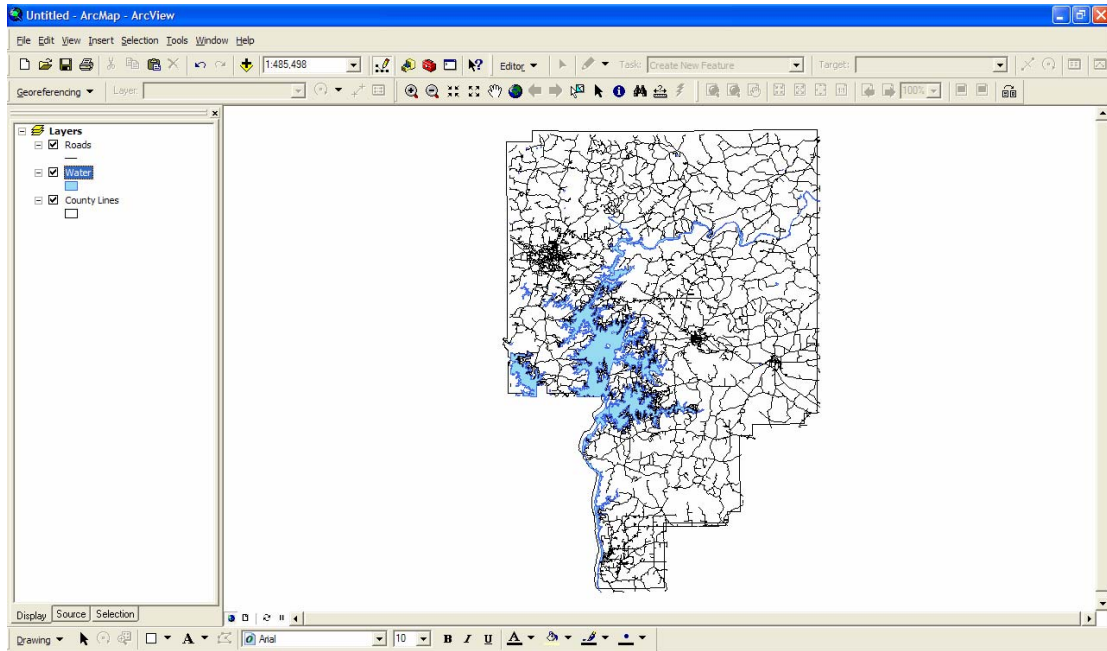
Figure A-10 Final Map (Full Extent and Feature Symbols/Names Altered)

Appendix B Managing TIGER Files Road Networks

Once an ArcGIS map has been created, it will be used for the storing, handling, and analysis of data. To do this for a network of roads, the particular subset of roads being managed must be organized in ArcGIS. Most often TIGER files will include many roads that are not of interest in a study or project. The following guide will explain how to select and organize the specific roads of interest. This guide is based of the assumption that a base map of roads has already been created.

1. Create or determine a variable that will be used to distinguish an individual road project. For example if one project corresponds to a specific page number in a survey notebook, the roads may be sorted according to page number.

2. Right click the roads layer in the left pane of ArcGIS. Select "Open Attribute Table" from the menu.

3. At the bottom of the new window, click "Options"

4. Select "Add Field" from the menu. This will bring up the interface in Figure B-1.
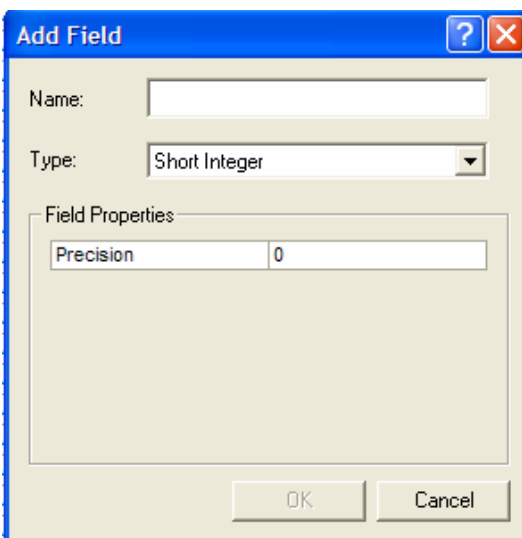

Figure B-1 Add Field Interface

5. In the Name field, type the name of the variable being used to organize the roads.

Note: Field names are limited to 10 characters and may not include spaces, but may

include underscores.

6. Select the type from the drop down menu. Short Integer should suffice. It will allow

the user to input integers from -32,000 to 32,000. Choose the appropriate precision.

Click Okay.

7. The new field appears at the far right of the attribute table. Now the specific roads

must be selected. Minimize the attribute table.

8. Right click Roads layer and select "Label Features". This will bring up the road names

for each feature.

9. Click the Zoom Button () and draw a window around the area containing the first

road or interest.

Note: If at any point the entire county needs to be viewed, click the Full Extent Button

(). Also, the Previous Extent button () will bring the view to the last extent viewed.

10. Click on the Select Features Button ().

11. Move down and select the line feature of the road of interest. The feature should then

be highlighted in a cyan color.

12. Hold the down the Shift key and continue selecting line features until one complete

road project length is highlighted.

Note: Often times an entire roadways length is not included in a project. This is okay. If

a specific length of roadway is needed to be highlighted, use the Measure tool () to

measure the appropriate length. Then select all features comprising this length.

13. Once an entire project length has been selected, click Editor located in the top toolbar. A drop down menu will appear. Select "Start Editing". ArcGIS may ask which file is to be edited. Select the file corresponding to the roads shapefile. This begins an editing session. Within an editing session, the user is able to add, delete, or alter data contained in an attribute table.

14. Restore the Attribute Table previously minimized. Notice the column names have changed from gray to white. This signifies that these columns are able to be altered. If the column headers are still gray, the editing session was not properly started.

15. At the bottom of the table, change the "Show:" option from All to Selected. This alters the table to show only those features that were previously selected. These rows should again be highlighted in cyan.

16. Scroll to the right to the newly created column. Insert the value being used to designate this particular road project.

17. Click Editor, again, and select "Save Edits". This saves the edits made.

18. Continue selecting individual project lengths and assigning each an individual designation value within the attribute table.

19. Once all the roads have been designated, save edits once more. Then, click Editor and select "Stop Editing". This exits the editing session.

20. Now that each road has been given a designation, reenter the attribute table. Scroll to the right to the newly created road designation column. Right click the column header and select "Sort Descending". This sorts all the rows by this column and brings all the rows with no designation (a column value of 0) to the bottom of the table.

21. One other helpful organization tool is freezing/unfreezing columns. For example, sort the data so that all relevant projects are at the top of the table (step 20). Now, right click the column heading "FENAME" and select "Freeze/Unfreeze Column". This freezes the road names to the left of the table allowing the user to scroll through the table columns while still being able to see the road's name. Freezing this column, along with the road designation column, is often helpful.

Appendix C Adding and Editing Data in ArcGIS

It is important to be able to add and edit data within attribute tables in ArcGIS. Using GIS as a pavement management tool requires the addition of many types of data and its organization within GIS. This guide will explain two different methods for entering and editing data within an attribute table. This guide assumes both that a base map of the county has been created and that the particular road projects have been organized and designated within the attribute so that each designated road project is easily accessed. If either of these things is not done, please refer to previous guides to accomplish these tasks before proceeding.

Single Value Entry

The first method covers entering data of a single value per road project. This means that this applies to data for which one road project contains one value for the entire length of the project. This allows the user to disregard which particular segment of the project the data is being entered and therefore may work with the attribute table outside of ArcGIS. This can be a simpler way to handle the data

1. Open ArcGIS.

2. Open the map project of interest.

Note: The project should be in the state noted in the introduction of this guide.

The data field must be created in ArcGIS before data may be added outside of the program.

3. Right click the roads layer title in the left pane. Select "Open Attribute Table".

4. Click the "Options" button at the bottom of the table.

5. Select "Add Field" from the menu.

6. In the Add Field interface (Figure C-1), enter the name of the data being entered.

Note: Field names can contain 10 characters and may not include spaces, but may include
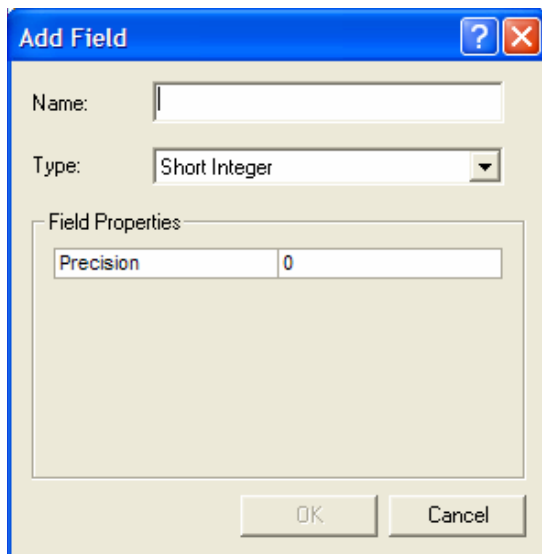
underscores.

Figure C-1 Add Field Interface

7. Choose the appropriate type of data being entered.

      a. Short Integer – consists of all integers from -32,000 to 32,000

      b. Long Integer – consists of all integers from -2 billion to 2 billion

      c. Float – consists of all numbers, including decimals, but is limited to 7

      significant digits. (Example: 3,004.234 of 1.839476)

      d. Double – same as a Float, but may contain 15 significant digits.

8. Enter the precision, and scale if using a float, of the data. Precision defines the number

of digits that can be stored in a field and scale defines the number of decimal places for a

float or double.

9. Click OK.

The new field (column) will appear to the far right of the table.

10. Exit the attribute table and save the project file. Exit ArcGIS

Now the actual data for the field will be added outside of ArcGIS using Microsoft Excel.

11. Navigate to the location in the computer containing the files used to create the map project.

Each shapefile has a database file (.DBF) associated with it. This file manages all the data contained in the attribute table.

12. Locate the .DBF file associated with the shapefile containing the road line features for the county being studied. The .DBF file will contain the same file name as the shapefile with a .DBF extension.

13. Right click the file and choose "Open With".

14. Choose Microsoft Excel from the list as the program to open the file.

This opens the attribute table within Excel.

15. Create a new column in the far left of the spreadsheet. In the same row as the rest of the column labels, label this column FID. This column does not carry over from GIS to Excel and must be recreated.

16. In this newly created column, number each row starting with 1 and continuing in increments of 1 through the entire collection of rows. This is done because the rows must be in the same order they start in when the file is saved. Otherwise, this will alter the geo-referencing with ArcGIS.

17. Click the gray cell located in the top right hand of the spreadsheet. This selects the enter spreadsheet.

18. Under the Data menu, select "Sort".

19. Sort all the data according to the column variable used for designating the individual road projects in descending order. This brings all the roads contained in the project to the top of the table.

20. Enter all the appropriate data for each individual road project in the appropriate cells.

21. Return the rows to their original condition by sorting all cells using the FID column created.

22. Save the file. Keep the data in the .DBF file format. Excel will alert you to this in a message. Exit Excel. Excel may prompt again to save the file. Click Yes. Save again as a .DBF file format.

23. Re-enter ArcGIS and check the attribute table for the new data values to ensure that the entry was successful.

Multiple Value Entry

This section covers the entering of data that has multiple values. This means that for one specific road project, the relevant data may have several values. For example, one road project may have multiple values of texture or IRI that the user would want to represent separately. Since dealing with the attribute table alone in Excel gives the user no sense of which individual feature relates to which location on a road. The entry of this type of data will have to be entered within ArcGIS

1. Create the new field for the data within ArcGIS as described in Steps 1 – 9 in the above section.

2. Use the Zoom button ( ) to draw a window around and zoom in on the particular

road of interest.

3. Use the Select Features button ( ) to select the road line feature for which a value

will be entered (selected features will be highlighted in cyan). Hold the Shift key down

and continuing selecting line features corresponding to the same datum value.

Note: Some data corresponds to a certain length of a road. Determine the length of a road

segment by clicking the Measure button ( ) and tracing the road. The distance will

appear in the bottom left of the screen. This helps in determining which features would

be included in a 2 mile stretch of road for example.

4. Once the appropriate road features for a datum value are selected, re-enter the attribute

table.

5. At the top of the screen, click "Editor" and select "Start Editing".

6. Select the appropriate file which contains the features and attribute table for the road

line features and click OK. This will start an editing session in which specific values of

an attribute table can be added, altered, or deleted.

7. At the bottom of the attribute table, switch the "Show:" option from All to Selected.

This makes the table display only the rows for the features that are currently selected.

8. Enter the datum value in the appropriate row and column being manipulated.

9. Under Editor, select "Save Edits".

10. If a roadway has only two values, it may be easier to change the Show: option to all

and enter the other value for that roadway in the appropriate non-highlighted rows for

that specific road project. The selected road features will still be highlighted in cyan.

11. To clear the selected features, click "Clear Selected Features" located under the Selection menu.

12. Continue the aforementioned steps to enter data for road project segments as necessary. Remember to save edits often!

13. When done editing the attribute table, save the edits a final time and then select "Stop Editing" located under the Editor menu.

14. Save the map project.

Appendix D Displaying Data in ArcGIS

Once data about pavement condition has been added to the attribute tables in ArcGIS, it is important to be able to present this data clearly. This is done in ArcGIS through displaying attributes in the attribute table with different symbols and colors. The following methodology outlines how to display data for roads that is contained within the attribute table of the road's shapefile.

1. Open ArcMap and open the current map project being utilized. Add a new road shapefile to the project. The new layer is added so that roads without the data being displayed will still be visible in a lower layer.

2. Right click the Roads layer name. In the menu that appears select properties. This will open the Layer Properties window shown in Figure D-1.
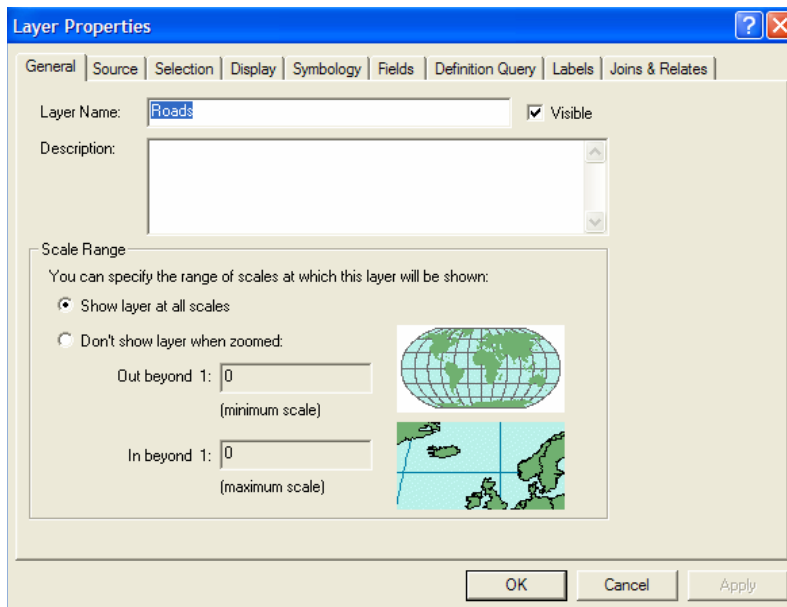

Figure D-1 Layer Properties Window

3. Select the Symbology Tab. In the left window, select the Quantities category. The window should then appear as shown in Figure D-2.
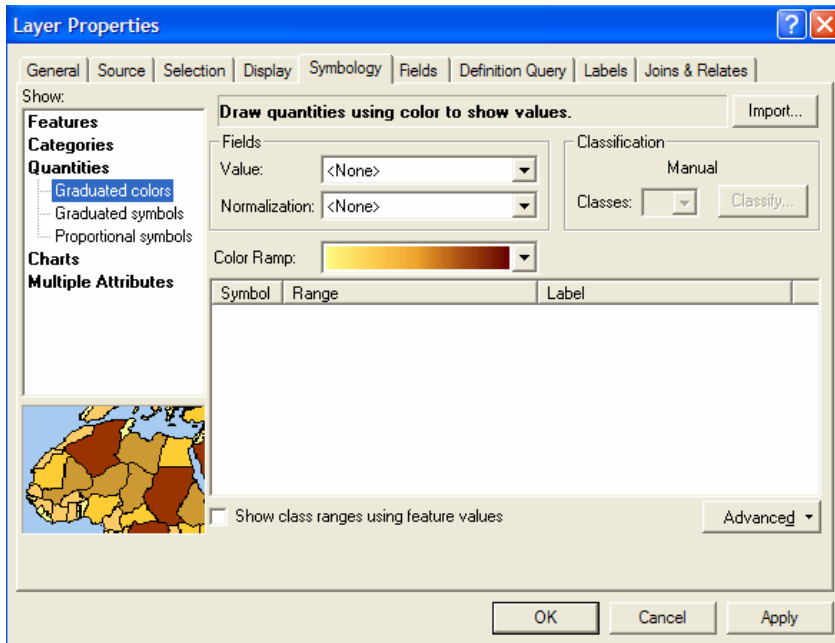
Figure D-2 Layer Properties (Show Quantities) Window

4. In the Fields section of this window, use the Value: dropdown menu to select the name of the particular value being displayed. ArcGIS may display a message saying that the maximum sample size has been reached. Click OK.

5. To limit the sample size to the roads being managed with this system, click the now available Classify button. ArcGIS will again give the maximum sample size warning again. Click OK.

6. Under the Data Exclusion section, click the Exclusion button. This will open the interface shown in Figure D-3. Here users may exclude certain roads from the sample based on criteria entered.
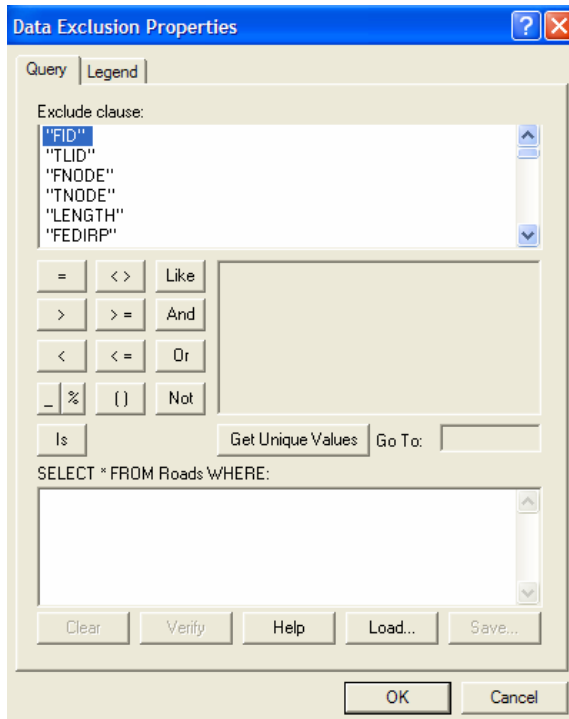
Figure D-3 Data Exclusion Properties Window

7. Scroll through the list under "Exclude clause" and choose the variable used to organize

the data, for example page number. Double click this variable. The name should appear

in the lower box. Then select the equal sign. This should appear beside the previously

chosen variable in the lower box. Lastly, click "Get Unique Values". This will display

all the values for the variable being excluded. Select zero. Click Ok. This now has

excluded all rows which did not possess a page number which would be the subset of

roads not being managed by this map project.

8. In the Classify window, alter the breaks in data being used by changing the number of

data classes under the Classification section. The values for data breaks may be altered in

the right hand window. Once the number of classes and data breaks has been set to the

appropriate values, click OK.

9. Alter the labels for each data class by clicking the label names and entering the new values.

10. Alter the color gradient being used by using the dropdown menu located in the middle of the window.

11. The symbols may be altered by selecting the symbol itself or clicking on the title "Symbol" and selecting "Properties for all symbols". Here symbol color, width, and other properties may be set to desired settings. Change all symbol widths to at least 2.0. This will allow them to be easily seen against the other road layers.

12. Once all labels and symbology are set to desired settings, click apply and then ok.

13. The newly symbols should appear on the base map. If they do not, make sure that the layer created to display this attribute is located at the top of the list in the layer name frame on the left side of the screen. The layer on the top of this list will appear on the top all other layers on the map. Figure D-4 shows this methodology completed for the potholes attribute in Tallapoosa County.
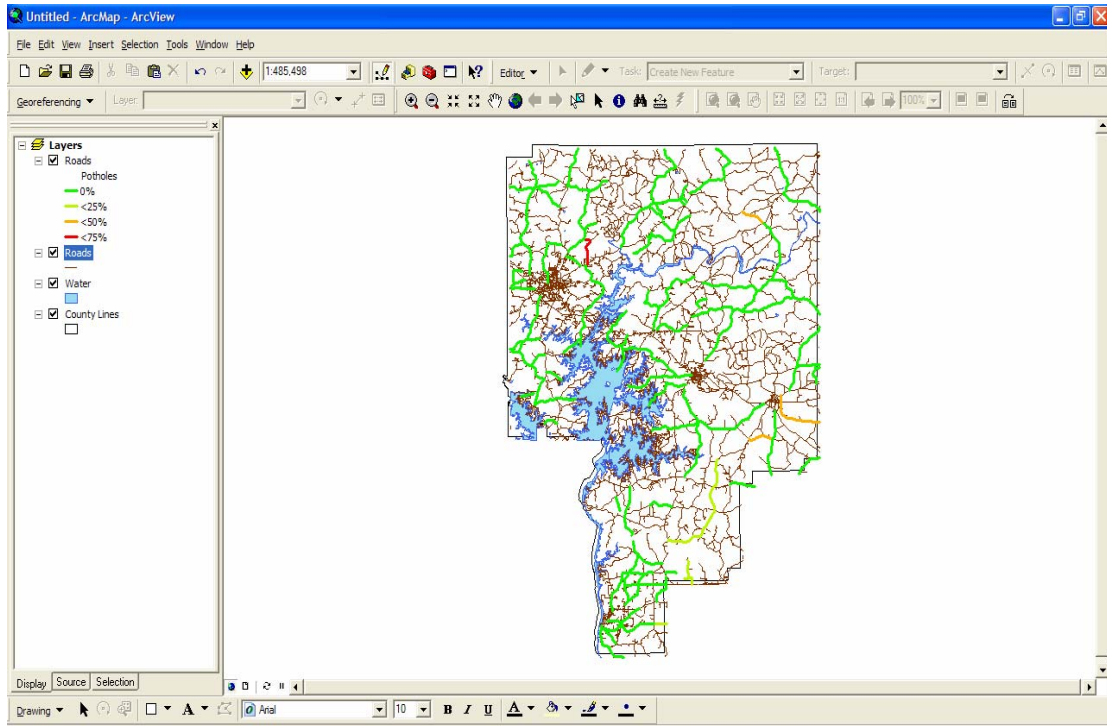
Figure D-4 Displayed Potholes Attribute for Tallapoosa County

Appendix E Extracting ARAN Van Data and Preparing for ArcGIS

The following is the methodology for taking files compiled by the ARAN van and processing the data into a useable format. The methodology is limited to the processing of texture and IRI data since these are the only two parameters studied by this research. This guide will describe how to process this data using the View computer package so that it is viewable in Microsoft Excel. It will also describe how this data was used in obtaining values of texture and IRI for each road. The steps are based off of the assumption that the data has been taken off of the database in the ARAN van in the form of a data CD or other data storage device.

1. Create a new folder in the C:\ drive to store the data files from the van.

2. Copy all data files to be processed into this newly created folder.

3. Open the View program. Note that to control the view program different commands are used. To toggle between commands use the arrow keys up and down. To select a command press the right arrow key or enter. To go back, press the left arrow key.

4. Scroll down to and select the "Data Files" command.

5. Select "Data Directory".

6. In the space labeled "Data:" enter the location of the newly created folder which holds the data. Set this location for "Reports:", "Process:", and "Output:" as well. Press enter after this address is entered in all four positions. The data files from the van stored in this folder should then appear in the window below.

7. Scroll down and select "Select Files".

8. Scroll through the list and select each file in the folder by highlighting the filename and pressing the space bar. A diamond should appear next to the filename to tell you that it has been selected.

9. Once all files have been selected, back out to the "Data Management" menu.

10. Scroll down to and select "Process Data".

11. Scroll down to and select "Texture". Next, select "Translate to text files". This creates readable files for all texture data gained.

12. Next, back out to the "Process Data" menu.

13. Scroll to and select "roughness Profile (SI)".

14. Scroll to and select "Data process".

15. Select "4. IRI". This process the IRI data contained in the files into a readable format.

16. Close the VIEW program.

17. Navigate to the folder containing the original data and the processed data.

18. Each file of the type 2R1 contains the texture data. Each file of type 220 contains IRI data.

19. Create a new folder to hold the translated Microsoft Excel files.

20. Open each texture (2R1) and IRI (220) file. Resave the file in this new folder and change the format the file is saved as to a Microsoft Worksheet. Now the data is ready to be analyzed.

The following methodology details how the texture and IRI data was analyzed for this thesis.

1. Start with opening the files containing texture data. The reason to begin with the texture data is because this is the easiest way to divide the road's length (chainage) into different pavement conditions.

2. Create a scatterplot of texture vs. chainage. Texture data is the column labeled MTD for macrotexture data.

3. Use this scatterplot to determine if any erroneous data exists. This data may come from bridges, that may be noted, or other sources, such as the van running off the road momentarily. Delete any of these erroneous data points from the dataset.

4. Visually determine if the how many segments of different textures are present along the road's length. Note the chainage at any point the road's texture changes.

5. Take average of each different texture segment of road. This value will stand as the texture value for that segment of road. If only one texture is present, take the average of the entire road's length.

6. Perform this for each texture data file.

7. Next open the files containing IRI Data. Now create a scatterplot of IRI (both left and right) vs. chainage. Note any erroneous data and exclude these points from the dataset.

8. Divide the IRI data according to the same segments as the texture data for the particular road being analyzed. This is so that the averages of IRI represent the same road segment as the texture averages. This is helpful when enter the data into ArcGIS.

9. Take the average of right IRI and left IRI according to the chainage segments used for the same road in texture. Again, if the road only had one texture present, take IRI averages for left and right over the entire length of the road. Use these and texture averages in the analysis using ArcGIS.