WV DPMS

DISTRICT LEVEL PAVEMENT MANAGEMENT SYSTEM FOR WEST VIRGINIA DOH DISTRICT 5

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ABSTRACT

WV DPMS
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The motoring public has an expectation that they will be provided with roads that are both safe and in satisfactory condition. State highway agencies' investment of public funds to keep roads in good condition pays large rewards in terms of savings for road users. Highway agencies using a Pavement Management System (PMS) will be provided with information for better decisions to ensure the tax-paying public gets the best value for their dollars.

This project consists of developing a useful and efficient network-level PMS for District Five of the West Virginia Division of Highways. The study area includes the counties of Grant, Hardy, Mineral, Hampshire, Morgan, Berkeley, and Jefferson in the eastern panhandle of West Virginia. District personnel must maintain approximately 1,340 miles of paved roadway. A review of the existing pavement management practices of District 5 was made and the West Virginia District Level Pavement Management System (WV DPMS) was developed. Existing data was used for the initial analyses and procedures to collect future data are presented.

WV DPMS consists of an inventory, condition assessment, treatment recommendation, priority analysis, performance model, and budget requirements. The WV DPMS will identify maintenance options, help prioritize competing road sections for immediate attention, and anticipate future deterioration. The WV DPMS will also aid in justifying budget requests to keep roads in good condition. The system is directed toward achieving the best possible value for the available public funds in providing and operating smooth, safe, and economical road surfaces. This report documents the methods used for the development of a PMS, the recommendations for implementation of the system, and the recommendations for the preservation of pavements in the study area. The project is a case study to demonstrate the effectiveness of WV DPMS and also serves to provide District 5 with better decision-making tools. The field investigation, analysis, implementation procedures, and conclusions are presented for the application of WV DPMS for the West Virginia DOT. Other Districts in the state will be able to immediately implement WV DPMS following the methods and procedures presented in this report.

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A premature thanks is given to the WV DOH personnel who will actually use this pavement management system. My intentions all along were to create a system that would actually be used and not just set on a shelf somewhere.

Finally, thanks are given to my parents for supporting me throughout my years of academia. My father, Mr. William Ford, was very helpful in answering questions, researching information, and explaining WV DOH policies and procedures. The words of encouragement that he and my mother gave inspired me to finish this project.

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CHAPTER 1 - INTRODUCTION

This project consists of developing a network level pavement management system (PMS) for District Five of the West Virginia Division of Highways (WVDOH). Existing pavement management practices of District 5 were reviewed and the West Virginia District Level Pavement Management System (WV DPMS) was developed.

The field investigation, analysis, implementation procedures, and conclusions are presented for the application of WV DPMS for the WVDOH. The management system developed consists of an inventory, condition assessment, treatment recommendation, performance model, priority analysis, and budget estimates. This thesis documents the methods used for the development of a PMS, the procedures used to implement the system, and the recommendations for the preservation of pavements in the study area. The study area includes the counties of Grant, Hardy, Mineral, Hampshire, Morgan, Berkeley, and Jefferson in the eastern panhandle of West Virginia. District 5 contains approximately 1,340 miles of paved roadway. Of that total, about 815 miles are secondary roads and 525 miles are primary roads. Primary and secondary roads in District 5 are designated based on the nomenclature of the DOH personnel. All US numbered and WV numbered routes are categorized as primary roads. State local service roads are classified as secondary roads.

1.1 PROBLEM STATEMENT

Highway transportation is a trillion-dollar business in America (Federal Highway Administration, 99). In fact, the average US household spends more than 20% of its net income on the purchase and operation of motor vehicles. Subsequently, the motoring public has an expectation of safe roads in satisfactory condition. State highway agencies' investment of public funds to keep roads in good condition pays large rewards in terms of savings for road users (Nichols, et al, 86). Highway agencies using PMS are provided with information for better decisions to ensure the tax-paying public gets the best value for their dollars.

Pavement management systems are part of the broader field of roadway management. Roadway management is a planning process. The five basic steps of the planning process include: (1) define the problem, (2) define the objectives, (3) generate alternatives, (4) evaluate the alternatives in terms of the objectives, and (5) select the best alternative (Deighton and Sztraka, 95). The roadway includes the pavement, sidewalks, drainage structures, bridges, signs, lights, etc. In most cases, pavements make up the majority of the investment and maintenance cost of roadways (Deighton and Sztraka, 95). The PMS aids in the planning process by helping to evaluate the alternatives in terms of the objectives (i.e., best product for the least money), and by identifying the best course of action.

Pavement management does not replace or interfere with good pavement design, materials, maintenance, rehabilitation, or other procedures. Instead, pavement management provides a means for synthesizing these activities to maximize pavement life and benefits (Haas, et al, 94). Professional judgement is enhanced, not replaced, by a PMS.

A PMS can be customized to meet specific needs or it can follow existing guidelines and practices. The American Association of State Highway and Transportation Officials, AASHTO, guidelines on pavement management defines two levels of PMS as:

> Network-level decisions are concerned with programmatic and policy issues for an entire network. These decisions include establishing pavement preservation policies, identifying priorities, estimating funding needs, and allocating budgets for maintenance, rehabilitation, and reconstruction. Project-level decisions address engineering and technical aspects of pavement management, i.e., the selection of site-specific maintenance, rehabilitation, and reconstruction actions for individual projects and groups of projects. A comprehensive PMS includes components to assist in both network and project-level decisions. (AASHTO, 90).

The system user must determine the necessary level of PMS and develop or customize the system accordingly. The desired outputs of the system dictate what level of PMS is developed.

The State of West Virginia owns and maintains approximately 32,000 miles of roadway, 24,000 miles of which are paved. Of this mileage, 1,744 miles are on the National Highway System (NHS) and receive federal funding (Federal Highway Administration, 99). WV DOH utilizes a PMS for their NHS roads but do not have a systematic approach to managing their non-NHS roads. There are about 22,000 miles of paved non-NHS roads that do not receive federal funds. This research focuses on the needs of the non-federal aid paved highways in West Virginia.

District 5 has already taken steps towards implementing the Road Surface Management System, RSMS, developed by the New Hampshire Technology Transfer Center, for their non-NHS roads (Amtower, 00; New Hampshire T^2 Center, 92). RSMS has been available to District 5 for some time but they do not utilize it to its full potential. One of the reasons given was the fact that RSMS is set up for city streets and their corresponding names and identity. District 5, and all other districts in the State, use a route number scheme and the pavement networks are on a much larger scale than accommodated by RSMS. District 5 engineers experienced many input problems with

RSMS and consequently could not receive the desired output from the system (Amtower, 00).

1.2 OBJECTIVE

The objective of this research project was to develop a PMS for district offices of the WV DOH. This objective statement infers that the system will provide the user with the following capabilities:

- Define procedures for collecting inventory and condition information about the district level highway network.
- Provide a database structure for storing and managing the inventory and condition information.
- Document procedures for managing the data.
- Provide analytical capabilities for determining treatment needs, and associated costs for each pavement section in the network.
- Prioritize the relative urgency of the needed treatments.
- Evaluate budget needs for each treatment category.
- Estimate the future needs for treatments.
- Perform long term budget allocations.

1.3 SCOPE AND LIMITATIONS

The scope of the WV DPMS focuses on the non-NHS roads that are managed at the district level of the WV DOH. This scope restriction implies multiple limitations on the program, including:

- The non-NHS roads managed at the district level are predominately surfaced with hot-mix asphalt concrete. Thus, only factors associated with hot-mix asphalt concrete were included in the system. This limitation affected the types of surfaces recognized in the program, types of distresses, treatment types and costs, and pavement performance models.
- All roads in the non-NHS network have low traffic and truck volumes. The low traffic volume allows use of a limited set of treatment options for the system.
- District offices do not have the funding for sophisticated data collection and analysis methods. Only manual data collection methods were considered for use in the WV DPMS.
- The system needed to operate within the existing computer environment of the district offices. This limited program development to microcomputers and their available support software. This limitation drove the decision to develop the WV DPMS within the Microsoft Office (Simpson and Olson, 96) environment using the Access and Excel programs.

1.4 RESEARCH APPROACH

The research approach included an in-depth literature survey of pavement management practices, focusing on procedures and implementation in local highway agencies. The next step was an in-depth evaluation of other PMSs, including the New Hampshire RSMS, relative to the current state of the practice and the needs of WV DOH District Engineers. An interview was conducted with the Director of Engineering for District 5 of the WV DOH about the shortcomings of RSMS with respect to their application.

The evaluation of RSMS was used to structure a PMS meeting the needs of District 5. This structure includes data collection methodologies, analysis, and project and treatment selection procedures. The WV DPMS was then programmed in Microsoft’s Access database and Excel spreadsheet, supplemented with programs in Microsoft’s Visual Basic for Applications (Simpson and Olson, 96). The analysis performed with the Access program estimates the pavement area needs for each treatment type. This information is transferred to the Microsoft Excel template for budget planning analysis. Analyses were performed on the District 5 data and reports were generated.

THESIS OVERVIEW

The literature review is presented in Chapter 2. The system design is described in Chapter 3. WVDPMS was used to evaluate budget allocation and funding needs, based on the current pavement condition of District 5, as documented in Chapter 4. The conclusions and recommendations from this study are presented in Chapter 5. Many of the procedures and methodologies required for implementation of WVDPMS are presented in the Appendices. Appendix A contains the forms needed for collection of inventory and condition data. Appendix B and C present the methodologies for the collection of inventory and pavement condition data, respectively. Appendix D documents the pavement distress and condition factors considered in the WVDPMS; this appendix provides instructional material for a condition assessment training workshop. Appendix E is the users' manual for the WVDPMS.

CHAPTER 2 - LITERATURE SURVEY

The methodology and use of pavement management systems have evolved for over thirty years. Consequently, there are ample amounts of journals and publications pertaining to the topic. Literature exists on everything from how to create, implement, and use a PMS, to experiences of successful and unsuccessful attempts at using a PMS. Since there is an abundance of literature about PMS available, this particular review focused on the recommendations of agencies using PMS, PMS components, and maximizing the efficiency of a PMS. The topics that were reviewed include:

- the history of pavement management systems,
- the experiences of a small agency,
- the experiences of a large agency,
- available PMS,
- data collection needs
- data management,
- pavement condition factors,
- pavement repair methods,
- treatment selection procedures,
- methods of prioritizing competing road sections by various factors,
- and implementation suggestions.

The criteria for the reviewed information were that the information be from a respected, reliable source and that the sources be reasonably current. All of the literature that was investigated was published in the last ten to fifteen years.

2.1 HISTORY OF PAVEMENT MANAGEMENT SYSTEMS

There are approximately 4 million miles of highways, roads, and streets in the United States. Of that 4 million miles, approximately 2.2 million miles are paved roads. The National Highway System (NHS) encompasses 160,000 total miles with 46,000 miles included in the Interstate System. The NHS consists of highway routes and connections to transportation facilities and also includes highways designated as part of the Interstate System. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 eliminated the historical Federal-aid Systems and created the NHS. The National Highway System Designation Act of 1995 approved the NHS that was established under ISTEA. Roads on the NHS are funded by federal dollars. With only 160,000 miles being on the NHS, there are approximately 2 million miles of non-federal-aid mileage in the United States (FHWA, 99). An efficient and economical way of funding and managing these state-maintained roads and meeting the needs of the non-federal-aid highways had to be devised.

The roads not federally funded are rural minor collector roads, rural and urban local roads, and those owned and maintained by state agencies. Various methods have been used by highway agencies to manage the funding of highway needs within their jurisdiction. Most of the procedures used to manage pavements that were classified as non-federal-aid roads were informal, based on judgement and experience of long-term employees (Nichols, et al, 86). There is no evidence in recently published literature and reports that this practice has changed. These procedures were somewhat effective and were useful to the agency. However, when key personnel retired, quit, or left the agency, the entire “database” and the management plan was sometimes lost.

Management systems are the application of systems engineering and basic decision making concepts to regulate our infrastructure. They provide a structured and documented way of helping to get the most out of the funds that are spent on the infrastructure.

The American Association of State Highway Officials, AASHO, initiated a study in 1966 to make new breakthroughs in pavement engineering. The intent was to provide a theoretical basis for extending the AASHO Road Test that took place from 1958 to 1962. In 1968, researchers at the University of Texas began a new approach to pavement design using a systems approach. Similar independent efforts were being carried out at the same time in Canada to structure the overall pavement design and management problem. A third related undertaking in this area was that of the Texas Transportation Institute of Texas A&M University as part of their work for the Texas Highway Department (Haas, et al, 94).

The term “pavement management system” began to be used in the late 1960’s by these groups of researchers to describe the entire range of activities involved in providing pavements. At this time, two major projects were conducted to develop initial operational systems. The largest of these was Project 123 conducted by the Texas Highway Department, Texas A&M University and the University of Texas. Many reports and manuals have resulted from this research, beginning with Report 123-1 in 1970.

The second major research effort was carried out in the National Cooperative Highway Research Program (NCHRP) Project 1-10, initiated in 1968. A second phase was carried out by Hudson and McCullough to develop an actual working system for implementation at the national level. Lytton, et al. at Texas A&M carried out a third phase on implementation, and a fourth phase was continued at Materials Research and Development, Inc., in California (Haas, et al, 94).

Pavement management emerged in the mid seventies as computers became more user friendly and were designed to provide answers to agencies responsible for the task of selecting pavement rehabilitation treatments and timings for their roadways. The philosophies of pavement management began to gain acceptance by agencies nationwide. State agencies such as Washington and Arizona began the development and implementation of pavement management systems.

Because pavement management was such a new concept, no standards were available to the agencies of the early developers of these systems. Some of the earliest emphasis was in the direction of optimization of multi-year programs. Consequently, very sophisticated systems that relied on linear programming and Markovian probabilities to select optimal strategies for given budget parameters were developed.

What started as an uncomplicated methodology quickly shifted into the hands of researchers and educators who explored the components of pavement management as a high-level exercise. The end result of increasing technical sophistication was reliance on pavement management systems as “black boxes” which selected and scheduled projects, but had few practitioners who actually understood the output of the systems (National Highway Institute, 98).

Many states were buying into the concept of pavement management by the late 1970’s. They purchased systems that used the technically complicated methodologies. Many users were disappointed with these elaborate systems. Huge sums of money were spent on the development of these systems with varying degrees of success. The concept of pavement management appeared to be little more than a dying fad (National Highway Institute, 98).

Several activities served to advance pavement management systems during the 1980's. They included the First and Second North American Conferences on Pavement Management held in Toronto, Canada. In the 1990's, the Intermodal Surface Transportation Efficiency Act (ISTEA) mandated the use of management systems for the selection of cost-effective strategies to improve the performance of transportation systems. The Federal Highway Administration (FHWA) established a policy on pavement management. All State Highway Agencies were required to have an operational system by January 1997 to comply with ISTEA. However, before the designated implementation date, the National Highway System (NHS) legislation in 1995 made the use of management systems optional rather than mandatory. In the last few years, other activities have emerged such as the development of an AASHTO Task Force on Pavement Management, the issuance of AASHTO Guidelines for PMS, ASTM (American Society for Testing and Materials) standard guidelines, and an Advanced Course on Pavement Management and various other courses on pavement management. In addition, the Transportation Research Board (TRB) Committee A2B01 on Pavement Management began to emerge as more of an influential body on the future directions of pavement management (National Highway Institute, 98).

The FHWA developed and offered a training course on the development and use of PMS by local agencies. This course included a simplified structure for PMS as shown on Figure 2.1 (FHWA, 85).

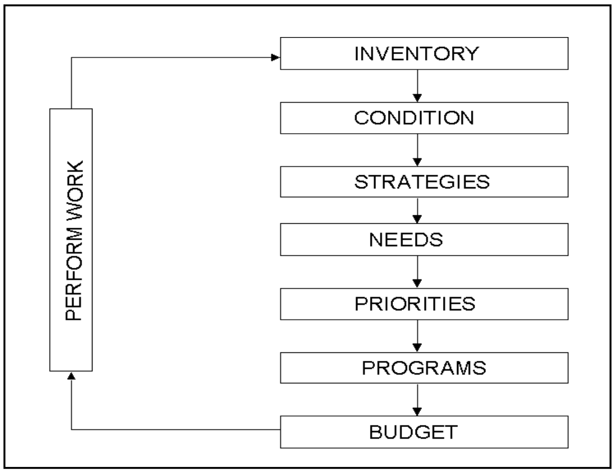


Figure 2.1 FHWA PMS framework

Within the last twenty to thirty years, pavement management systems have been developed to help plan maintenance and rehabilitation of pavements. The systems are still changing, maturing, and becoming more efficient as agencies and users become more experienced and proficient.

2.2 LOCAL AGENCY EXPERIENCES

WV DPMS will be used by a functional group, the district offices, within a large agency, the DOH. The districts have to compete for available funds from the central office and often act as a separate small agency. In this sense, the functional groups, district offices, operate similar to local highway agencies; both face similar limitations such as a lack of sophisticated measuring equipment, inexperienced personnel, lack of manpower, and fixed budgets. Several reports focus on the special needs of local agencies, providing insight into the needs of the district offices.

Many local agencies do not possess the abilities and means to assemble the necessary resources to implement a complicated PMS (Colony, 87). Local agencies' systems should be able to function on minimal data, must not depend upon complex measurement devices, and must address, in a clear and concise way, the essential requirements for planning and budgeting pavement improvement and repair.

The FHWA recommends that local agencies should collect only the information that is necessary to carry out the management plan. The details required should be dictated by the end use of the data. For example, if a selection of a treatment alternative is made from distress information, the condition survey forms must include that distress. Conversely, any data not used in the management or decision process should be eliminated. More information than is necessary slows down the survey process, reduces reliability of data, requires more computer storage and programming, and is nonproductive (Monismith, et al, 90).

The person in charge of a local agency pavement management often does not have a permanent staff to assist with pavement management work (Broten, 97). To supplement the work effort, many small agencies use summer interns and/or part time staff to carry out the work. Although necessary, this structure may not be ideal for providing good continuity of work effort and quality control. Small agencies should guard against two areas of concern. First, there should not be a reliance on a single person within an agency that is responsible for pavement management. To illustrate, if a pavement manager leaves unexpectedly, all of that knowledge and experience can be lost and the learning process has to start over again. Broten (97) recommends a minimum PMS staff of two people. Cross training of these personnel is also advised. This would ensure that the employees would be skilled in the various aspects of PMS such as condition surveys, data entry, and the analyses of the results. The second item of concern is degradation of data integrity. This can be the result of bringing in inexperienced staff from other divisions within the agency during the busy data collection and data entry periods. The agency must be careful to make sure that the integrity of the data is maintained. They can accomplish this through a good training program and an enforced quality control program. For example, the group that instructs and trains the employees should be the same one that perform the training every year (Broten, 97).

The Washington State DOT report details the experiences of the City of Renton, Washington (Broten, 97). To improve data collection efforts, only college engineering students were used as interns. The thought behind this was that the students would have a greater interest in the type of information being collected, and therefore would care about the quality of the information they were collecting. The city would also rotate the work that the interns were doing to break up the monotony of collecting visual distress data and data entry. The city hired the same engineering consulting firm every year to do their training. The consulting firm presents a training course that consists of one day of classroom instruction and two days of field instruction. During the field instruction, the interns rate road segments independently and the instructor works with them until they are rating the roads correctly and consistently with one another (Broten, 97).

Nationwide, other agencies relate accounts of using undergraduate college interns to perform the condition surveys and data entry (Stephens, 86). Proper training was carried out accordingly and care was taken to keep the integrity of the data and the results.

Colony (87) proclaims that small agencies should seek advice on the determination of unit costs and on the available repair strategies for each distress. The agency may or may not have someone who is experienced in road maintenance treatments and their corresponding costs. Recent projects in the area should be reviewed to get up-to-date unit price bids.

Broten (97) recommended small agencies develop a manual with a description of pavement distress types and their causes. The manual should include photographs of various distresses and descriptions of the cause of each distress. A list of suitable treatments should be provided to address the different distress types, as well. The manual will help ensure that the visual rating is consistent, as all surveyors will be looking for the same problems.

2.3 LARGE AGENCY EXPERIENCES

A PMS pavement condition rating based on visual inspection is an extension of common informal practice (Nichols, et al, 86). Some highway personnel currently rely heavily on visual inspection and experience to schedule maintenance activities. One problem with this approach is that experience is difficult to transfer from one person to another. It can also be difficult to use the information to objectively explain maintenance decisions to governing bodies. The condition rating technique and the PMS attempt to make human judgement more objective, to make it more consistent, and to make it easier to explain to others (Nichols, et al, 86).

Once the decision has been made by the agency to implement and utilize a PMS, the agency must commit to the system's methodologies and practices and develop continuity. Maintaining continuity in the system could include hiring a full-time person working in a moderate-sized agency or an equivalent amount of effort put forth by existing employees. In one presented case, establishing a comprehensive computerized system required an annual outlay of $50,000 to $75,000 to pay the employee's salary and to fully implement, use, maintain, and adequately analyze the results. However a manual system of inventories and ratings could be managed for substantially less. A manual system is one in which there is no complicated measuring equipment, sophisticated data entry or management, or computer software to perform the analysis. Where maintenance superintendents and crew leaders participate in the system, they can accomplish much of the fieldwork along with their other tasks (Castleberry, 94).

The Virginia Department of Transportation (VDOT) recorded the time required for three raters to evaluate pilot study areas. It took 10.31 min/mile for office work, 9.32 min/mile for travel time, and 37.68 min/mile for the actual rating, for a total of 57.31 min/mile for the entire crew (McGhee, et al, 91).

Based on the time required to rate the pilot areas, the researchers with VDOT saw a need for at least one additional full-time employee for each district in order to implement the PMS on their 33,906 miles of paved secondary roads. Along with the added employee, a van with a distance measuring instrument, a laptop computer, a portable measuring wheel, and office space for the employee with access to a personal computer were also necessary for each district (McGhee, et al, 91).

The Texas Transportation Institute at Texas A&M University presented treatment costs and budget determination for larger agencies. The researchers at Texas Transportation Institute maintain that the costs for repairing pavements that are at the same condition level can vary considerably due to non-pavement factors. These factors include traffic control devices, shoulder repairs, curb and gutter repairs, manhole adjustments, etc. The authors also found that geometric design and safety improvements needed during rehabilitation may cost more than the actual pavement repairs. Failure to identify these hidden costs can provide false cost estimates and mislead the manager. The authors maintain that it is generally not possible to know the details necessary to determine specific cost estimates during the network-level analysis. Detailed estimates should be obtained during the project-level analysis.

Along those same lines, the researchers from the Texas Transportation Institute assert that network-level prioritization or optimization really identifies a list of candidate management sections and treatment cost categories for the available funding. The final selection of sections and treatments must be completed at the project-level. The list from the network-level analysis should be considered a planning list and the first step in the programming process (Texas Transportation Institute, 94).

2.4 AVAILABLE PAVEMENT MANAGEMENT SYSTEMS

2.4.1 Public and Private Domain Software

The public domain software is provided at a nominal cost. The programs are usually implemented by the requesting agency with little or no additional assistance. Private domain software is developed and sold by private entities. The systems are often more complex and have more capabilities than public domain software but they are more expensive to purchase and implement. Table 2.1 and 2.2 describe some of the available public and private domain systems, respectively (Texas Transportation Institute, 1994).

Available PMS	***Developers***	***Features***
NIS (Needs Inventory Software)	Mc*Trans*	Numerous data fields: right-of-way width, traffic signals, sidewalks, curbing, parking, speed, and so forth; inventory for bridges; unsurfaced roads analyses; user cannot edit a field easily; only generates needs analysis.
PMS-ITRE	The Institute for Transportation Research and Education, North Carolina State University	Focuses on asphalt concrete pavements only; contains user modifiable deducts for condition rating; can store pavement history.
MicroPAVER	American Public Works Association	Supports both English and metric units; includes paved and unpaved roads in analyses; context sensitive help accessed by pushing F1 key.
BAPMS (Bay Area PMS)	Metropolitan Transportation Center, Oakland, CA	User can examine multiple budget scenarios and funding allocations; provides an interface with AutoCAD, a computer aided design program that allows user to display results of PMS.

Table 2.1 Features of Available Public Domain PMS

2.4.2 Road Surface Management System (RSMS)

A detailed review was performed on the Road Surface Management System, RSMS, because of District 5’s experiences with this particular program. The system was reviewed and analyzed to determine its advantages and disadvantages.

The New Hampshire Technology Transfer Center, NH T^2, developed RSMS as a public domain pavement management system (NH T^2, 92). Since its inception in the early 1990’s, many agencies have adopted this management system. The developers from the University of New Hampshire recognize that each PMS, no matter how complex

Available PMS	***Developers***	***Features***
CTL PMS	CTL Engineering, Inc., Columbus, OH	Includes optional data sorting fields such as subdivision, state route number, shoulders, curb height, inlets, and so on; user can enter the number of years desired to "repair" the network of roads and the yearly cost is calculated.
dROADLOG	Deighton Associates Limited	Includes unsurfaced roads; can be used with English or metric units; is easy to use and understand.
RM-AC (Road Manager)	Vanasse Hangen Bruslin, Inc.	Includes interface with AutoCAD; allows data to be imported from other PMS such as RSMS and MicroPAVER; stores sidewalk data, sign inventory, pavement marking, and equipment data.
dROAD/dTIMS	Deighton Associates Limited	Allows for integrated automated mapping through the use of AutoCAD and can graph past and future condition indices; requires numerous inputs.
RoadScan	Huntingdon Engineering and Environmental, Inc.	Allows an interface with GIS, Geographical Information System; graphical and text reports can be generated; can handle English or metric units; includes unsurfaced roads in analyses.
DSS (Infrastructure Decision Support Software)	ERES Consultants, Inc.	Includes unpaved roads in analyses; can store a variety of information including right-of-way widths, shoulder information, speed limits, and so forth; integrated automated mapping capabilities.

Table 2.2   Features of Available Private Domain PMS

or sophisticated, must contain three components. They are a road inventory, a road condition survey, and a report of the recommended repair strategies. They state that the prevailing thought is to promote a system that can be easily customized or adjusted to meet the needs of individual communities. The PMS should complement current practices by incorporating local input that would provide repair alternatives, distress and repair relationships, and repair costs pertinent to the road network. Data collected and entered into the system form the basis for objective decisions about overall road surface management and repair strategies (NH T^2, 92).

The RSMS is a network management system. The results from the analysis are not meant to be used for the specific design of a given road section but rather used to identify which general maintenance strategies could be applied to the individual roads in the network (NH T^2, 92).

One of the developers of RSMS maintains, “RSMS is not a complete PMS, but rather a network-level decision support tool. The main function of RSMS is to store and analyze data, and to generate reports that will assist municipal officials in making cost-effective decisions” (Kercher, 99).

RSMS was created for “any city or town” (NH T^2 Center, 92). This scope is reflected in the structure of the system and associated terminology. Users of RSMS must identify a maintenance division responsible for each section in the network. RSMS uses city street classification terminology, such as local streets, collectors, arterials. The street classification is used in the prioritization and ranking scheme.

2.5 DATA COLLECTION NEEDS

“The data bank is the heart of a system” (Monismith, et al, 90). The PMS will never be beneficial to an agency if the system does not contain the correct and proper data. Many PMS users have recommendations on what data to collect and how to collect it. Following an extensive review of those suggestions, some of the more eminent and notable ones are presented for the potential WV DPMS user.

2.5.1 Inventory Data

An inventory of the roads that are encompassed in an agency can serve many useful purposes. The inventory can retain basic information on the characteristics of the road system in one place. Important information that may be helpful to future personnel, such as construction and maintenance history, is archived and available for review. Once the inventory is collected, a condition assessment can be performed on the defined road sections. Another important feature of the inventory is that the data such as roadway length and width is needed when estimating the cost of alternative road improvements (Nichols, et al, 86).

The road inventory should be conducted by a two-person team. The team will need a vehicle and an accurate distance-measuring device. They will also need a map showing the established inventory section boundaries. The team should drive along the selected route to identify the designated section boundaries. Next, they should measure and record the physical dimensions of each section. Finally, the team should drive back along the route and complete the inventory forms and record the length of the section (Nichols, et al, 86).

2.5.2 Condition Data

As pavement maintenance costs continue to rise, it is essential to have fast, reliable methods to accurately determine a pavement’s condition. Many decisions that are supported by the PMS are based on the condition survey. Condition surveys are performed to determine the type, severity, and quantity of surface distresses. The type and time of application of the corrective treatment is a function of the properties of the distresses that are surveyed (National Highway Institute, 98).

While the inventory defines the network for which an agency is responsible, the condition assessment describes the state of the roads. Condition information is used to evaluate the current condition, determine rate of deterioration, project future condition, determine maintenance needs, and determine the costs to repair the pavement sections (Texas Transportation Institute, 94).

The main purpose of the pavement condition survey is to identify existing distresses in the road surface that may affect pavement performance. Once the distress type is identified and evaluated as to the extent and severity, appropriate corrective measures can be decided on and proposed budgets can be created (National Highway Institute, 98).

A two-person team is also recommended for the pavement condition rating (Nichols, et al, 86). The individual ratings from each team member should be averaged to have an accurate rating value for each road section. Another suggestion is to have the same people collect the data and perform the rating from one year to the next. Finally, the authors of the publication suggest carrying out the condition ratings during the same time of year, usually either late spring or early summer. This period is just prior to the time when scheduled maintenance is normally done. The correct maintenance could be applied in a timely fashion by completing the data collection and analysis (Nichols, et al, 86).

The South Dakota Department of Transportation also maintains that condition surveys should be conducted by rating teams of at least two members. The team members should discuss discrepancies that occur and reach a consensus for handling the variation of opinion. If one team member consistently ranks the pavements much higher or lower on a pavement condition scale than the other rater, the team should discuss the reasons for these differences (Zimmerman , et al, 94).

The Texas Transportation Institute evaluated walking surveys versus riding or windshield surveys. A walking survey involves the inspector walking the section when traffic levels or protection permit. The inspection can be completed while standing at the side of the road. The inspectors can use their pace, or walking stride, when estimating the quantity of distresses. A riding or windshield survey entails the inspector traveling in a vehicle moving at about 5 to 15 mph. Distresses are usually identified by the rater and the area affected is estimated as a percentage of the road surface. In both cases, the distress data can be recorded on paper forms for later entry into the database or data can be entered into a portable computer at the site. The authors maintain that manual distress collection can vary from a detailed walking survey to a riding survey at 50 mph. The ability to identify lower severity levels decreases and fewer distress types are identified and recorded as speeds increase (Texas Transportation Institute, 94). Monismith, et al (90) determined that walking surveys provide more accurate data than riding surveys, but costs are higher. The degree of accuracy required should be considered when selecting the data collection methodology. If the users desire more accurate data, they should use a walking survey, provided they have the time and resources to accomplish it.

The Texas Transportation Institute stresses that collecting condition information is generally the most costly part of the initial implementation and updating of the PMS (Texas Transportation Institute, 94). Therefore, much thought and care must be put into choosing and carrying out the data collection process.

2.6 DATA MANAGEMENT

The input, manipulation, and analysis of the data are vital to the efficient use of the PMS. The experiences of various agencies were reviewed and recommendations on data management are provided for the user.

A PMS's road inventory database can contain records of all the roads within an agency's jurisdiction. Over time the inventory database will include construction information, maintenance and rehabilitation records, traffic data, and other elements needed for decision making and budgeting. The road inventory database is an excellent source of information about a district's infrastructure and road network. The pertinent information is archived in a database for later use. The PMS can also document the "value" of a district's pavement investment with the addition of the condition survey. The present condition of the district's roads can be ascertained and a future analysis can be made based on possible application of treatments (Broten, et al, 94).

Much of the effort that is required in implementing a PMS is the effort, and associated costs, of establishing and validating the data files. Once this step is completed, only a periodic update of the various files is necessary (McGhee, 84). Once condition inventory and descriptive data are in automated files, there are numerous uses for the information. The major uses of the condition inventory data are the establishment of priorities for actions and treatments and in the projection of future treatment and repair needs. Large agencies can input information through remote terminals into the district office to cut down on delays in data handling (McGhee, 84).

Broten (97) recommends checking 10 % of the entered data for accuracy. This can be done by printing out a sample of the entered data in hard copy form and then comparing it to the original data forms. It is recommended that a person other than the one entering the data perform the quality check.

Broten (97) also recommends making a backup of the database. This involves simply making a copy of the data so that if the database is damaged or lost, the copy can be retrieved and used to replace the damaged database.

2.7 PAVEMENT CONDITION FACTORS

There are a wide variety of pavement condition factors and distresses. The user of WV DPMS must be aware of the different types of distresses that could possibly be found in the district they manage. The existence and quantity of a distress in a district determines if it is to be measured, recorded, or analyzed within the PMS. This section provides a broad list of flexible-pavement distresses, the causes, and the corrective procedures.

2.7.1 Longitudinal Cracks

Longitudinal cracks are individual cracks, parallel to the roadway centerline. Longitudinal cracks most frequently occur at the joint between adjacent lanes or at the edges of the wheel paths in a rutted pavement. These cracks can start as hairline cracks and widen with age and wear. Longitudinal cracks provide a path for water to enter the subsurface layers and subgrade resulting in the development of fatigue cracking at the joint between lanes and raveling. Longitudinal cracks, when found in the wheel paths, can also signify the beginning of alligator cracking.

The density of the asphalt concrete at construction joints is typically lower than the rest of the pavement. The lower density of the asphalt concrete results in lower tensile strengths. As surface temperatures drop to a level such that the thermally induced shrinkage stresses exceed the tensile strength of the asphalt concrete at the joint, longitudinal cracking will develop. Longitudinal cracking can develop at any place in the pavement if shrinkage stresses exceed the tensile strength of the pavement; however, it will usually first occur at a construction joint due to the lower tensile strength. In addition, the higher voids in the asphalt concrete at the joint also allow for increased oxidation hardening, which makes the pavement more susceptible to cracking and raveling.

The longitudinal cracks that develop at the edges of rutted wheel paths are often caused by heavy loads, especially when combined with high tire pressures. Residual stresses develop in the asphalt concrete adjacent to the wheel path as asphalt concrete in the wheel path compacts due to the excessive loads and/or tire pressures. When the residual stresses exceed the tensile strength of the pavement, longitudinal cracks develop.

Sealing can repair longitudinal cracks, provided the treatment is made in the early stages of crack development. If the cracks are less than ¼ inch wide, fog seals can be used. Fog seals involve a light application of a slow setting emulsion. If the cracks are ¼ inch wide or greater, fog sealing will not be effective. Cracks wider than ¼ inch must be filled with crack sealant. Once raveling develops at the crack edges, the needed repair is more extensive, sometimes requiring an overlay. In general, longitudinal crack repair typically involves a variety of maintenance techniques, depending on the severity of the crack (Roberts, et al, 96).

2.7.2 Transverse Cracks

Transverse cracking is also referred to as low temperature or thermal cracking. Transverse cracks are perpendicular to the roadway centerline. The cracks are often approximately equally spaced. Transverse cracks develop when the surface temperature drops to a level such that thermally induced shrinkage stresses exceed the tensile strength of the asphalt concrete.

Transverse crack repair is similar to longitudinal crack repair. Small transverse cracks can be fog sealed and crack sealant can be used for wide cracks. Milling can eliminate the difference in elevation of the road surface in cases where the sides of the cracks are at different elevations. In advanced stages of transverse crack development, overlays may be required (Roberts, et al, 96).

2.7.3 Fatigue Cracks

Fatigue cracking is also commonly known as alligator cracking. Fatigue cracking starts with individual longitudinal cracks developing in wheel paths. With time and traffic, additional longitudinal and transverse cracks develop and the cracks become interconnected. This results in a closely spaced crack pattern that resembles the pattern on an alligator’s back. The irregular pieces of pavement vary in size, but are typically less than 12 inches across. If pavement areas with alligator cracking are not treated, potholes eventually develop.

As the name fatigue cracking suggests, the primary cause of this pavement distress is repeated traffic loading which stresses the pavement to its fatigue life limit. Alligator cracking is also associated with loads that are too heavy for the pavement structure. Fatigue and alligator cracking formation is accelerated by insufficient pavement drainage because the pavement layers become saturated and lose strength. Inadequate pavement thickness due to poor design or quality control during construction combined with repetitive passes with overweight trucks can also induce alligator cracking. The cracking starts at the bottom of the asphalt concrete layer where the tensile stresses are the greatest. With continued traffic loading, the cracks migrate to the surface.

Depending on the extent, repair strategies for alligator cracking typically include patching, overlays, or reconstruction techniques. Alligator cracking that occurs infrequently in a particular section can be corrected with patching. Overlays are often used to correct alligator cracks that cover an extensive area but the thickness of the overlay must be sufficiently designed to carry the number of expected loads. Removal and replacement of material with patching techniques may be needed to repair localized areas of alligator cracking. Pavements with alligator cracking require careful investigation to determine the cause of alligator cracking. If poor subgrade drainage is the root cause, drainage improvements are necessary. If the pavement structure is fatigued due to repetitive loading alone, a stronger pavement structure is needed to carry the anticipated traffic (Roberts, et al, 96).

2.7.4 Block Cracks

Block cracking is an interconnected series of longitudinal and transverse cracks, which divides the pavement into approximate square pieces. Block cracking often occurs on facilities with low ADT, or Average Daily Traffic. Block cracking is found more often in large parking areas rather than on roads. Unlike alligator cracking, block cracking can extend the full width of a road. Block cracking is generally caused by shrinkage of the asphalt concrete due to volatilization, oxidation hardening of the asphalt, and thermal stresses.

Block cracking allows the infiltration of water into the subsurface. In the early stages of block cracking, a surface seal can be used to reduce surface water infiltration. At the advanced stages of distress, either a thick overlay is placed on the existing surface or the old material is removed and replaced with a new asphalt concrete surface (Roberts, et al, 96).

2.7.5 Edge Cracks

Edge cracking occurs along the shoulders of the pavement and looks similar to longitudinal cracks. Edge cracking typically occurs within 1 to 2 feet of the pavement edge. Cracking can occur as a result of poor shoulder support, excessive traffic loads, or a high percentage of heavy trucks on an insufficiently designed road. Depending on the severity and extent, edge cracking is usually repaired with either preventive maintenance (thin overlays, chip seal, and others), routine maintenance (patching), rehabilitation (thick overlay), or reconstruction techniques. If the problem is lack of edge support, material must be added to the shoulders to bring it up to the road level and the material should be properly compacted (Roberts, et al, 96).

2.7.6 Rutting

Rutting is a depression of asphalt concrete in vehicle wheel paths. The surface depressions created in the wheel paths result from either continued consolidation or lateral displacement of the asphalt concrete under traffic. Some of the factors that cause rutting are insufficient compaction during construction, poor mix design (high asphalt content, excessive mineral filler, rounded aggregate, etc.), inadequate drainage, and poor subgrade strength. The pavement section must be carefully examined to determine the cause of the rutting before a specific treatment is selected. Minor rutting can be repaired with surface milling and preventive maintenance techniques, such as rut filling with microsurfacing. Major rutting requires surface milling and rehabilitation (thick overlay). Sections with poor drainage conditions also require drainage improvements to increase subgrade strength (Roberts, et al, 96).

2.7.7 Raveling

Raveling is the loss aggregate from the asphalt concrete matrix as a result of a bond loss between the aggregate and the asphalt binder. The loss of bond between the aggregate and binder can occur as a result of asphalt cement oxidation, poor compaction, or insufficient asphalt content. A poor aggregate/binder bond can also occur when aggregate containing deleterious material is used in the asphalt concrete mix. When raveling occurs at the pavement surface, the asphalt concrete layer progressively disintegrates downward. Minor raveling can be repaired with preventive maintenance treatments, while major raveling requires thick overlays or recycling of the pavement surface (Roberts, et al, 96).

2.7.8 Patches

Patches are sections of pavement that have been removed and replaced. Patches are typically used to repair localized pavement defects or to cover utility trenches. A patch failure can lead to widespread pavement distress problems. Patches are defects relative to the original pavement. Even patches in good condition can accelerate the rate of pavement distress development because it can permit the intrusion of water into the subsurface layers and subgrade if the patch is not constructed and sealed properly (Kercher, 99).

Patch cracking and distortions typically occur when the root cause of a pavement defect was not properly corrected before the patch was placed. Patches over utility trenches typically fail when the trench was not adequately back-filled and compacted.

Patches that have minor cracking can be repaired with preventive maintenance techniques so that surface water does not enter the subsurface. Pavement sections with a high extent of severely cracked and distorted patches will need reconstruction (Roberts, et al, 96). Extensive settlement in utility trenches may require additional repair to the utility trench prior to pavement repairs (Kercher, 99).

2.7.9 Potholes

Potholes allow water to collect and are a hazard to motorists. They are considered a progressive failure. At first, small fragments of the top layer become dislodged from the road surface. Over time, the distress progresses downward into the lower layers of the pavement. Potholes are often located in areas of poor drainage.

Potholes are formed when the pavement disintegrates under heavy traffic loading. This is due to inadequate strength in one or more layers of the pavement structure, usually accompanied by the presence of water. Most potholes would not develop if the root cause (various types of cracking or other distress) was repaired before it developed into a pothole.

Excavating localized areas and replacing the base and surface materials repairs potholes. The removal of inferior materials and proper compaction of the new materials is essential. Improvements in drainage may be required if the intrusion of water is causing the subgrade to weaken (Kercher, 99).

2.7.10 Ride Comfort

Pavement roughness is produced by surface deviations that create a response in the suspension system of the travelling vehicles. Pavement roughness is important because this is the pavement property that is most noticeable to the travelling public. Devices used to measure pavement roughness include response type road roughness meters and an inertial profilometer (Roberts, et al, 96).

Pavement roughness can be evaluated subjectively by determining the comfort of the driver, or ride comfort. Ride comfort is defined as a user perceived reduction in ride quality due to pavement surface irregularities. Ride comfort is an encompassing term because it includes conditions that are not accounted for in the other categories, such as corrugations, sags, humps, frost heaves, and settlement, to name a few. A subjective opinion made by the motorists/surveyor can be used to estimate pavement roughness.

The causes for loss of ride comfort are varied. They include poor drainage, insufficient design and material, and inferior base. Subsequently, the corrective procedures are many and should be based on the specific causative mechanism (NH T^2, 92).

2.7.11 Drainage Condition

Drainage condition is not a pavement distress per se. However, water can be very detrimental to the pavement and must be considered and analyzed. The severity of a poor drainage condition is judged by the ability for precipitation to flow from the road surface to a location that does not influence roadway travel or surface conditions. Visual indicators of drainage problems include accumulation of debris and fine aggregate on the traveled road surface. Other directives of poor drainage include road shoulders that are above the edge of pavement, standing water, and outwashes or accumulations of sand along the edge of the road. Evaluation during or just after a rainfall can be very beneficial in assessing drainage conditions.

The lack of, or poor performance of, ditches, gutters, drop inlets, and other drainage structures results in poor drainage. Lack of a crown in the pavement surface also promotes water-induced damage. The crown aids in shedding water from the traveled way so that water does not stand on the surface.

Repairs for poor drainage include reestablishing or creating a crown in the road and/or maintaining or creating the necessary drainage features (NH T^2, 92).

2.8 TREATMENT ALTERNATIVES

There are numerous treatment alternatives for the pavement manager to consider. The available treatment alternatives have been categorized as: Do Nothing, Routine Maintenance, Preventive Maintenance, Rehabilitation, and Reconstruction. A variety of treatments can be included in each of these categories. The treatment alternatives and average cost for each alternative are presented in the following sections.

2.8.1 Do Nothing

Pavements in excellent condition justify a “do nothing” decision. The surface should not have any visible distresses. However, just because maintenance is not needed now, it does not mean that the road surface will not require service later. Obviously, this is the cheapest alternative to be considered. It also may be the correct alternative for a specific section that is in excellent condition.

2.8.2 Routine Maintenance

Routine maintenance is performed to correct a specific pavement failure or area of distress. Routine maintenance typically includes crack sealing and patching.

2.8.2.1 Crack Seal

Crack sealing is a routine maintenance activity that involves removing debris and filling the cracks with a rubberized asphalt sealant. The sealant prevents water from entering the pavement structure and underlying soil, which will reduce the ability of the soil to support the pavement. This technique seals environmental cracks such as transverse and block (Kercher, 99). Alligator cracks usually do not receive this treatment due to the intensity of the cracking pattern. Generally, cracks that are open in the range of 1/4 to 1/2 inches are suitable for crack sealing (Roberts, et al, 1996).

Sealing procedures should take place in the spring or fall when the cracks are about halfway open (Kercher, 99). It is vital that the crack be clean and dry to assure a good bond between the pavement and sealant. Crack sealing costs approximately $0.50 per linear foot (NH T^2, 92). Figure 2.2 depicts a crack sealing procedure (Zaniewski and Mamlouck, 96).

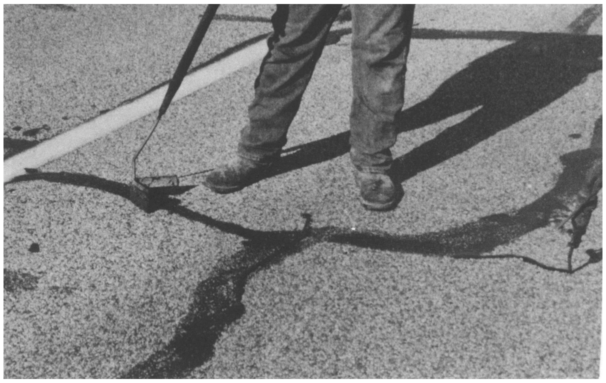


Figure 2.2 Crack Sealing

2.8.2.2 Patching

Patching is a common way to repair a localized area of distress. This alternative stabilizes the pavement structure and prevents water from entering the pavement and subgrade. Patching of failed areas prevents further damage to the pavement and improves safety. Patching also repairs potholes, failed patches, and localized cracking. This process involves removing inferior material and replacing it with adequate material. Patching costs approximately \$10.00 per square yard of patch (NH T^2, 92). Figure 2.3 shows a patch compaction during application (Infrared Process, 00). Adequate density is mandatory for satisfactory patch performance.

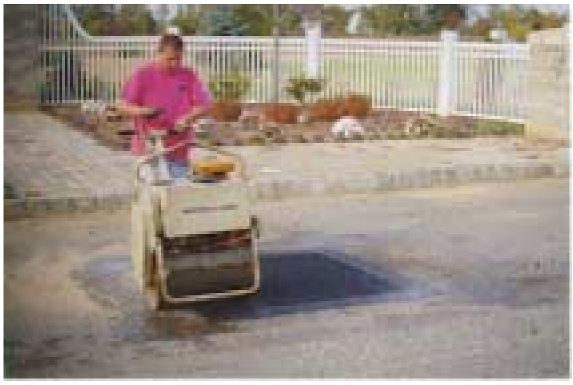


Figure 2.3 Patching

2.8.3 Preventive Maintenance

Preventive maintenance is used to preserve or extend pavement service life. Preventive maintenance typically includes fog seal, chip seal, slurry seal, microsurfacing, and thin overlay.

2.8.3.1 Fog Seal

Fog sealing is a surface treatment applied continuously to the entire surface of a section of road. This alternative involves a light application of a slow setting emulsion, diluted by an equal amount of water. This emulsion is sprayed on the surface. The objective is to restore the asphalt cement at the pavement surface. Fog seals can retard the oxidation of asphalt at the surface, seal fine cracks, prevent the intrusion of water into the pavement structure, and rejuvenate raveled areas (Roberts, et al, 96). A typical fog seal application can be seen in Figure 2.4 (Zaniewski and Mamlouk, 96).

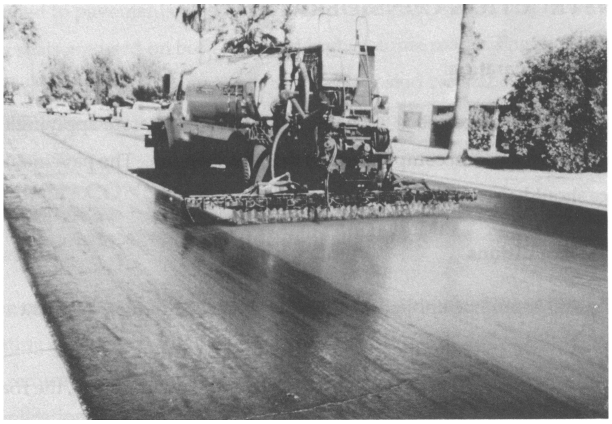


Figure 2.4 Fog Sealing

The treatment is suitable for low volume roads that can be closed for four to six hours, the time required for the emulsion to set up sufficiently. Fog seals cost approximately $0.50 per square yard (NH T^2 Center, 92).

2.8.3.2 Chip Seal

Chip seals are a preventive maintenance technique consisting of one or more layers of asphalt binder covered with aggregate. The existing road surface is sprayed, usually with emulsified asphalt, and then covered with a thin layer of uniform size aggregate. The surface treatment is compacted as soon as possible. After an adequate curing period, loose stone chips should be swept away to prevent debris damage. A chip sealing application is depicted in Figure 2.5 (Zaniewski and Mamlouk, 96).

Chip seals will not correct imperfections such as rutting, and will not provide structural strength. Chip seals may not suitable for high speed, high volume roads because there is a possibility that the loose aggregates on the surface will be picked up by vehicle wheels and projected through the air. However, if properly designed and constructed, chip seals are economical, easy to place, and reasonably durable. They can prevent moisture penetration, improve skid resistance, and prevent further oxidation and surface raveling of old pavements (Kercher, 99). Chip seals cost approximately $0.85 per square yard (Geoffroy, 94).

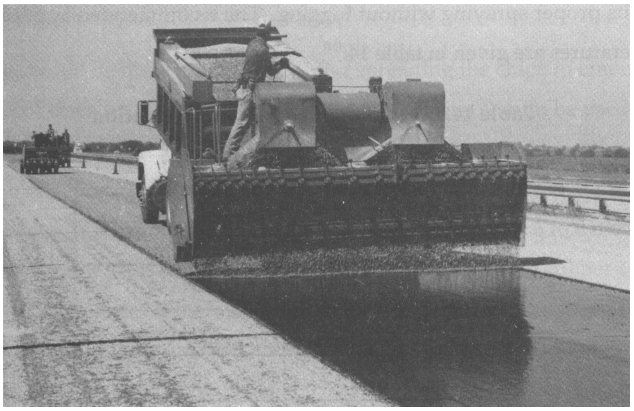


Figure 2.5 Chip Sealing

2.8.3.3 Slurry Seals

A slurry seal is a homogenous mixture of emulsified asphalt, water, well-graded fine aggregate, and mineral filler. The components are mixed in a special truck-mounted mixing chamber. The slurry material is transferred into a spreader box that distributes the slurry in a thin, smooth layer. Flexible rubber squeegees mounted along the spreader box control the thickness of the slurry seal layer. An example of a slurry seal project is presented in Figure 2.6 (Zaniewski and Mamlouk, 96). Layer thickness is approximately equal to the maximum aggregate size. Common thicknesses are slightly greater than 1/8 inch (Type I slurry), slightly greater than 1/4 inch (Type II), and 3/8 inch using larger aggregate (Type III).

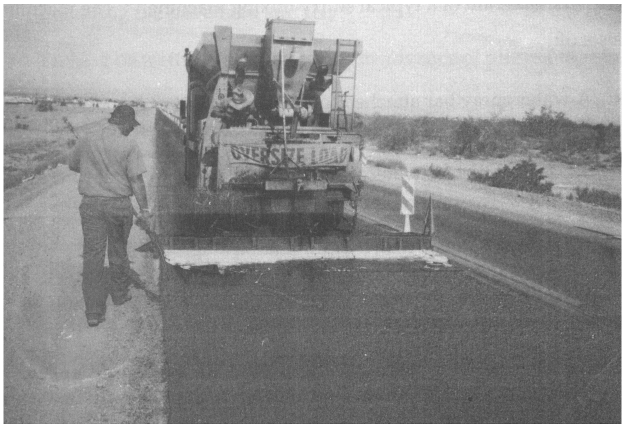


Figure 2.6 Slurry Sealing

Type I slurry is used for filling fine surface cracks or as a possible preparation for hot mix asphalt (HMA) overlay or chip seal. It is also very useful in parking lots or on paved shoulders where the primary functions of the treatment are surface sealing and replacement of surface materials. Type II is the most commonly used as it can repair moderate to severe raveling and can restore skid resistance. Type III seal is reserved for pavements having surface irregularities and requiring a thicker seal with larger aggregate.

This type can effectively fill slight depressions, preventing water ponding and reducing the probability of hydroplaning (Roberts, et al, 96).

Another benefit of slurry seals is quick curing. Traffic can be placed back on to the road surface in considerably less time than conventional overlay methods. At an average cost of $0.64 per square yard, it has been found to be a cost-effective preventive maintenance alternative (Geoffroy, 94).

2.8.3.4 Microsurfacing

Microsurfacing is a desirable treatment for the following purposes: seal cracks, prevent infiltration of water and air, stop raveling, and improve skid resistance. It may also be applied as a rut filler. However, like other surface treatments, it cannot correct major deficiencies such as potholes and severe alligator cracking.

Microsurfacing consists of applying a uniform mixture of well-graded fine aggregate, polymer-modified emulsified asphalt, water, mineral filler, and any necessary additives to the road surface. The mixture is usually applied in 3/8 to 5/8 inch thick layers and requires a special machine for the application (Kercher, 99). Figure 2.7 is an example of a microsurfacing application (FHWA, 00).

The microsurfacing mixture hardens through a curing process and does not require compaction. Microsurfacing can be applied rapidly and cures quickly, usually within an hour. Microsurfacing does not require manhole and utility adjustments and provides for minimal loss of curb height. It can correct minor surface irregularities and the average cost is $1.17 per square yard (Geoffroy, 94).

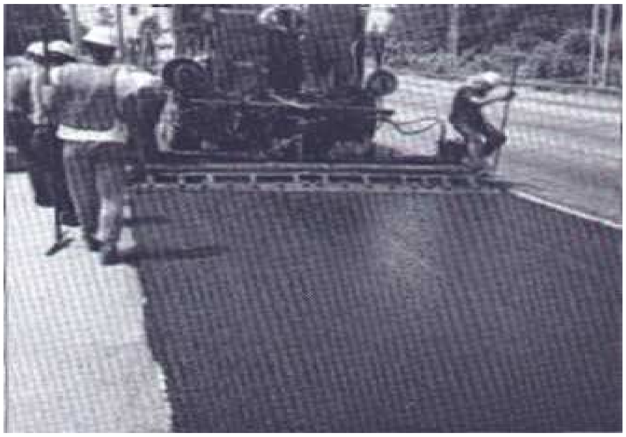


Figure 2.7 Microsurfacing

2.8.3.5 Thin Overlays

Thin overlays of hot mix asphalt (HMA) are traditionally used to correct moderate raveling or rutting, reduce roughness, restore skid resistance, and protect a deteriorating pavement. Thin overlays are typically placed up to 1 inch thick. Overlays can be a very cost-effective way of extending the pavement life, as well as immediately improving the surface. The life of the pavement is extended since the cracks are sealed to prevent the infiltration of air and moisture (Roberts, et al, 96). Thin overlays do not improve the structural capacity of the pavement. They should not be used on highly distressed pavements. Presented in Figure 2.8 is an illustration of a thin overlay procedure (Full Depth Reclamation, 00).

Thin overlays are very effective and useful in cases where the roadway has existing curbs and sidewalks. Thick overlays may fill the curb reveal. With the use of a milling machine, an inch or less of existing, deteriorated surface can be removed and then replaced with a thin overlay. Thin overlays typically cost \$2.10 per square yard (NH T^2, 92) and are effective at protecting, leveling, and sealing the roadway.

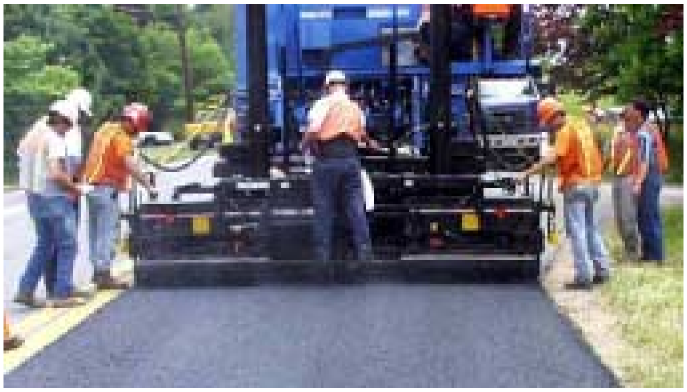


Figure 2.8 Thin Overlay

2.8.4 Rehabilitation

Rehabilitation consists of a thick overlay and is performed to improve the structural integrity of the pavement. Milling may be used to remove a distressed surface prior to overlaying.

If the objective is to increase structural capacity and correct smoothness, the alternative of choice is a thick overlay. Thick overlays are overlays 2 inches or thicker. The average cost of thick overlays is $3.60 per square yard (NH T^2, 92). A thick overlay application is presented in Figure 2.9 (National Asphalt Pavement Association, 97).

If the existing pavement is in poor structural condition, the overlay can prematurely fail due to inadequate support. Deficiencies should be corrected prior to the overlay. This includes inadequate drainage, potholes, failed patches, alligator cracking, and others. (Kercher, 99). Thick overlays require milling operation if the curb and sidewalk system is to be maintained. Manholes and other utilities need to be adjusted.

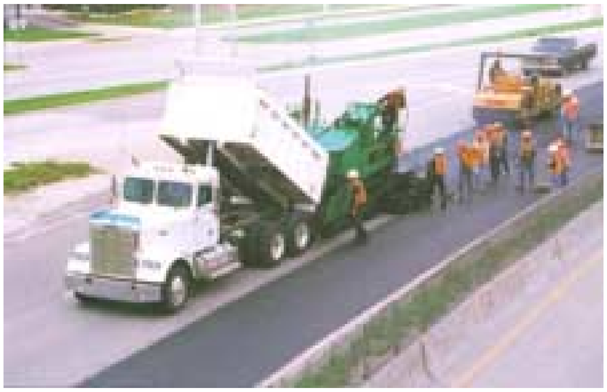


Figure 2.9 Thick Overlay

2.8.5 Reconstruction

Reconstruction is the removal and replacement of the pavement surface. Pavements requiring rehabilitation deteriorate rapidly to a point thus necessitating reconstruction. For highly deteriorated pavements, surface treatments or overlays are not cost effective. Removal and replacement of the existing pavement is required. Prior to placing the new pavement, all deficiencies such as weak subgrades or poor drainage should be corrected. If this step is not taken, the new pavement will fail prematurely.

There are two main types of reconstruction: full-depth and partial-depth. Full-depth reconstruction involves the complete removal of the existing pavement structure, down to the subgrade. Partial-depth reconstruction involves removing only the upper portion of the pavement and replacing it with new materials (Kercher, 99). An example of a partial-depth reconstruction project that includes cold-in-place asphalt recycling is provided in Figure 2.10 (Full Depth Reclamation, 00).

Certain distress types signify the need for reconstruction. For example, if high severity, high extent alligator cracking, depressions, and/or rutting are encountered, it is a good indicator of inadequate base support. A full-depth reconstruction must be performed to alleviate the problem (Roberts, et al, 96).

Reconstruction is the most expensive alternative, costing approximately $14.85 per square yard for full-depth reconstruction (6 inch asphalt base replacement and 2 inch asphalt pavement overlay) (NH T^2, 92).

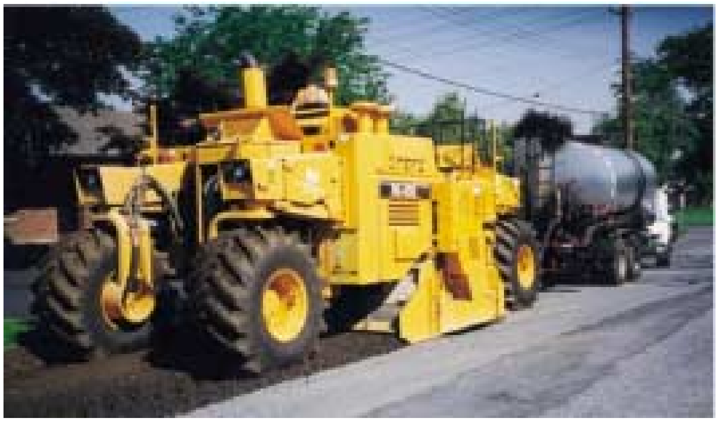


Figure 2.10 Full-depth Reconstruction

2.8.6 Treatment Cost Information

Table 2.3 exhibits all of the treatment alternatives presented herein and their corresponding costs. These costs are estimates from a variety of sources and from various years. An adjusted price was calculated to determine the current year’s cost based on the Consumer Price Index (“Consumer Price Indexes”, 2001). Agencies developing a PMS should look to local sources for accurate cost information.

Treatment Alternative	***Typical Cost***	***Year***	***Typical Cost in 2001 (CPI adjusted)***
Do Nothing	$0.00	----	$0.00
Routine Maintenance			
Crack Seal	$0.50 / linear ft	1996	$0.56 / linear ft
Patching	$10.00 / sq. yd of patch	1996	$11.20 / sq. yd of patch
Preventive Maintenance			
Fog Seal	$0.50 / sq. yd	1992	$0.63 / sq. yd
Chip Seal	$0.85 / sq. yd	1994	$1.01 / sq. yd
Slurry Seal	$0.64 / sq. yd	1994	$0.76 / sq. yd
Microsurfacing	$1.17 / sq. yd	1994	$1.39 / sq. yd
Thin Overlays	$2.10 / sq. yd	1996	$2.35 / sq. yd
Rehabilitation			
Thick Overlays	$3.60 / sq. yd	1996	$4.03 / sq. yd
Reconstruction			
Full-depth Reconstruction	$14.85 / sq. yd	1996	$16.64 / sq. yd

Table 2.3 Typical Costs of Treatments

Table 2.3 illustrates that the treatment costs increase as the complexity of the repairs increase. This relation is also illustrated in Figure 2.11 (“Asphalt Overlays”, 00). The figure exhibits the results of delaying treatments and how the necessary funds can grow exponentially over time. It is important to know which treatments are actually included in each treatment category and when to apply them. A useful statement that can be easy to remember is “*the right treatment, on the right road, at the right time*”.

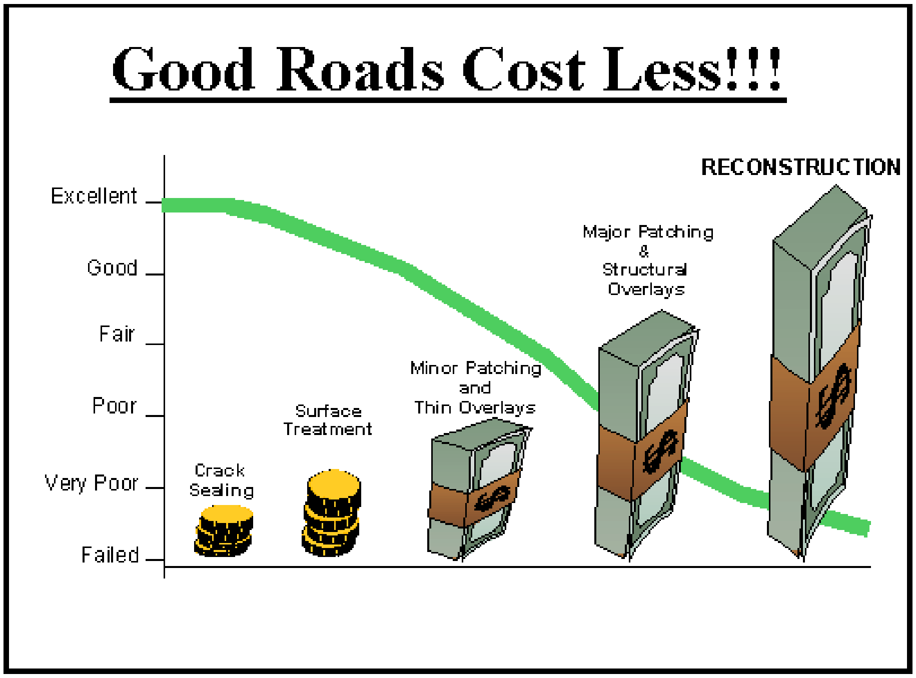


Figure 2.11 Cost of Delaying Repairs

2.8.7 Pavement Treatment Combinations

Many times, it is beneficial and necessary to combine alternatives, rather than use one exclusively. A routine maintenance alternative followed by a preventive maintenance measure may provide the best solution for a specific pavement. Alternatively, the necessary treatment combination may be a rehabilitation procedure that comes after a routine maintenance treatment. The list of possible combinations includes (Roberts et al, 96):

- Crack sealing/Patching and Surface Sealing (fog seal, slurry seal);
- Crack sealing/Patching and Preventive Maintenance (chip seal, thin overlay, microsurfacing);
- Surface Milling and Preventive Maintenance;
- Crack sealing/Patching and Thick Overlay;

- Surface Milling and Thick Overlay.

2.9 TREATMENT SELECTION

The process used to select feasible treatment alternatives from a set of available alternatives can range from simple judgement to a decision tree or an expert systems approach. The latter considers various combinations of factors such as structural adequacy, surface thickness, functional class, traffic and other factors (Haas, et al, 94).

A treatment selection model may employ the cause-based strategy. This means that pavement condition data is used to help identify pavement problems and recommend feasible treatments. Specific distress characteristics are the most important information to help select appropriate treatments (Herabat and Songchitruksa, 00).

The development of a repair needs model during initial implementation of a PMS involves the agency staff devising a set of decision rules as to how it currently identifies segments in need of repair and what treatments to apply. A decision tree or matrix is often used to express these rules. The decision tree or matrix is a way of defining the rules that dictate when a segment is identified as needing repair and what treatment to apply to that segment. The rules are then incorporated into the PMS (Broten, 97).

When individual condition measures are used in data analysis, the agency is usually restricted to using a set of decision trees. The type of decision tree used is partly a function of the way the condition data are collected and analyzed. Decision trees connect the distress information to a treatment. Generally, when more than one treatment is triggered in a road section, the most comprehensive treatment identified is selected or there is a set of rules that defines the precedence treatments (Texas Transportation Institute, 94).

The purpose of the treatment selection in the network-level analysis is to determine the funds necessary to apply the treatment needed. The treatment should be considered a “network-level budget planning treatment” rather than an actual maintenance or rehabilitation treatment. The selected treatment is primarily used to assign a fund need level to each section of pavement and should generally be considered a cost category rather than an actual treatment (Texas Transportation Institute, 94).

2.10 PRIORITY ANALYSIS

Once an agency has identified pavement sections requiring repair and has assigned the feasible treatments to the sections, the planned work needs to be prioritized. This prioritization is necessary because there is rarely enough funding available to perform all of the recommended projects (Broten, 97). The available funds must be allocated among the sections being managed (Texas Transportation Institute, 94).

Pavement sections should be selected as candidates for funding and repair based on methods that are rational and can be justified to funding authorities. The agency’s staff must have a set of procedures that they understand and can follow to select pavement sections for funding from the complete list of sections needing work. The procedures can then be used to justify selecting certain sections to funding authorities and the community (Texas Transportation Institute, 94).

There are a few different approaches that are used in prioritizing competing sections. Subjective project selection involves an agency reviewing its list of potential projects and then prioritizing the projects using personal judgment and experience. This procedure has the advantage of being quick and simple, but it is subject to bias and inconsistency. The results are usually far from optimal (Broten, 97). Another approach involves using ranking methods. This method is based on a set of rules or guidelines that are established by the managing agency. Projects can be ranked, or prioritized, based upon pavement condition, functional classification, truck traffic, political considerations, and so on. It is up to each agency to decide which factors to use in the prioritization process (Broten, et. al, 94).

It is important for an agency to carefully choose which method of project prioritization it will use within its PMS. The prioritization method used will have a significant impact on the benefits received from the pavement dollars expended. The Washington State Department of Transportation states that "it has been estimated that a simple ranking procedure can provide an agency with 20% to 40% more benefit than subjective project selection" (Broten, 97).

There are two priority strategies that must be considered: prioritizing among all of the sections and prioritizing within the selected treatment categories. If the agency decides to prioritize within the treatment strategies, the agency should consider the non-pavement-related factors in establishing priorities because the sections are all in about the same condition (FHWA, 85). Examples of non-pavement-related factors include traffic levels, classification, and costs. These factors portray what is occurring at each section and are a slightly more sophisticated version of the ranking process (National Highway Institute, 98).

In cases where only the distresses and the condition of the pavement are used for ranking sections, the pavements with the greatest quantity of distress are the first to be repaired. This procedure is sometimes referred to as the "worst first" process. Worst first approaches seem to be logical in that those sections that are in the worst condition create the most complaints from the pavement users and lead to the greatest user cost. However, this approach fails to consider the benefits of utilizing a pavement preservation program (Texas Transportation Institute, 94).

In most cases, the recommendations from the ranking at the network-level provide a starting point for a more thorough analysis. Project-level analysis is required to identify the most cost-effective treatments and the final treatment selection for each section. Network-level prioritization really identifies a list of candidate management sections and treatment cost categories for the available funding. The list from the network-level analysis should be considered a planning list and a budgeting tool.

The prioritization process provides a ranked order list of pavement sections based on criteria established by the managing agency. This is a structured method to select sections deemed most important to the responsible agency. The process should reduce arbitrary decisions about sections to be funded, reduce the effect of outside influences, and give the staff something to support decisions to the public (Texas Transportation Institute, 94).

2.11 IMPLEMENTATION OF A PMS

To be successful and efficient, a PMS must be accepted at all management and employee levels within the district. Upper-level management, pavement managers, and maintenance personnel must buy into the ideals of the PMS and use it to assist in making decisions and plans.

However, a pavement management system is more difficult to implement than most management and engineering programs because of its multiplicity. A PMS relies on several different departments within an agency (such as planning, design, materials, construction, and maintenance) to collect, check, enter and use data (Deighton and Sztraka, 95).

Implementation of a PMS occurs only when the recommendations of the software are routinely used to assist in selecting pavements to repair, allocating funds among competing pavement requirements, determining overall network needs, and justifying funding needs to governing authorities and the public (Broten, 97). A successful PMS must assist in the decision making process (Deighton and Sztraka, 95).

2.11.1 Implementation Problems

Unfortunately, not everyone initially sees the benefits of creating and using a PMS. There are potential roadblocks in existence that could be detrimental to the agency's implementation of a PMS. The following are just a few of the problems one should be aware of and be ready to overcome.

2.11.1.1 Turf protection

The PMS requires and provides information that often crosses several formal and informal lines of communication and authority within an organization. Information is power within an organization and access to information may influence who has the formal authority or informal power to make decisions. When a PMS is implemented in an existing or newly formed group of the organization, the remaining groups within the agency (planning, maintenance, design, operations, and administrative) may feel threatened by the new power of the PMS group. This is especially evident if the PMS group appears to be preparing to make decisions for which the other groups were previously responsible. The other groups within the agency may resist implementation of a PMS to prevent a perceived loss of power (Broten, 97).

2.11.1.2 Fear of exposure

The PMS will provide structured information that may not have been widely available prior to adoption and implementation of the system. Those individuals who have been making decisions with less than complete information may resist implementation because they fear that the PMS will show that their decisions were incorrect or less accurate than they have previously stated. The person may be afraid that the PMS will show that they may not have chosen the appropriate treatment at the correct time (Texas Transportation Institute, 94).

2.11.1.3 Outside influence

Some personnel may refuse to use anything that was not developed "in-house". Consequently, excessive amounts of money may be spent in creating a PMS when existing processes could be adopted with a few relatively inexpensive modifications. There is a balance needed between standard pavement management components and agency-specific needs. Although every highway agency is organized differently, they all have similar management needs and requirements. Customization is necessary in almost any PMS implementation (Texas Transportation Institute, 94).

2.11.1.4 Resistance to change

The researchers at the Texas Transportation Institute conducted surveys and analyzed agency personnel. They determined that people like doing things the way they have always been done. Some people just do not want to change. These people are present in many public agencies. They do not want to expend the effort to reshape their thinking, their decision making process, and their work habits. Sometimes these individuals are insecure with their own positions and knowledge, and are afraid to try something different. They may wonder how the changes will affect their role within the organization and worry that they may lose power, responsibility, or importance (Texas Transportation Institute, 94).

2.11.1.5 One person show

As sometimes is the case, one person conducts the PMS implementation within an organization. This individual is involved in the system development and implementation, and may be the only one who receives pavement management training. If the person who knows the system does not have good communication skills or has a personal desire for power, others within the agency will either know nothing about the system or will be turned off by the efforts of the key individual. If that one person should leave the district, the PMS efforts could easily be abandoned. It may take several weeks or months to replace that person and the knowledge may be lost (Broten, 97).

2.11.2 Overcoming Problems

There are many different obstacles that can stand in the way of an agency receiving the benefits of a PMS. However, there are steps an agency can take to overcome the potential challenges.

One of the most important implementation steps for an agency is to inform people of what a PMS is, how it works, and what it can do for them. People are less likely to fear and reject a new practice if they know the details. Everyone in the chain of command in the district should be informed and the public and their elected officials should be made aware of the system. This can be accomplished through formal presentations, training sessions, and informal discussion. Broten (97) recommends using internal newsletters to agency personnel to promote improvements made possible by the PMS. This has allowed people throughout the agency to understand the types of information the system provides and their role in the project selection process.

It is also very helpful to involve all personnel that will be affected by or will use the recommendations of the PMS. This will help educate them on the ideology behind pavement management and help them "buy into" the system.

Similarly, training is vital to implementation and effective use of the PMS. The training must address all of those who will be affected by the PMS. This includes each individual who is responsible for some aspect of the system, or who will receive information from the system. They should understand the capabilities of the system and the importance of their contribution to the overall success of the program. It is also important that cross training be used to prevent the reliance on one or two individuals for the operation of the system. If several people are familiar with the system, the agency's PMS efforts will not be lost if key individuals leave the district. The agency should also request clear documentation of the system operations and procedures. This will prove very helpful in times of staff turnover and in their training (Broten, 97).

Some other tips for successful implementation include (Broten, 97):

- Matching the operation requirements of the PMS to the resources available in terms of staffing and data requirements;
- Identifying the data needed to support the decision making process and tailor the data collection plans and resources accordingly;
- Match the PMS to current management procedures where possible and to the political realities within the district;

- Identify important divisions and managers and keep them involved throughout the implementation process to gain their support;
- Take advantage of external training opportunities (seminars, meetings, and conferences);
- Demonstrate the improved responses to questions from throughout the agency by addressing questions promptly and thoroughly.

In response to any potential drawbacks, there are perhaps thousands of agencies that have implemented and used some form of a PMS. In most cases, they have found that the benefits outweigh any drawbacks. Many agencies have applied the tools in their PMS to make more cost-effective decisions and improve the overall condition of their pavements (Broten, et al, 94). While pavement management should not be thought of as a process without problems, there are numerous positive factors and ways to overcome problems.

2.11.3 Checklists for Evaluating a System

2.11.3.1 Evaluating a PMS

The users of the PMS should have the capabilities to decide if the system they are using or considering meets their needs. The following eight criteria can serve as a checklist for a PMS user (Monismith, et al, 90).

- ❑ Simplicity in overall operation of the system;
- ❑ In-house capability (complete operation by the using organization);
- ❑ Implementation time (should look for a fast implementation time, probably less than one year);

- Condition survey detail (should have high degree of detail but be pertinent to your agency);
- Implementation costs (should be as low as possible);
- Prediction model inclusion (should be able to predict future performance of pavements);
- Prioritization features (provision for ranking projects according to priority);
- Flexibility (ability to change parameters or modify system to your needs).

2.11.3.2 Implementation Steps

Once a district or agency decides that a PMS is the right one for them, they will need to implement the system. The process of implementing a PMS can be summarized in the following steps (Deighton and Sztraka, 95).

- Select the sections of roads in the district that is included in the PMS;
- Apply the data collection techniques;
- Check the data for accuracy, repeatability, and reasonableness;
- Analyze the data and check the outputs;
- Calibrate the outputs using historical performance data and engineering experience;
- Fine tune the data collection and analysis procedures;
- Check the individual data files and database management system;
- Check the outputs and reporting capabilities of the database manager;
- Fine tune the analytical software programs;
- Rerun the above steps to be sure the PMS is operating correctly;
- Expand the analytical capabilities, outputs, and reports as needed;
- Update equipment as needed;

- Continuously monitor, evaluate, and recalibrate the PMS using a feedback system.

2.11.3.3 Evaluating Implementation Success

After the implementation the PMS user should check to see how the system is being applied. The following conditions indicate a successful implementation (Colony, 87).

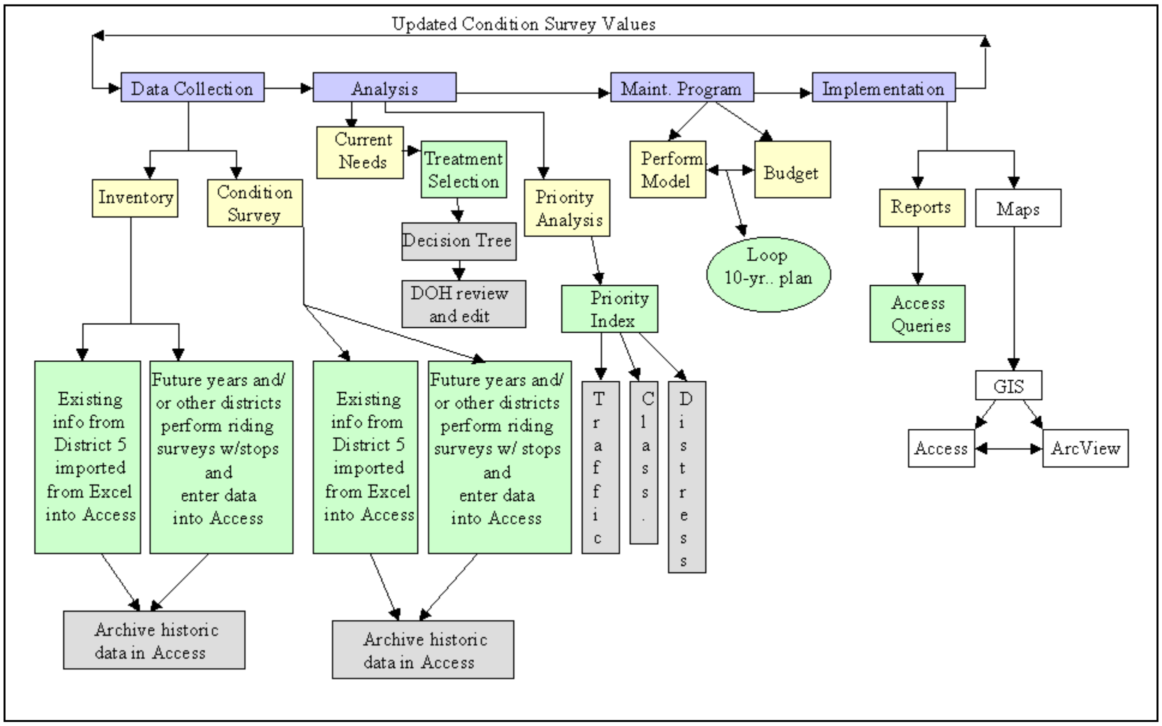
- A complete cycle of the process was completed, from condition survey to presentation of a list of recommended projects, including estimated costs and priority ranking.
- The resulting project recommendations were reasonable and practical, as judged by prevailing local practices, and cost estimates were realistic.
- The work described in the first item was completed within a reasonable time (allowing for training of all personnel) and without undue stress on the manpower and equipment resources of the district.
- District personnel participated in all aspects of the work to an extent sufficient to enable them to develop an understanding of the value, purposes, and limitations of the PMS and to continue the program in ensuing years unassisted by research personnel.

In addition, a successful implementation requires that management use the output from the system for formulating budgets and selecting projects. Initially, management should compare the PMS recommendations to decisions made without the system. Discrepancies should be evaluated to determine if the PMS is making “better” recommendations or if the system needs to be adjusted to reflect the needs of the agency.

CHAPTER 3 - WV DPMS DESIGN

3.1 OVERVIEW OF WV DPMS

WV DPMS closely follows the structure developed by the FHWA, Figure 2.1. The system specific design is presented in Figure 3.1. WV DPMS consists of four components: Data Collection, Analysis, Maintenance Programs, and Implementation. These areas are briefly described in the following sections to orient the reader. Then each component of the system is presented in detail.



Updated Condition Survey Values
Data Collection
Analysis
Maint. Program
Implementation
Inventory
Condition Survey
Current Needs
Treatment Selection
Decision Tree
DOH review and edit
Priority Analysis
Priority Index
Perform Model
Budget
Loop 10-yr.. plan
Reports
Maps
Access Queries
GIS
Access
ArcView
Existing info from District 5 imported from Excel into Access
Future years and/ or other districts perform riding surveys w/stops and enter data into Access
Existing info from District 5 imported from Excel into Access
Future years and/ or other districts perform riding surveys w/ stops and enter data into Access
Traffic
Class.
Distress
Archive historic data in Access
Archive historic data in Access

Figure 3.1 Framework for WV DPMS

3.1.1 Data Component

District 5 personnel have already put forth effort into collecting inventory and condition data. The data collection was performed in 1998 and 1999. This existing data on road inventories and condition assessments was used in WV DPMS. By using existing data and techniques that are already in place, it will be easier to implement the new system.

3.1.1.1 Inventory

District 5 personnel performed the initial inventory data collection. The data were in a Microsoft Excel spreadsheet format. The data were imported into the Microsoft Access database program for analysis and archiving. Future inventory data collection will be a riding or windshield survey with periodic stops. The information is recorded on data forms and then entered into the Microsoft Access database. The data are stored in Access files for analysis and archiving.

3.1.1.2 Condition Survey

District 5 personnel have evaluated the condition of their non-NHS roads using RSMS (NH T^2 Center, 92) condition survey forms and criteria. The data were in a Microsoft Excel spreadsheet format. The data were examined and transposed to match the new WV DPMS criteria presented herein and the data were imported into the Microsoft Access database. Future pavement condition data collection will be a riding survey with four stops per section, making use of a supplied condition survey worksheet. The condition data are manually recorded on forms and then entered into the Microsoft Access database.

3.1.2 Analysis Component

The analysis procedure is programmed within the Microsoft Access database and within Microsoft Excel. Existing inventory and pavement condition data from District 5 were imported from a Microsoft Excel format into the Access database. Future entries and analyses (current needs and priority analysis) will be performed in the Access software program. Microsoft Access allows the user to store and manage large collections of information, analyze the data, and present the information in specialized reports. The proposed budget and maintenance program are analyzed in the Microsoft Excel format.

3.1.2.1 Current Needs Analysis

A current needs analysis generates a list of treatments that should be applied to each section in the current year depending on the condition of the pavement. The treatment selection uses a decision tree. The decision tree is a mechanism designed to assign a specific treatment to a particular distress. The Access software is programmed to assign the treatment alternatives to the section and the analysis is fully automated. Personnel from the WV DOH reviewed the outputs of the current needs analysis to decide if the decision tree results are realistic and correct and to see if the current needs analysis program is running accurately.

3.1.2.2 Priority Analysis

The priority analysis ranks the sections based on a priority index. The priority index is a function of three factors, traffic (AADT values), classification (primary or secondary), and the distress index (determined from condition ratings). A weighting value is assigned to each of the priority factors to represent the district’s perception of significance. The current needs analysis is combined with the priority analysis to identify candidate projects.

3.1.3 Maintenance Program Component

3.1.3.1 Performance Model

The PMS needs a performance model for estimating the future condition of the pavement network and the pavement treatment needs. The predicted needs are based on the current needs analysis, available funding levels, and the estimated result of performing or not performing the recommended treatment. A needs transition model is used to create the performance model. The model shows the consequences of funding or not funding a certain percentage of needed maintenance projects. Those projects that are not funded will transition to a lower level of pavement quality, possibly needing a different type of treatment.

3.1.3.2 Budget

The estimated budget report is based on analysis performed in the Microsoft Excel program. The current needs from the Microsoft Access program, unit costs, percentage of needs funded, and performance model factors are entered and various funding scenarios are generated. An estimated ten-year plan is created based on the entered factors.

3.1.4 Implementation Component

3.1.4.1 Reports

Running queries within the Access software generates reports of the analysis and maintenance program. The reports present the prioritized sections and the specific treatments to be applied. Also presented is the proposed ten-year budget and treatment plan from the Microsoft Excel analysis.

The process described above should be performed annually as updated condition survey values are gathered. Data collection, analysis, maintenance program determination, and implementation will be conducted on a yearly basis and the PMS should be a cyclic process.

3.2 WVDPMS FIELD PROCEDURES

This section describes the procedures that must be followed to collect the inventory and condition data. The required information and the data collection methodology of the inventory and pavement condition surveys are presented.

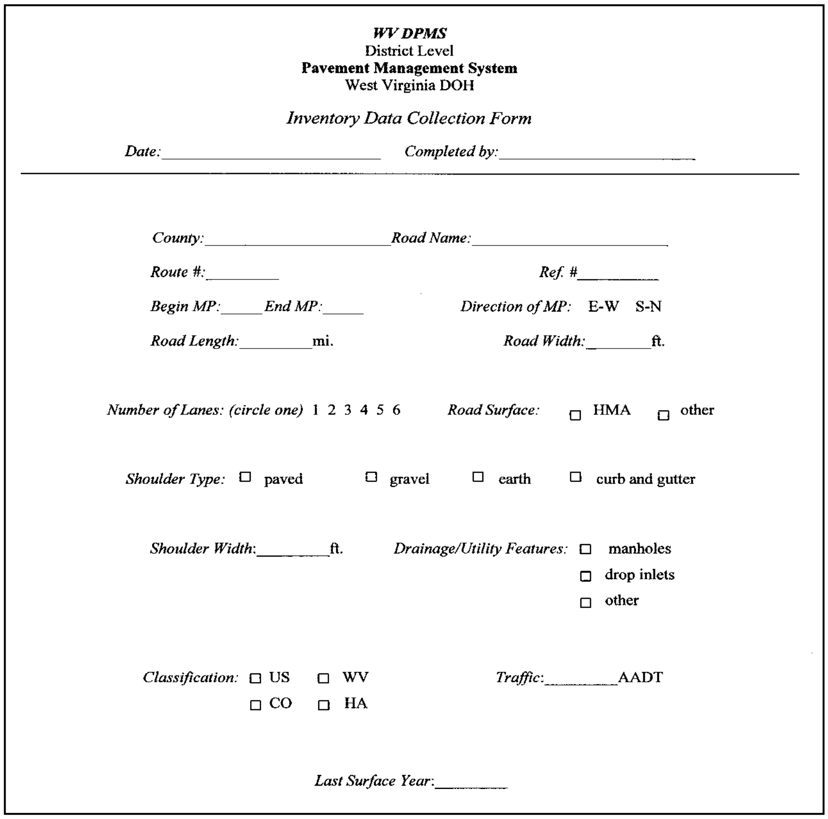
3.2.1 WV DPMS Inventory

The personnel in District 5 have completed inventories of their roads that detail the length, width, and classification of each route. They defined their road sections by using straight-line diagrams that detail the district's infrastructure. The data has been archived in a Microsoft Excel spreadsheet format but has been imported into the WV DPMS Microsoft Access database program for analysis and archiving.

District 5 personnel must perform more inventory data collection if they decide to add mileage to the management system. Similarly, other districts that decide to implement this system will have to collect inventory data. Inventory data collection will be a riding or windshield survey with periodic stops to make measurements. The information is manually recorded on inventory data collection forms, Figure 3.2, and then entered into the Microsoft Access database. Appendix A presents a copy of this form for reproduction and distribution. The data are stored in Access files for analysis and archiving.

The inventory is the first phase of the PMS implementation process. There are a number of categories that comprise the inventory for WV DPMS. The categories included in the inventory are:

- Road Name,
- Route Number,
- Reference Number,
- Begin Mile Post,
- End Mile Post,
- Road Length,
- Road Width,
- Number of Lanes,
- Road Surface Type,
- Shoulder Type,
- Shoulder Width,
- Drainage/Utility Features,
- Classification,
- Traffic, and
- Last Surface Year.



WV DPMS
District Level
Pavement Management System
West Virginia DOH

Inventory Data Collection Form

*Date:*__________________________ *Completed by:*__________________________

*County:*______________________*Road Name:*________________________

*Route #:*_________ *Ref. #*__________

*Begin MP:*_____*End MP:*_____ *Direction of MP:* E-W S-N

*Road Length:*_________mi. *Road Width:*_______ft.

Number of Lanes: (circle one) 1 2 3 4 5 6 *Road Surface:* ☐ HMA ☐ other

Shoulder Type: ☐ paved ☐ gravel ☐ earth ☐ curb and gutter

Shoulder Width:_________ft. *Drainage/Utility Features:* ☐ manholes ☐ drop inlets ☐ other

Classification: ☐ US ☐ WV ☐ CO ☐ HA *Traffic:*_________AADT

Last Surface Year:_________

Figure 3.2 Inventory Data Collection Form

3.2.1.1 Defining Management Sections

Before any inventory information is recorded, the road system must be divided into sections. The road sections limits are determined so that each section is consistent in both its physical characteristics and in the various factors that can affect pavement deterioration. Factors that can be considered when defining sections include:

- Changes in pavement type
- Intersection with a crossroad
- Major change in traffic volume
- Change in pavement structure (thickness, material, and other characteristics)
- Boundary of previous construction project or previous seal coat/overlay project
- City, town, or county limits
- Railroad grade crossings
- River or stream crossings
- Minimum or maximum section length so that the section is of reasonable size.

District 5 established road sections based on straight-line diagrams from previous years and paving projects. Straight-line diagrams are used to record and archive information about the roads included in a district and they denote mileposts, intersections, and other roadway features. Some of the District 5 road sections end at mileposts or intersections. However, some road sections were extended to include the boundaries of previous maintenance or construction projects. This extension helped in maintaining continuity in present and future work by creating more manageable sections.

Road sections should be approximately 1 to 5 miles in length. This is the length of most projects that are contracted out and performed. When defining the 1 to 5 mile road section, the user should attempt to define the section homogenous in pavement type, structure, county limits, and boundaries of previous projects. If the homogenous sections are too long, they should be broken down into smaller sections using the factors included herein.

3.2.1.2 Method of Collecting Inventory Data

District 5 personnel collected the existing inventory data for WV DPMS in the fall of 1998, using two man crews, consisting of engineers and project supervisors. Each crew was issued a vehicle equipped with a distance-measuring device. The inventory data were observed and recorded onto data forms. The inventory data collection was performed prior to the development of WV DPMS and methodologies used for the initial data collection do not exactly match the WV DPMS methodologies.

Future inventory data collections should follow the procedures presented herein. This would include any updates that District 5 makes to their inventory database or an undertaking by other districts that decide to use WV DPMS. These procedures are reproduced in Appendix B for future reference and are to be distributed to the survey crews.

A two-person team should perform the road inventory data collection. The accuracy and quality of the data is maintained by having each team member check and validate the data. The team will need to be provided with a vehicle and a device to accurately measure distance. A distance-measuring device that can be mounted on the dash of a vehicle is a good tool to perform this task. The crew will also need a district map showing the road section boundaries that have been established for WV DPMS and forms for recording the inventory data. The completed forms should be taken back to the district office and the data should be entered into the Access database.

The actual survey of the road inventory will be a riding survey conducted at slow speeds. However, the driver of the vehicle must be aware of blind curves and poor sight distances and drive accordingly. When the driver decides to stop and get out of the vehicle, flashing lights should be turned on and the vehicle should be completely off the road. For example, a team member wearing a reflective safety vest may get out of the vehicle to measure the width of each road section at the section boundary. The other categories included in the inventory such as number of lanes, surface types, shoulder characteristics, and drainage features can be determined from the vehicle.

3.2.1.3 Filling Out Inventory Data Collection Forms

The forms should be filled out according to the methods described in this section to provide continuity and accuracy. All members of the team should read this section before collecting the inventory data and filling out the form. Each line of the form, as seen in Figure 3.2, is explained.

Date: the date of the actual collection of inventory data should be noted on the first line of the form.

Completed by: the person(s) that complete the form should print their name legibly so that they can answer any questions that may arise.

County: the county that the road section is located in.

Road Name: the specific name of the road that the section is located on.

Route #: the designated route number that is assigned to the road section; it can be found on county maps or posted signs.

Ref. #: this number can be assigned at a later time to coordinate the road section between relational databases. The field is not currently needed. It was provided to facilitate future upgrades to WV DPMS if a GIS program is implemented.

Begin MP & End MP: the assigned mile posts for the beginning and end of the section as designated by straight-line diagrams or signs.

Direction of MP: circle the direction that the survey crew travels from the beginning of the section to the end.

Road Length: this value can be determined from the straight line diagrams. It can also be measured using the distance measuring devices found in the team's vehicle and can be measured while traveling at slow to normal speeds. If the value from the distance measuring device varies from the length found in the straight-line diagrams, note the measured length and then determine where the discrepancy lies. The correct length must be entered into the database because this value is used in calculating section repair costs.

Road Width: the crew will have to get out of their vehicles at the beginning of each new section to measure the road width. The crew should take care to be safe and not to disrupt traffic. This measurement can be done with a measuring wheel. If the width of the surveyed road section appears to change by more than 2 feet within the section, the varying road widths should be averaged and the mean road width should be reported.

Number of Lanes: the appropriate number of lanes of the road section should be circled on the form.

Road Surface: the crewmember should check the correct box. "HMA" is short for hot mix asphalt and the "other" category can be concrete pavement, chip seal, and other surface types.

Shoulder Type: a check should be placed in the pertinent box according to the shoulder type found in this section of road.

Shoulder Width: the crew will have to carefully stop the vehicle and get out to measure the width. The shoulder width of each new road section will have to be determined and reported. This measurement can be done concurrently with the road width measurement. If the shoulder width changes within the section, an average value should be estimated and noted.

Drainage/Utility Features: a check should be made in the appropriate box, depending on what features are located within the road section.

Classification: mark the appropriate box to indicate road classification. WV and US routes are considered primary roads and the CO (County Routes) and HA (Orphan Roads) are considered secondary roads.

Traffic: the average annual daily traffic, AADT can be retrieved from previous records or a new traffic count can be performed. The value can be determined before or after the field data collection occurs.

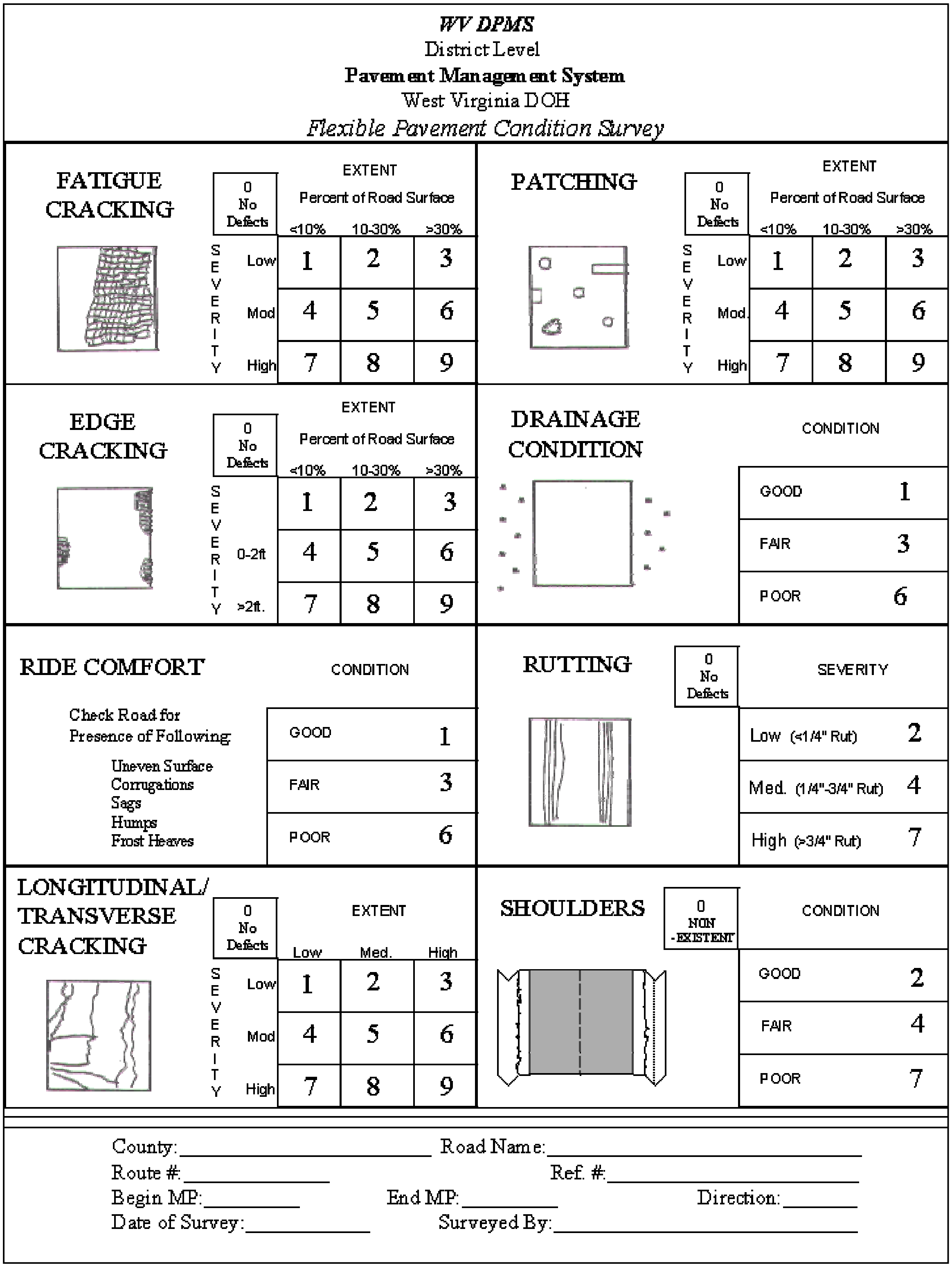
Last Surface Year: write in the year of the last resurfacing or reconstruction job that occurred on this road section. If good maintenance records are not available, ask personnel that may have worked in the district when the section was last repaired. If the section has not been resurfaced, write down the year the section was built.

The crewmembers should agree on the values that are entered onto the collection form. If there is a discrepancy, the difference should be resolved.

3.2.2 WV DPMS Pavement Condition Survey

District 5 personnel have also assessed the condition of some of some of their roads using RSMS (New Hampshire T^2 Center, 92) condition survey forms and criteria. The initial pavement condition data collection was performed prior to the development of WV DPMS. Methodologies used for the initial data collection were those of RSMS and do not exactly match the WV DPMS methodologies. However, the data that were collected exists in a Microsoft Excel spreadsheet format and were imported into the Microsoft Access database and transposed to match the new WV DPMS criteria.

Future data collection will follow procedures laid out herein and will be recorded on the forms, Figure 3.3. The form is a modification of the RSMS forms that District 5 personnel have previously used. A copy of the condition data collection form, suitable for reproduction, is given in Appendix A. Users need to periodically update the condition data. The following condition survey information is a summary of the detailed procedures presented in Appendix C. The specific instructions were placed in a stand alone appendix to permit reproduction and distribution to the data collection crews.



WV DPMS
District Level
Pavement Management System
West Virginia DOH
Flexible Pavement Condition Survey

FATIGUE CRACKING

0 No Defects

SEVERITY	EXTENT – Percent of Road Surface <10%	10-30%	>30%
Low	1	2	3
Mod	4	5	6
High	7	8	9

PATCHING

0 No Defects

SEVERITY	EXTENT – Percent of Road Surface <10%	10-30%	>30%
Low	1	2	3
Mod.	4	5	6
High	7	8	9

EDGE CRACKING

0 No Defects

SEVERITY	EXTENT – Percent of Road Surface <10%	10-30%	>30%
	1	2	3
0-2ft	4	5	6
>2ft.	7	8	9

DRAINAGE CONDITION

CONDITION	
GOOD	1
FAIR	3
POOR	6

RIDE COMFORT

Check Road for Presence of Following
Uneven Surface
Corrugations
Sags
Humps
Frost Heaves

CONDITION	
GOOD	1
FAIR	3
POOR	6

RUTTING

0 No Defects

SEVERITY	
Low (<1/4" Rut)	2
Med. (1/4"-3/4" Rut)	4
High (>3/4" Rut)	7

LONGITUDINAL/ TRANSVERSE CRACKING

0 No Defects

SEVERITY	EXTENT Low	Med.	High
Low	1	2	3
Mod	4	5	6
High	7	8	9

SHOULDERS

0 NON-EXISTENT

CONDITION	
GOOD	2
FAIR	4
POOR	7

County:__________ Road Name:__________
Route #:__________ Ref. #:__________
Begin MP:__________ End MP:__________ Direction:__________
Date of Survey:__________ Surveyed By:__________

Figure 3.3 Flexible Pavement Condition Survey Form

3.2.2.1 Information Needed

The surveyor must be able to visually identify pavement distresses, including type, severity, and extent. The type of distress tells what sort of damage has developed, the severity tells how bad the damage is, and the extent gives the quantity of the damage that is present. All three factors are necessary to determine the type and timing of maintenance and how much the corrective procedures will cost.

3.2.2.2 Distresses Types and their Causes

One of the recommendations taken from the literature was to create a manual with a description of pavement distresses, their significance, possible mechanisms, and corrective procedures. The manual should help ensure that the visual rating is consistent since all surveyors will be looking for the same problems. This manual, presented in Appendix D, describes the distresses identified for WV DPMS.

WV DPMS considers and analyzes pavement conditions and distresses commonly found in District 5 and in West Virginia. This is important because it addresses one of the failures of other PMS. WV DPMS includes various types of cracking, surface deformations, and distresses that are prevalent in the study area and can be measured without expensive, mechanical measuring devices. The conditions and distresses included are: Fatigue Cracks, Edge Cracks, Ride Comfort, Longitudinal/Transverse Cracks, Patches, Drainage Conditions, Rutting, and Shoulders. District 5 presently surveys all of the listed distresses except shoulders. WV DOH personnel and other engineers reviewed an initial list of distresses considered for WV DPMS. It was determined that the condition of the shoulders is a critical measure that should be surveyed and recorded and the Shoulders category was added to the form.

The eight distresses and their corresponding descriptions are presented in Appendix D so that the users can reference this manual and distribute copies to the surveyors. The *WV DPMS Treatment Alternatives*, Section 3.3.1, provides a more detailed description of the corrective procedure classifications (i.e. routine and preventive maintenance, rehabilitation, restoration, and reconstruction).

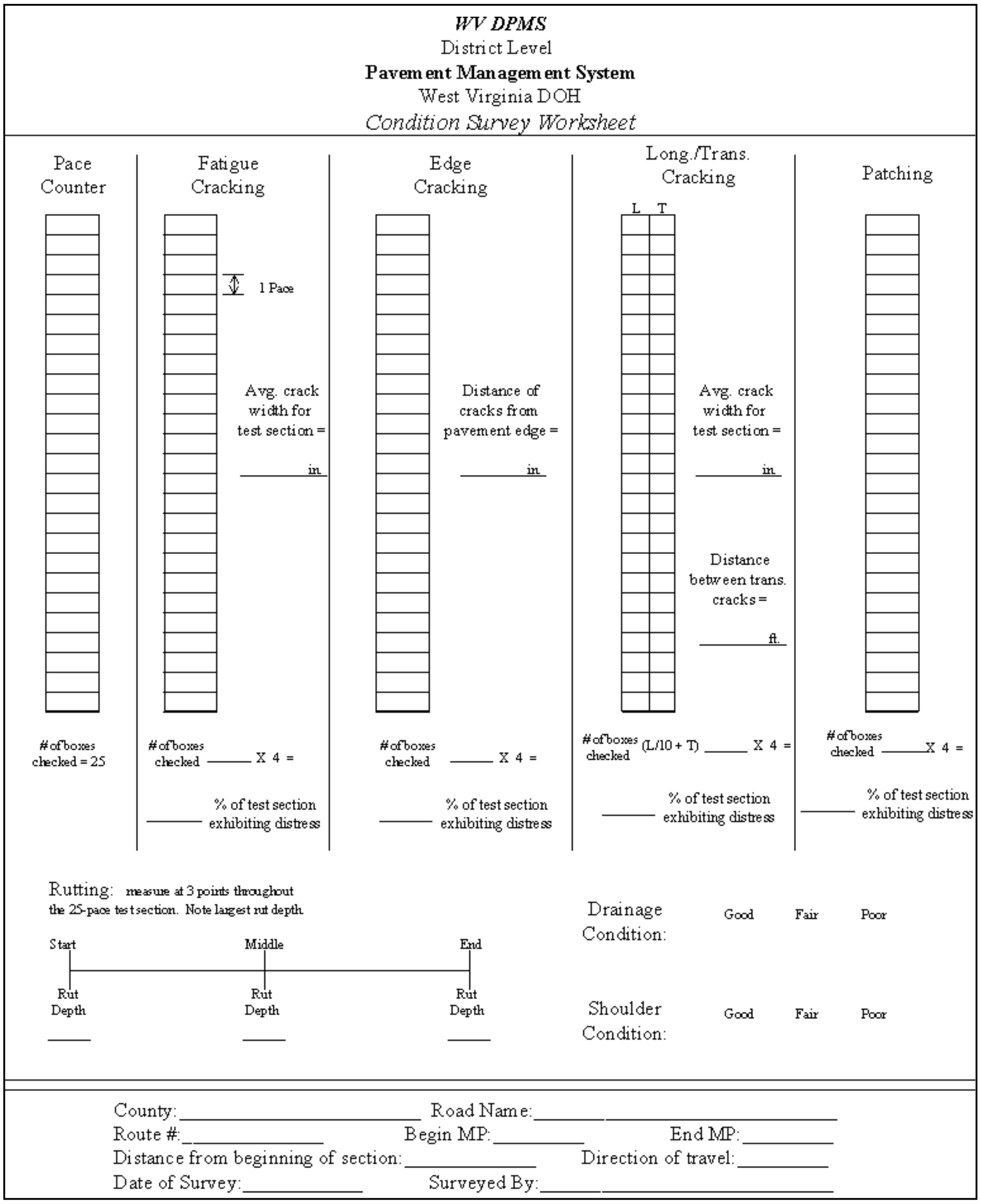
3.2.2.3 Method of Collecting Pavement Condition Data

The personnel in District 5 conducted a pavement condition survey in 1998 and 1999. The surveys were performed in the late fall and winter months. Engineers and project supervisors were used to do this phase of the work. Crews of two people were given vehicles equipped with distance measuring devices and measuring wheels to measure sections and distresses. The survey was a windshield survey with periodic stops. The driver would drive at a slow speed and get off of the traveled way when possible, making sure the vehicles lights were flashing to warn passing motorists. The surveyors would stop approximately four times in a two-mile section and measure the distresses in a 100-foot segment of roadway. This procedure would give the surveyors a good idea of the type, extent, and severity of distresses occurring in the whole section. The distress values were manually recorded on the supplied data forms. A two-person crew covered approximately 4 to 5 miles per day.

In order to utilize WV DPMS, future pavement condition surveys should follow the procedures laid out herein. District 5 pavement managers will have to re-assess the condition of their pavements in future years and must follow the WV DPMS procedures. Similarly, other districts that implement this system should follow the same guidelines. The procedures for collecting condition assessment data are presented in the following sections and are also presented in Appendix C so that it can be reproduced and distributed to the survey crews.

The WV DPMS pavement condition survey requires a visual inspection of the distresses. WV DPMS involves identifying road distress characteristics, estimating the severity of the distress, and assessing the extent of the severity. Severity applies to the degree of deterioration of the distress. Extent refers to the frequency or amount of distressed road surface area. Both the severity and extent are rated on a pre-established scale. The criteria for determining the severity and extent are explained in detail in Appendix C. The crewmembers should read and understand the criteria before rating the distresses. Following this procedure will ensure that the crews are recording data according to the same criteria and that the quality of data is ensured.

The WV DPMS condition survey should be a windshield survey with four stops within the road section. The driver should drive at a slow speed and get off of the traveled way when possible, making sure the vehicles lights are flashing to warn passing motorists. The surveyors should stop four times in a road section, and measure the distresses in a 25-pace segment of roadway (approximately a 60 to 75 foot test section). The condition survey worksheet, Figure 3.4, should be filled out at each test section to identify the extent, severity, and condition of the distresses. The distress values for the entire section are manually recorded on the supplied flexible pavement condition survey forms, Figure 3.3.



WV DPMS
District Level
Pavement Management System
West Virginia DOH
Condition Survey Worksheet

Pace Counter

# of boxes checked = 25

Fatigue Cracking

1 Pace

Avg. crack width for test section =
________ in

# of boxes checked ______ X 4 =

______ % of test section exhibiting distress

Edge Cracking

Distance of cracks from pavement edge =
________ in

# of boxes checked ______ X 4 =

______ % of test section exhibiting distress

Long./Trans. Cracking

L T

Avg. crack width for test section =
________ in

Distance between trans. cracks =
________ ft.

# of boxes checked (L/10 + T) ______ X 4 =

______ % of test section exhibiting distress

Patching

# of boxes checked ______ X 4 =

______ % of test section exhibiting distress

Rutting: measure at 3 points throughout the 25-pace test section. Note largest rut depth.

Start Middle End

Rut Depth ______ Rut Depth ______ Rut Depth ______

Drainage Condition: Good Fair Poor

Shoulder Condition: Good Fair Poor

County:______________________ Road Name:______________________
Route #:______________ Begin MP:_________ End MP:_________
Distance from beginning of section:_____________ Direction of travel:_________
Date of Survey:____________ Surveyed By:______________________

Figure 3.4 Condition Survey Worksheet

The survey should be done by a 2-person team that has been trained to recognize pavement distresses and record the data. Two-person teams are used to ensure quality and accuracy and to reduce any bias or subjectivity that may exist.

The team will need to be provided with a vehicle to transport them to the survey site and to perform the survey. They will also need a district map showing the established section boundaries and what roads they need to survey. The crew should also be given a measuring tool to determine the severity and extent of the pavement distresses. The surveyor will use the tool to determine the severity of the pavement distress by gauging crack widths or measuring rut depths. The extent can be measured with aid of the condition survey worksheet. Detailed procedures on how to use the worksheet are presented herein and are also printed in Appendix C for future reference.

The flexible pavement condition survey forms, Figure 3.3, have been created to facilitate quick surveys and swift data entry. The forms are supplied in Appendix A and should be copied and distributed to the survey teams. Pertinent information such as Road Name, Route Number, and Mileposts should be entered first, so as to coordinate with the sections identified in the inventories. Then the assessment of distresses in each test section can begin. At the end of the road section and the completion of the worksheets for the four test sections, the distress rating values can be noted on the condition survey form. The surveyor should record the worst severity and extent level they observe in the section. The surveyor can either highlight or circle the appropriate field for each distress type, as determined by the criteria. For example, for a section exhibiting low extent, moderate severity longitudinal/transverse cracks, the surveyor would circle or highlight the number 4. Then when the condition survey data is entered into the Access database, the number 4 is entered into the appropriate field.

3.2.2.4 Supplementals to Condition Surveys

Condition Survey Worksheet

Procedures are presented herein to determine the severity and extent levels of certain distresses. Survey crewmembers should use the provided worksheets, as seen in Figure 3.4, during their periodic stops to help determine and measure the distress characteristics. The condition survey worksheet is supplied in Appendix A so that it can be reproduced and distributed to the appropriate personnel.

The distresses that are analyzed with the aid of the worksheet are Fatigue Cracking, Edge Cracking, Longitudinal/Transverse Cracking, Patching, Drainage Condition, Rutting, and Shoulder Condition. Ride Comfort is not included on the worksheet because it is a subjective condition that is best measured after the crew has driven over the road section. The distresses that are on the worksheet, except for Drainage Condition, Rutting, and Shoulders, are rated based on severity and extent levels. The severity levels are measured directly with specific tools such as levels, straight edges, and rulers. However, extent levels are based on a percentage and could be harder to accurately determine. The condition survey worksheet enables the surveyor to accurately evaluate the extent, or percentage of road surface exhibiting distresses, on the test section. The worksheet also provides a means of recording the various measurements used in determining a severity rating. At the end of a section and the completion of the four test sections, the surveyor can review the measurement data for the section and report the most severe rating observed in the section. Knowing the condition of the test sections will help in determining the condition of the entire road section.

A condition survey worksheet should be filled out each time the crew stops within the road section. To use the worksheet, a crewmember will get out of the vehicle and locate a safe place to survey. The surveyor will take 25 paces along the paved surface. The surveyor should pace, stop, look, and record, 25 times in each test section. The pace should be a normal stride covering approximately 2 to 3 feet. As each pace is made, the surveyor should stop and look for Fatigue Cracks, Edge Cracks, Longitudinal/Transverse Cracks, or Patches within the pace length and the road width. If one of these distresses is encountered on the pavement within the pace length, a check should be placed in the corresponding box. If no distress is observed in the respective pace, the corresponding box should be left blank. The pace counter column is used to help the surveyor keep track of the number of paces they have completed. At the end of the 25-pace test section the number of checked boxes for each distress should be counted. This value should be multiplied by 4 to yield the percentage of the 25-pace test section that is exhibiting the distress.

For example, if there are 5 checks in the Edge Cracking portion of the worksheet after completing the 25 pace analysis, 20% of the test section is exhibiting Edge Cracking. After completing four test sections within the road section, the extent levels for each distress should be examined. If the extent levels for Edge Cracking for all four test sections within an entire road section are 20%, the surveyor can determine that the extent of Edge Cracking for the entire road section is 20%, or Medium Extent. Therefore, the entire road section should be designated as Medium Extent Edge Cracking. If the test sections are exhibiting drastically different extent levels for each respective distress, the highest extent level should be noted on the condition survey form.

The extent rating for Longitudinal/Transverse Cracking is handled slightly different from the other distress surveys. Both types of distresses are considered in the same survey because they are treated and repaired in the same manner. However, there is a difference in the measurement of the extent of the distress. A longitudinal crack may extend the entire length of the test section at a construction joint. Although this is not a drastic distress, it would be reported as 100% cracking for the test section and an inappropriate treatment may be selected. Transverse cracking may be more severe than the longitudinal cracking but would only be counted and checked a few times in the pace-check box using the procedures of the other distresses. A 25-foot transverse crack may only be counted once in a test section because of its orientation and the way the survey is conducted; whereas, a 25-foot longitudinal crack may be recorded as 10 checks. To compensate for these possible problems and to balance out the significance of each distress in the treatment selection process, the worksheet has been created to equalize the distresses. The equation, L/10 + T, is used for the Longitudinal/Transverse Cracking portion of the condition survey worksheet. The surveyor will observe the two types of cracking within each pace and check the box accordingly, L for longitudinal crack and T for transverse crack. At the end of the test section the surveyor will add up the longitudinal, L, boxes checked and divide that number by 10. They will also sum the number of transverse, T, boxes checked. These two values will be added together and multiplied by 4 to determine the total percentage of the test section exhibiting longitudinal and transverse cracks. For example, 20 “L” boxes were checked and 4 “T” boxes were checked. Therefore, 20 would be divided by 10 and then added to 4. The resulting value, 6, would be multiplied by 4 to determine the percentage of the test section exhibiting longitudinal and transverse cracking.

The severity ratings should be made concurrently with the extent ratings. A representative sample of the observed distress should be selected. The representative sample should be evaluated within the test section and the measurement should be noted on the worksheet. Specifically, the user must survey the width of the fatigue cracks, the distance of edge cracking from the edge of pavement, the width of the longitudinal or transverse cracks and the distance between transverse cracks in the test section. When all of the test sections have been analyzed, the most extreme severity rating exhibited in the test sections should be used to rate the entire road section. For example, if the largest longitudinal/transverse crack measured in any one of the test sections was $^{1}/_{8}$ inch wide, the severity rating would be Low for the entire road section.

Rutting is measured on each test section to accurately determine what is occurring in the entire road section. This distress can be measured by using a straight edge, for example, a four-foot piece of wood, and a ruler. The surveyor should measure rut depths at three distinct points within the test section. The various points include the area preceding the first pace of the test section, a point after the twelfth pace, and a point after the twenty fifth pace. This will give a representative sample of the rut depths within the test section. After completing assessment at the four stops and subsequent test sections, the severity of Rutting for the whole road section can be determined. The largest rut depth that is measured in the test sections should be the reported value for the entire section on the condition survey form. For example, the largest rut depth that was measured at any of the points in the various test sections of a road section was ½ inch.

Therefore, the severity rating would be Medium for the road section and the number 4 would be highlighted or circled on the condition survey form.

The remaining two distresses are Drainage Condition and Shoulder Condition. The condition of these categories should be circled on the form at the end of the test section after observations of the test section have been made. When the entire road section is completed, the worst rating on any one of the test sections should be the rating for the entire road section. For example, if the drainage condition for one of the test sections was determined to be Poor, the entire section would be rated Poor and the number 6 would be highlighted or circled on the condition survey form.

At the bottom of the condition survey worksheet are spaces to note the county, road name, mileposts, and other characteristics of the section that is being examined. This information is needed to match the worksheets to the condition survey form for the respective road section. The distance from the beginning of the section and the direction of travel should also be noted in case future investigations of the test sections are necessary.

The worksheets should be archived along with the condition survey forms for future review should any problems arise.

Immediate Maintenance Report

District 5 personnel presented a desire to have an immediate maintenance report that they could have with them while conducting the condition surveys. The prevailing thought was that the survey crew might notice a problem that necessitates immediate attention. The problems that they may encounter include potholes, drainage issues, edge drop-offs, or shoulder conditions. A form was created that will enable the survey crew to note problems they might observe during the condition survey collections and to report them to the proper personnel. The immediate maintenance report form is supplied in Appendix A.

To help the maintenance crew find the area in need of repair, the specific location of the problem must be noted by the survey crew. The mileposts that the section is located within and the approximate distance from the beginning of the section should be reported. The direction of travel from the beginning of the section should be noted, as well, to pinpoint the problem. Knowing the exact location of the maintenance emergency will speed up the corrective procedures.

As noted on the form, potholes should be reported if they are observed in the section. Potholes should be repaired immediately because they pose a hazard to motorists (Kercher, 99). As a consequence of being managed as they appear, potholes are not included in the management system. However, this distress must be corrected and the immediate maintenance report form helps in doing so. A patch of cold mix or hot mix asphalt should be applied to the pothole as soon as possible.

Edge drop-offs should be reported if the drop-off is greater than 1 ½ inches. This value was chosen because District 5 felt this to be the critical measurement in this situation and wanted to monitor and repair any drop-off exceeding 1 ½ inches. This measurement can be made when the survey crew makes their periodic stops within a road section.

Drainage conditions should be reported if the ditches, gutters, and/or other drainage structures do not appear to be functioning correctly. Standing water around drainage structures is a good sign that the structure is not working. Ditches must be regraded to improve the slope of the ditchline so that water will drain. Culverts, drop inlets, and other drainage structures should be cleaned or replaced with larger capacity structures as quickly as possible.

The shoulder condition should be reported if water is ponding near the edge of pavement. Water that does not drain to the ditches or other drainage structures may cause a hazard to motorists in the form of hydroplaning. Ditches should be regraded and/or material should be added to the shoulders as soon as possible.

Space for comments is included on the form so that the survey crew can note any information they think will be beneficial to the maintenance crew. The completed forms should be given to the maintenance supervisor at the end of the day's survey data collection or as promptly as feasible.

3.2.2.5 Condition Survey Summary

The condition surveys should be performed annually. Road conditions can and do change quite drastically within a year (Nichols, et al, 86). The practice of annual surveys will help maintain a good grasp on the condition of the district's roads and make WV DPMS more efficient. The surveys can be performed by DOH personnel during their down time or "off-season". Otherwise, part-time staff should be hired to conduct the surveys. This can include engineering students who are hired as summer interns or other part-time employees. The surveyors should be trained to recognize the distress and to measure the extent and severity of it. It would be beneficial if the same surveyors were used every year to maintain quality and accuracy of the data.

3.3 WVDPMS ANALYTICAL METHODS

An explanation of the WV DPMS analyses is given in this section. Included are the methods used to select the recommended treatment, the procedures used to prioritize and rank the competing road sections, the development of a performance model, and methods to determine a proposed budget.

3.3.1 WV DPMS Treatment Alternatives

One of the steps of a pavement management system is determining which maintenance alternative to implement on a roadway. Meetings with engineers and District 5 personnel helped in determining which treatments should be considered in WV DPMS. It was pointed out that one of the problems of other PMS is that the recommended treatments were often different from what the agency practiced at the project-level. To avoid useless outputs, only treatments that are available to, and utilized by the State DOH, are recommended in WV DPMS. The available treatment alternatives have been categorized as Do Nothing, Routine Maintenance, Preventive Maintenance, Rehabilitation, Restoration, and Reconstruction. WV DPMS identifies the recommended treatment category, and uses an average unit price of each treatment for estimating section repair costs. A description of the WV DPMS treatment alternatives and the treatment selection process are presented in this section.

3.3.1.1 Treatment Description and Costs

The treatment alternatives that are included in each WV DPMS treatment category and the average cost for each alternative are presented in the following table, Table 3.1. The unit costs for each treatment alternative were derived from cost data from 1999 projects within District 5 and from past experiences. Notice that the costs vary depending on the designation of primary or secondary road. One reason for this discrepancy is that a heavier mix design is often considered on primary roads to account for the higher traffic volumes. A heavy mix design constitutes more strict compaction requirements. Another reason the unit costs are different is the traffic control requirements on primary roads. Primary roadwork necessitates more signs and flaggers because of side roads, advance warning signs, and such. Furthermore, primary roads often have traffic volumes that require using a non-skid pavement, as designated by State DOH specifications. The difference in cost between skid resistant material and normal pavement material in District 5 is $2.00 to $3.00 per ton (Amtower, 00). For these reasons, there are two distinct unit costs for overlay treatments on primary and secondary roads.

Additional costs are added in to the unit costs of some of the treatment alternatives. For instance, $0.20 per square yard is added to the unit costs for all of the overlay treatments to cover crack sealing procedures and preparatory work that is often necessary. Crack sealing costs approximately $0.50 per linear foot (New Hampshire T^2 Center, 92). Based on the assumptions made in WV DPMS for cracking in the highest extent level, the sealing costs are $0.15 per square yard. To be conservative and to cover any unforeseen preparatory work, the unit price of asphalt overlays is increased by $0.20 per square yard. The additional $0.20 per square yard is not added in to the reconstruction unit cost.

Treatment	***Application***	***Unit Costs*** **Primary Roads**	***Unit Costs*** **Secondary Roads**
Do Nothing	----	$0.00	$0.00
Routine Maint.	Crack Sealing/Patching	$0.20 / sq. yd	$0.20 / sq. yd
Preventive Maint.	110 lb./sy (1 in. wearing I)	$2.26 / sq. yd	$2.17 / sq. yd
Rehabilitation	165 lb./sy ($^1/_2$ in. scratch and 1 in. wearing I)	$3.29 / sq. yd	$3.15 / sq. yd
Restoration	330 lb./sy (1 ½ in. Base II, ½ in. scratch, and 1 in. wearing I)	$6.39 / sq. yd	$6.10 / sq. yd
Reconstruction	Remove and replace pavement surface (6 in. Base II and 2 in. asphalt overlay)	$18.00 / sq. yd	$16.00 / sq. yd

Table 3.1 Available WV DPMS Treatment Alternatives and Unit Costs

3.3.1.2 Treatment Selection

The WV DPMS treatment selection model employs the cause-based strategy. This strategy uses pavement condition data to recommend treatments. Specific distress characteristics are the most important information to help select appropriate treatments. The criteria established for selecting what treatments to apply and when to apply a treatment are based on judgement, experience, and existing DOH policies. Interviews with District 5 personnel and experts in the pavement field resulted in a basic set of rules that are expressed in a decision tree, presented in Table 3.2. The rules have been incorporated into the Access database program for analysis and selection of treatments.

A treatment is identified for the section depending on the extent and severity of a distress or the condition of the distress. For example, consider a road section with moderate extent, high severity Fatigue Cracking. The user could manually look at the decision tree matrix, Table 3.2, and determine that number 5, or Restoration, is recommended in this situation. Note that the treatments and the respective assigned numbers are at the bottom of Table 3.2. This selection process has been fully automated by programming the decision tree into the WV DPMS Access database. The user simply enters the condition data and the program generates the recommended treatments.

Fatigue Cracking

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2	2	4
	Mod.	1	3	3	4
	High	1	5	5	6

Patching

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2	3	4
	Mod.	1	4	4	5
	High	1	5	5	6

Edge Cracking

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2	2	2
	Mod.	1	2	4	4
	High	1	4	4	4

Drainage

Good	1
Fair	2
Poor	2

Ride Comfort

Good	1
Fair	1
Poor	4

Rutting

None	1
Good	1
Fair	4
Poor	5

Long/Trans Crack

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2	2	3
	Mod.	1	3	3	4
	High	1	4	4	4

Shoulders

None	2
Good	1
Fair	2
Poor	2

Treatment	# Assigned
Do Nothing	1
Routine Maintenance	2
Preventive Maintenance	3
Rehabilitation	4
Restoration	5
Reconstruction	6

Table 3.2 Treatment Selection Rules

Most pavement sections exhibit more than one distress type. In this case, the dominant treatment strategy, or highest assigned number, is identified as the treatment selection for the section. The dominant strategy will repair the distress that triggers it and will also repair other distresses in the section.

For example, if a section exhibits high extent, moderate severity Edge Cracking it would result in a number 4 on the decision tree matrix and the recommended treatment would be Rehabilitation, denoted by the number 4 at the bottom of Table 3.2. If the same section has low extent, low severity Patching it would yield a number 2 on the decision tree matrix and the recommended treatment would be Routine Maintenance, represented by the number 2 in Table 3.2. The dominant strategy for the section would be the higher assigned number, 4, and the corresponding treatment, Rehabilitation. This treatment would correct the edge cracking and patching distresses concurrently. This identification of the treatment suffices at the network-level but may need to be further analyzed at the project-level. Routine maintenance procedures may need to be applied to the section before overlaying with HMA.

The purpose of the treatment selection in the network-level analysis is to determine the funds necessary to apply the treatment needed. The treatment should be considered a "network-level budget planning treatment" rather than an actual maintenance or rehabilitation treatment. It is primarily used to assign a fund need level to each section of pavement and should generally be considered a cost category rather than an actual treatment. Further analysis must be performed on the section and adjoining sections before the final selection of a treatment is made. For example, in a six-section segment of roadway, three consecutive road sections need Restoration, the fourth section evokes

Rehabilitation, and the remaining two sections call for Restoration. The recommendation for the fourth section would be neglected and the six-section segment would receive Restoration treatments to achieve continuity in the programming of projects. Engineering judgement and past experience should be utilized in the final selection of treatments.

District 5 personnel and others reviewed the results of the software generated treatment alternatives for accuracy and consistency. This procedure should be practiced frequently to make sure that the recommended treatments are being correctly identified and selected. If the reviewers do not agree with the recommended treatments, the decision tree in the Access program should be altered to correspond with their ideal treatment selections.

3.3.2 WV DPMS Priority Analysis

Once a treatment is recommended for each section, the prospective projects must be ranked. This procedure is necessary because available funds may not be sufficient to perform every recommended repair. The available funds should be allocated among the managed sections in an objective, rational, and justifiable manner.

To accomplish this ranking, interviews were held with experts in the pavement management field and with District 5 personnel. It was concluded that the process would include prioritizing within the selected treatment categories. This means that a treatment is recommended for each pavement section and then each section that requires a specific treatment is grouped into a list, or treatment category. The projects are then chosen from the top of the list down until all available funds are accounted for.

Three factors are included in the procedures to select pavement sections for funding: traffic, classification, and distress values. Weighting values are assigned to the various factors to ensure that those deemed more important would be the contributing factor in the priority analysis. Each factor is discussed in detail in the following sections.

Each factor is multiplied by their respective weighting factors and then added to the other priority factors to determine the priority rating for each section. The equation used for the WV DPMS Priority Analysis is as follows:

$$PR = w_{tf}*TF + w_{cf}*CF + w_{df}*DF$$

Where: PR is the Priority Rating

TF is the Traffic Factor

CF is the Classification Factor

DF is the Distress Factor

w_{if} is the respective weighting factors

3.3.2.1 Traffic

District 5 personnel heavily emphasized the traffic factor. They felt that pavements experiencing high traffic volumes should have a higher priority than lower volume roads. This is supported by the fact that the ADT (Average Daily Traffic) is a measure of the demand for use of the road. The traffic count can be considered as an indicator of what the popular vote results may be if motorists were asked to choose priorities for pavement repair (FHWA, 85). Subsequently, an engineer from District 5 recommended assigning traffic the highest weighting factor, a factor of 5.

The technique used to consider traffic exposure on the pavements involves assigning a traffic factor based on ranges of ADT. The ADT values have already been determined by District 5 personnel and are included in the database for each pavement section. The ADT ranges and corresponding traffic factors are presented in Table 3.3. The traffic factors are arbitrary values that can be reassigned by each district to meet their needs. The traffic factor is multiplied by the traffic weighting factor and then added to the other priority factors to determine the priority rating for each section.

ADT	***Range***	***Traffic Factor***
0 – 999	Very Low	1.0
1,000 – 2,999	Low	1.1
3,000 – 4,999	Medium	1.2
Greater than 5,000	High	1.3

Table 3.3 Priority Analysis - Traffic Factors

3.3.2.2 Classification

The second factor that is accounted for in the priority analysis is the classification of the roadway. The classification categories considered in District 5 are US routes, WV routes, CO (County) routes, and HA (Orphan Road) routes. The designated classification often indicates the use and importance of a roadway to the overall transportation needs.

A higher value is assigned to both US and WV routes, the primary roads in the district, because of their purpose, use, and presumed importance. They receive similar funding levels of federal aid and are considered to be similarly important. The secondary roads are classified as CO or HA route. The orphan roads (HA) that are added to the system are considered as important as the county routes (CO) and receive similar funding levels and treatments as the county routes (Amtower, 00). These two designations will also receive similar values in the priority analysis. The classifications and their respective values are presented in Table 3.4. Once again, the classification factors are discretionary values that were assigned for the initial analyses and can be reassigned by each district. District 5 personnel felt that the classification of the road was the second most important priority factor and recommended assigning a weighting factor of 3. The classification factor is multiplied by the classification weighting factor and then added to the other priority factors to determine the priority rating for each section.

Classification	***Classification Factor***
US	1.2
WV	1.2
CO	1.0
HA	1.0

Table 3.4 Priority Analysis - Classification Factors

3.3.2.3 Distress

The other factor that is considered in the priority analysis is the distress encountered on the pavement section. More specifically, the distress(es) that triggers a specific treatment is used in this priority analysis. Depending on which distress(es) triggers the recommended treatment, a value is designated to the section. The priority values are assigned based on the severity of the distress and the safety hazards it may pose. For example, Ride Comfort and Rutting are assigned the highest priority values. This is because a possible hazardous situation is created when these two distresses are extreme enough to trigger a distress. Extreme rutting can cause ponding of water and potential hydroplaning of vehicles. The distress categories and their respective values are presented in Table 3.5. The District 5 representative felt that the distress was the lowest priority for them and they recommended assigning the distress the lowest weighting factor, 1. The distress that triggers the selected treatment for the section is referred to as the triggering distress. The triggering distress factor is multiplied by the distress index weighting factor and then added to the other priority factors to determine the priority rating for each section. Utilizing this method of prioritizing with the triggering distress values ensures that the sections in the worst condition are repaired first within each repair category.

Triggering Distress	***Distress Factor***
Ride Comfort	1.3
Rutting	1.3
Fatigue Cracking	1.2
Patching	1.2
Edge Cracking	1.1
Longitudinal/Transverse Cracking	1.1

Table 3.5 Priority Analysis – Triggering Distress Factors

3.3.2.4 Example Priority Analysis

To illustrate how this priority analysis works, an example problem is given. Three distinct sections have been recommended to receive Restoration treatments. There are only enough funds available to carry out two of the Restoration projects. A priority analysis must be performed to see which of the projects can be funded. The critical information about each section is given in Table 3.6.

Section	***ADT***	***Traffic Factor***	***Classification***	***Classification Factor***	***Triggering Distress***	***Distress Factor***
A	1,200	1.1	WV	1.2	Rutting	1.3
B	7,850	1.3	US	1.2	Fatigue Cracking	1.2
C	625	1.0	CO	1.0	Long/Trans	1.1

Table 3.6 Priority Analysis – Example Problem

The priority rating equation is as follows: $PR = 5*TF + 3*CF + 1*DF$

Where: PR is the Priority Rating

TF is the Traffic Factor

CF is the Classification Factor

DF is the Distress Factor

5,3,1 are the respective weighting factors

Therefore: $PR_A = (5)*(1.1) + (3)*(1.2) + (1)*(1.3) = 10.4$

$PR_B = (5)*(1.3) + (3)*(1.2) + (1)*(1.2) = 11.3$

$PR_C = (5)*(1.0) + (3)*(1.0) + (1)*(1.1) = 9.1$

Comparing the three sample sections, the highest priority would be section B with a priority rating of 11.3. The second highest priority would be section A and the lowest priority would be section C. Based on this priority analysis, the available funds to perform the Restoration treatments would go to sections B and A. It must be noted that the recommendations from the ranking at the network-level should be considered as a planning list and the first step in the project programming process. Project-level analysis is required to identify the final treatment selection for a section.

3.3.2.5 Additional Notes on Priority Analysis

This priority analysis ranks sections within the selected treatment categories. It should be pointed out that priorities among treatment strategies are a policy decision made by the DOH. The decision to perform certain treatment categories before other ones is beyond the scope of this system. However, serious consideration should be given to implementing a pavement preservation program that makes use of preventive maintenance strategies.

This prioritization process provides a ranked order list of pavement sections within each treatment category based on criteria established by the managing agency. This is a structured method to select sections deemed most important to the responsible agency. This process should reduce arbitrary decisions about sections to be funded, reduce the effect of outside influences, and give the staff something to support decisions to the public.

3.3.3 WV DPMS Section Repair Costs

At this point in the analysis process, sections needing repair have been identified, treatments have been recommended for those sections, and the sections have been prioritized. The next step is to determine how much it will cost to repair each section and to determine a tentative work program. This section explains how this process is performed in the software program.

The budget calculation is computed by simply multiplying the area of each section (length and width) times the unit cost for the respective recommended treatment. The unit costs are presented in Table 3.7. The unit costs have been derived from 1999 cost data and from the experiences and expertise of District 5 personnel. The difference in cost between primary and secondary roads is explained in the *Treatment Alternatives* section. In addition, the supplemental costs should be added into each project. These costs include signing, lane striping, and/or any unforeseen costs. The supplemental costs were determined from the experiences of District 5 personnel and based on historical data of past projects. The supplemental costs are not included in the budget analysis equations. However, after project-level analysis has been completed and a project program has been defined, the supplemental costs should be added to each proposed project.

Treatment	**Unit Cost – Primary Roads**	**Unit Cost – Secondary Roads**
Do Nothing	$0.00	$0.00
Routine Maintenance	$0.20 / sq. yd	$0.20 / sq. yd
Preventive Maintenance	$2.26 / sq. yd	$2.17 / sq. yd
Rehabilitation	$3.29 / sq. yd	$3.15 / sq. yd
Restoration	$6.39 / sq. yd	$6.10 / sq. yd
Reconstruction	$18.00 / sq. yd	$16.00 / sq. yd
Supplemental Costs	*$10,000 / project*	*$7,000 / project*

Table 3.7 Costs Used in Calculating Section Repair Costs

3.3.3.1 Example Repair Costs Calculations

To illustrate how this budget analysis works, an example problem is presented. All three of the sections in this example are classified as primary roads and a Restoration treatment has been recommended. The critical information about each section is given in Table 3.8.

Section	***Section Length***	***Section Width***	***Recommended Treatment***	***Unit Cost of Treatment***	***Cost to Repair each Section***
D	3.5 mi.	22 ft.	Restoration	$6.39 / sq. yd	$289,000
E	2.72 mi.	24 ft.	Restoration	$6.39 / sq. yd	$245,000
F	1.96 mi.	20 ft.	Restoration	$6.39 / sq. yd	$147,000

Table 3.8 Section Repair Costs – Example Problem Information

Initially, the section's length and width were converted into yards. Those two values were multiplied together to produce the section's area in square yards. The area of the section is then multiplied times the unit cost of the recommended treatment to estimate the repair cost of each section. To illustrate, calculations for Section D are presented below.

Repair Costs $_D$ = 3.5 mi. * (1760 yd/mi.) * 22 ft * (1yd / 3ft) * \$6.39 / sq. yd = \$288,657

If Section D is the only section included in this particular project, an additional \$10,000 is added to the cost of the project to cover signing, striping, and other supplementary costs on this primary road project. Therefore, the total cost of the project to repair Section D is \$299,000.

3.3.3.2 Section Repair Costs Summary

The calculation of the section repair costs is fully automated within the WV DPMS Access program. The user must enter the condition data for the road sections and run the analyses to generate the section repair costs. The unit costs that are used for the calculations must be checked for accuracy when WV DPMS is initialized or annually updated before the calculations are made.

The calculated total repair costs for all sections in each treatment category should be compared with the available funds. The funds should be applied towards the recommended projects based on the priority analysis until the available funds are spent.

The unit costs for the recommended treatments should be reviewed and edited as often as necessary. Examining the actual cost data of previous year’s projects and utilizing those values creates accurate unit costs and more accurate network-level budget analyses.

3.3.4 WV DPMS Performance Model

A pavement performance model is provided with WV DPMS to estimate the type and timing of pavement treatments as part of a multi-year improvement program. The predicted treatment needs are based on the current needs analysis, the anticipated funding level for each treatment category, and the estimated result of performing or not performing a recommended treatment.

The model developed for WV DPMS is a probabilistic model that predicts a distribution of values for a dependent variable. The model is based on Markovian theory, which is founded on the assumption that the probability something will change from one condition state to another is only dependent on its current state. In this particular application, this assumption means that a pavement section’s current condition is only dependent on its preceding prior condition and that the next year condition of a pavement section is dependent only on its current year condition. For each given condition state, estimates are developed to predict what percentage of the pavement sections in that state will stay in the same condition or move to another condition state (Broten, 97).

The Markov-based model recognizes and accommodates uncertainty. It is often used in situations where there is no historical database available. The experience of an agency can be incorporated into the model and the model can be calibrated in the future as more reliable field data becomes available (National Highway Institute, 98).

The WV DPMS should be continually improved as the historic database of performance data grows over time. However, during the early stages of using WV DPMS, expert opinion supplements the existing data to obtain a reliable performance model.

The WV DPMS performance model is shown in Table 3.9. The values in the table should be reviewed and edited to reflect the experiences and funding scenarios of each district. The first column, *Treatment*, contains the six treatment strategies that are utilized within WV DPMS. The second column, *Percent Funded*, exhibits the percentage of needs in each treatment category that is annually funded. This value may change over time and should be corrected, as more reliable data becomes available. The third and fourth column, both titled *If Funded*, represents the breakdown of what happens to the pavement area in each treatment category if they are funded for repair. Column three presents the percentage of the area that is transitioned and column four presents the treatment category that the pavement area is in after the transition. The numbers in the fourth column correspond to the number assigned to each treatment category in the first column. The final two columns, titled *Not Funded*, represent what happens to the pavement area if it is not funded for repair. Column five presents the percentage of the area that is transitioned and column six presents the category that the pavements are in following the transition. The numbers in the sixth column coincide to the first column's number designation.

To illustrate how the WV DPMS performance model works, the following examples are given. First, consider pavements in the Routine Maintenance category. In this example, Table 3.9, 100% of the needs in this treatment category are funded. Eighty percent of the funded pavement area in the Routine Maintenance category remains in the Routine Maintenance category; and twenty percent of the funded pavement area transitions into the next treatment category, 3, Preventive Maintenance. Since the Routine Maintenance treatments are crack sealing and patching, the pavement area is not significantly improved and does not transition to the Do Nothing category. Since 100% of the Routine Maintenance needs are funded in this example, the transition of the unfunded area is not presented and explained.

Next, consider the pavement area in the Restoration treatment category. In this example, 60% of the needs are funded. If the area is funded, 100% of that area is transitioned to the Do Nothing category for the next year. Of the remaining 40% of needs that are not funded, 80% remain in the Restoration treatment category for the next year and 20% transition down to the Reconstruction category.

Table 3.9 is programmed in the Excel template for budget analysis. The user can modify this table to reflect local conditions.

Treatment	**Percent Funded**	***If Funded*** **Percentage**	***If Funded*** **Becomes**	***Not Funded*** **Percentage**	***Not Funded*** **Becomes**
1. Do Nothing	100%	80%	1	------	------
	------	20%	2	------	------
2. Routine Maint.	100%	80%	2	0%	2
	------	20%	3	0%	3
3. Preventive Maint.	100%	80%	1	0%	3
	------	20%	2	0%	4
4. Rehabilitation	50%	100%	1	80%	4
	------	------	------	20%	5
5. Restoration	60%	100%	1	80%	5
	------	------	------	20%	6
6. Reconstruction	75%	100%	1	100%	6

Table 3.9 WV DPMS Performance Model Criteria

3.3.4.1 Using the WV DPMS Performance Model

The WV DPMS Access database program recommends treatments based on the current year's condition data and summarizes the area of each treatment category. The current needs in each treatment category are then entered into the WV DPMS Excel program. Depending on the current needs, the percentage of needs in each treatment category that is funded, and the performance model parameters, a proposed budget and maintenance program plan are generated for the next ten years. In following years, the users will only change the analysis year, the area of needs from the current needs analysis, and the performance model factors.

3.3.5 WV DPMS Budget Analysis

The needs are manually transferred from Access to Excel for each treatment. The Excel template computes a ten-year budget with user specified:

- Unit prices for treatments,
- total annual budget,
- and target distributions.

The template computes the annual needs and budget allocation. The user can vary the initial assumptions to perform a "what if" analysis to search for an optimum budget.

The budget distribution is then used in conjunction with the priority analysis to select the pavement sections for treatment. The list of recommended treatments from the WV DPMS Access template is sorted by county and then by treatment category. That sub-list is then ranked from highest to lowest priority by the priority rating that is calculated for each section. The sections are selected for repair in sequential order from the top of the list until all available, allocated funds are accounted for.

CHAPTER 4 – USING WV DPMS TO EVALUATE BUDGETS FOR DISTRICT 5

The WV DPMS software programs have been created to analyze the current practices of the district and to project its road conditions and budget if their procedures remain as they have been. The program has also been designed to recommend alternate funding scenarios and methods to maximize the efficiency and dollars of the district. This section presents and compares the current needs analysis from WV DPMS with the WV DOH District 5 expenditures and compares a ten-year maintenance budget plan with current and recommended practices being the variables.

4.1 WV DPMS AND WV DOH DISTRICT 5 COMPARISONS

The WV DPMS Access program was used to determine the current needs of the roads in District 5 based on the 1999 pavement condition data. This current needs analysis was performed using the WV DPMS condition survey criteria and decision trees. Table 4.1 exhibits the current needs analysis and presents the percentage breakdown of the area needing a specific treatment. Of the total 14, 397,076 square yards of roads contained in District 5, 64% of that area needs at least a rehabilitation treatment applied to it in the current year.

The total current cost needs were calculated by multiplying the area needing treatment by the average unit cost for each treatment. The resulting needed expenditures are presented in Table 4.2. The total amount necessary to fund every repair project would be $44,163,000. Of this needs budget, 98% of the total repair costs are allocated to Rehabilitation, Restoration, or Reconstruction. This figure goes along with the previous finding that the majority of the district's roads need at least Rehabilitation (Table 4.1).

Treatment	*Area needing treatment (square yards)*	*Percentage of total area in District 5*
Do Nothing	2,294,751	16 %
Routine Maint.	2,780,230	19 %
Preventive Maint.	178,974	1 %
Rehabilitation	5,368,339	37 %
Restoration	3,534,559	25 %
Reconstruction	240,223	2 %

Table 4.1 WV DPMS Current Needs Analysis - Area

Treatment	*WV DMPS Needs Expenditures*	*Percentage of total Needs for District 5*
Do Nothing	$0.00	-----
Routine Maint.	$556,000	1 %
Preventive Maint.	$403,000	1 %
Rehabilitation	$17,202,000	39 %
Restoration	$22,158,000	50 %
Reconstruction	$3,844,000	9 %

Table 4.2 WV DPMS Current Needs Analysis – Costs

Although it has been shown that the district needs approximately $ 44 million to repair all of its roads in the current year, it historically only funds $7,800,000. This value is only 18% of what is needed to fully repair every road in the district during the current year. This is a prime example of the importance of the priority rating analysis that is imbedded in the WV DPMS program. Table 4.3 presents the breakdown of District 5's expenditures for each treatment category and also shows what percentage of the dollars goes to each treatment. Less than 25% of the budgeted dollars goes to fund Preventive and Routine Maintenance.

Treatment	***WV DOH D-5 Expenditures***	***Percentage of total Expenditures for D-5***
Do Nothing	$0.00	-----
Routine Maint.	$1,000,000	13 %
Preventive Maint.	$800,000	10 %
Rehabilitation	$3,000,000	38 %
Restoration	$2,000,000	26 %
Reconstruction	$1,000,000	13 %

Table 4.3 District 5 Budget Distribution for each Treatment Category

Calculations were performed to determine what percentage of the total square yards of road in District 5 could be funded using the present budget distribution. The allotted dollar amount was divided by the unit cost for each treatment category to determine the square yards that could be funded in each category. The results are presented in Table 4.4. The Do Nothing square yards were determined by subtracting the total amount of funded square yards in the other treatment categories from the total square yards in the district. Notice that the district is funding 88% of the total area with funds that are allocated for Routine Maintenance or no repairs at all. The WV DPMS current needs analysis, Table 4.1, exhibited that only 35% of the district's road area warrant applying Routine Maintenance or no repair. Also notice in Table 4.4 that the district is only funding 9% of the total area with Rehabilitation, Restoration, and Reconstruction funds. The analysis of current needs, Table 4.1, revealed that 64% of the district's roads need at least a Rehabilitation treatment application. It is apparent from this comparison that the current practices of District 5 differ from the procedures and methods of WV DPMS.

Treatment	***WV DOH D-5 Expenditures***	***Square yards that can be funded by D-5***	***Percentage of total Area in district***
Do Nothing	$0.00	Remaining yards (7,726,216)	53.7 %
Routine Maint.	$1,000,000	5,000,000	34.7 %
Preventive Maint.	$800,000	360,360	2.5 %
Rehabilitation	$3,000,000	931,677	6.5 %
Restoration	$2,000,000	320,000	2.2 %
Reconstruction	$1,000,000	58,823	0.4 %

Table 4.4 D-5 Budget Allows Funding of Certain Amount of Road Area

Table 4.5 compares the current needs to the available funds and presents the percentage of each treatment category that can be funded. The table shows that Routine and Preventive Maintenance are actually over funded when compared to the WV DPMS current needs analysis. There also appears to be a large discrepancy in the amount of Rehabilitation, Restoration, and Reconstruction needs that can be funded and repaired. However, if the district considers the performance model, Table 3.9, and only funds the percentage of road area that will transition to the next treatment category if it is not funded, the discrepancy of funds versus needs is not as large. For instance, if 20% of the Rehabilitation treatment category needs (from Table 4.1) are funded, about 1 million square yards would be funded. This value is compared to the approximately 900,000 square yards that the district is funding in the Rehabilitation category. Similar comparisons can be made in the Restoration and Reconstruction categories, as well.

Treatment	*WV DOH D-5 Expenditures*	*WV DPMS Current Needs*	*Percentage Funded*
Do Nothing	$0.00	$0.00	100%
Routine Maint.	$1,000,000	$556,000	>100%
Preventive Maint.	$800,000	$403,000	>100%
Rehabilitation	$3,000,000	$17,202,000	17.5%
Restoration	$2,000,000	$22,158,000	9.0%
Reconstruction	$1,000,000	$3,844,000	26.0%

Table 4.5 Comparison of WV DPMS Current Needs to District 5 Expenditures

Obviously, the current procedures and methods of District 5 differ from those of WV DPMS. Without available, extensive historical data to analyze, the WV DPMS criteria and decision tree were manipulated to determine where the discrepancy in the methodologies lies. An attempt was made to ascertain the condition levels the district was considering when deciding what treatments to apply. The treatment selection process was altered in the WV DPMS Access program to get the WV DPMS needs budget distribution, Table 4.2, to be similar to the district's budget distribution, Table 4.3. It was confirmed that the district's current practice of treatment selection differed from what is proposed and explained in WV DPMS. Table 4.6 compares the treatment selection rules. The altered numbers, which correspond to treatment categories selected by the district, are given as the second number in the box. For example, the selected treatment for low extent, low severity fatigue cracking has been changed from Routine Maintenance, 2, to Do Nothing, 1. This is represented in Table 4.6 as 2 / 1. Notice that the treatment selection rules of the district and those recommended for WV DPMS are quite different. The district has a lower threshold for selecting treatments than is proposed in the new system. For instance, the district apparently selects to do no repair when the WV DPMS is recommending applying a Routine Maintenance treatment. Similarly, the district chooses to apply other more expensive treatments when the management program recommends the application of a less expensive treatment. The comparisons of proposed and current treatment selections are presented in Table 4.6.

Fatigue Cracking

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2 / 1	2	4
	Mod.	1	3 / 2	3 / 4	4
	High	1	5 / 4	5 / 4	6

Patching

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2 / 1	3 / 2	4
	Mod.	1	4 / 2	4	5
	High	1	5 / 4	5	6

Edge Cracking

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2 / 1	2	2
	Mod.	1	2	4	4
	High	1	4 / 2	4	4

Drainage

Good	1
Fair	2
Poor	2

Ride Comfort

Good	1
Fair	1
Poor	4

Rutting

None	1
Good	1
Fair	4 / 2
Poor	5 / 4

Long/Trans Crack

		Extent			
		None	Low	Mod.	High
Severity	Low	1	2 / 1	2	3
	Mod.	1	3 / 2	3 / 2	4
	High	1	4 / 2	4	4

Shoulders

None	2
Good	1
Fair	2
Poor	2

Treatment	# Assigned
Do Nothing	1
Routine Maintenance	2
Preventive Maintenance	3
Rehabilitation	4
Restoration	5
Reconstruction	6

Table 4.6 Comparison of Treatment Selection Rules

The goal of the WV DPMS developers is to use this system to preserve the pavements. Utilizing the WV DPMS criteria and treatment selection will improve pavement conditions to an acceptable level and decrease the chances of those roads degrading to worse conditions before a pavement preservation treatment can be applied.

4.2 USING WV DPMS TO OPTIMIZE BUDGETS

To determine if District 5 was maximizing their funds and efficiently managing their roads, the WV DPMS software programs were used. The current needs from the WV DPMS Access program were entered into the WV DPMS Excel template along with the current funding scenarios and budget levels. The current District 5 funding scenario is presented in Table 4.7 along with the performance model parameters that were used for analyses.

Treatment	**Percent Funded**	***If Funded*** **Percent**	***If Funded*** **Becomes**	***Not Funded*** **Percent**	***Not Funded*** **Becomes**
1. Do Nothing	100%	80%	1	------	------
	------	20%	2	------	------
2. Routine Maint.	100%	80%	2	0%	2
	------	20%	3	0%	3
3. Preventive Maint.	100%	80%	1	0%	3
	------	20%	2	0%	4
4. Rehabilitation	18%	100%	1	80%	4
	------	------	------	20%	5
5. Restoration	9%	100%	1	80%	5
	------	------	------	20%	6
6. Reconstruction	26%	100%	1	100%	6

Table 4.7 WV DPMS Performance Model Criteria – Current D-5 Practices

In addition, analyses were performed using the WV DPMS software programs to produce a potentially better budget and maintenance program for District 5. The current needs, performance model parameters, and unit costs remained the same for the comparison analyses, but the funding scenarios and budget were manipulated many times to identify a more efficient solution. One of the proposed funding scenarios and analyses criteria is presented in Table 4.8. The proposed budget was increased from $7.8 million, current District 5 expenditures, to $9 million, an increase of only $1.2 million per year. In this investigation, the goal was to eliminate the backlog for the Rehabilitation, Restoration, and Reconstruction needs within ten years. At the end of the ten years, all of the roads in the district would be receiving Routine and Preventive maintenance and remaining in good condition. The proposed budget allocations adjust each year to accommodate the projects that are or are not funded based on the performance model parameters. This example is not a final solution to District 5's problems; it is just one suggestion. District 5 personnel must examine this scenario and determine if this is the one they desire to use. The WV DPMS programs have been designed to easily customize and meet the needs of each particular district. The users can manipulate the numbers to match their experiences and accomplish their goals.

Treatment	Percent Funded	*If Funded* Percent	*If Funded* Becomes	*Not Funded* Percent	*Not Funded* Becomes
1. Do Nothing	100%	80%	1	------	------
	------	20%	2	------	------
2. Routine Maint.	100%	80%	2	0%	2
	------	20%	3	0%	3
3. Preventive Maint.	100%	80%	1	0%	3
	------	20%	2	0%	4
4. Rehabilitation	18%	100%	1	80%	4
	------	------	------	20%	5
5. Restoration	20%	100%	1	80%	5
	------	------	------	20%	6
6. Reconstruction	13%	100%	1	100%	6

Table 4.8 WV DPMS Performance Model Criteria – Proposed

The following figures present the comparison of the results of the WV DPMS Excel template analyses. The current District 5 practices are shown first, with the proposed practices immediately following. Figures 4.1 and 4.2 represent the budgets over the next ten years broken down by treatment category. Notice in the current scenario, Figure 4.1, that the budget is static; the treatment categories are allocated the same amounts each year. However, in the proposed scenario, Figure 4.2, the budget is dynamic; the allocation of the funds varies each year depending on the needs in the district. Figures 4.3 and 4.4 present the funding backlog by treatment category. This is a representation of the actual cost of funded treatments subtracted from the total costs to repair everything in the district. Notice the over funding of treatments in the current practice scenario, Figure

4.3. These dollars could be reallocated to other treatment categories to alleviate the backlog in other categories, as is the case in the proposed scenario. Figures 4.5 and 4.6 show the backlog of the area in each treatment category. Once again, this is a representation of the funded area subtracted from total area that needs repair every year. Just as in Figure 4.3, there is an over funding situation represented in the current practice scenario, Figure 4.5. Notice in the proposed scenario, Figure 4.6, the backlog of Rehabilitation, Restoration, and Reconstruction needs declines to zero by year 2010. Figures 4.7 and 4.8 exhibit the area of funded treatments over the next ten years for both the current practices and the proposed practices. In the proposed scenario, Figure 4.8, there is a shift in the budget distribution to fund the Routine and Preventive treatment categories in future years. Figures 4.9 and 4.10 present the area for funded contract treatments. This illustrates those projects that are contracted out which includes all of the treatment categories except Do Nothing and Routine Maintenance. These two figures better illustrate the shift to a Preventive Maintenance program because the non-contracted work is removed from the graph. The majority of the pavement sections are receiving Preventive Maintenance treatments by year 2007 in the proposed scenario, Figure 4.10. The roads are being maintained in good condition and more roads can be treated at this treatment level because of the decreased unit price of Preventive Maintenance. Figures 4.11 and 4.12 show the annual needs for District 5. This is a depiction of the needs for the following year after the current year’s work is funded and completed. Notice the decrease in Rehabilitation, Restoration, and Reconstruction needs and the increase in Routine and Preventive Maintenance needs in the proposed scenario, Figure 4.12. This is an ideal scenario because the valuable assets, the pavement sections, are being preserved at reasonable costs. Figure 4.13 illustrates the difference in the static and dynamic budgets and presents the funded contract work each year in each treatment category. Notice in the proposed dynamic budget scenario the decline in funded area for Rehabilitation, Restoration, and Reconstruction and the increase in Preventive treatments. The Rehabilitation, Restoration, and Reconstruction needs are being funded and are shifting to a Preventive Maintenance program.

This analyses demonstrates that with a budget increase of $1.2 million per year, the back log of Rehabilitation, Restoration, and Reconstruction treatments in District 5 can be completely eliminated in year 2010. The consequence of this funding and budget allocation is that in year 2011, the only capital funding need is for preventive maintenance. Approximately 1.3 million square yards would need funding at a cost of $2.20 per square yard, or about $2.86 million. Not only could the budget be reduced, but the pavements would be in excellent condition. The distress levels would not warrant rehabilitation of any pavement sections.

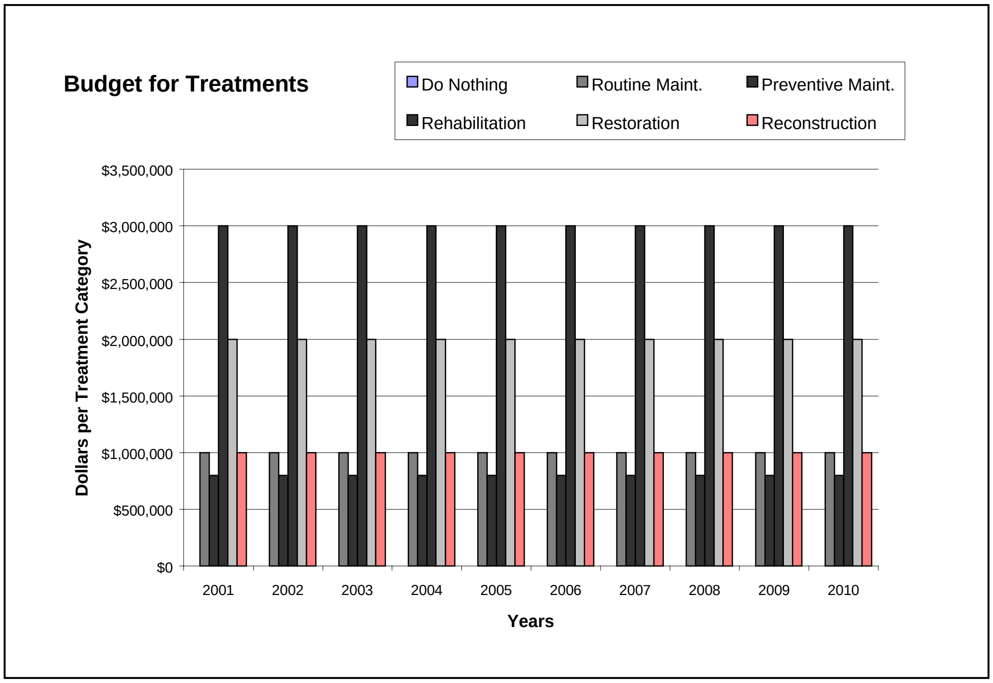


Figure 4.1 Budget for Treatments – Current D-5 practices

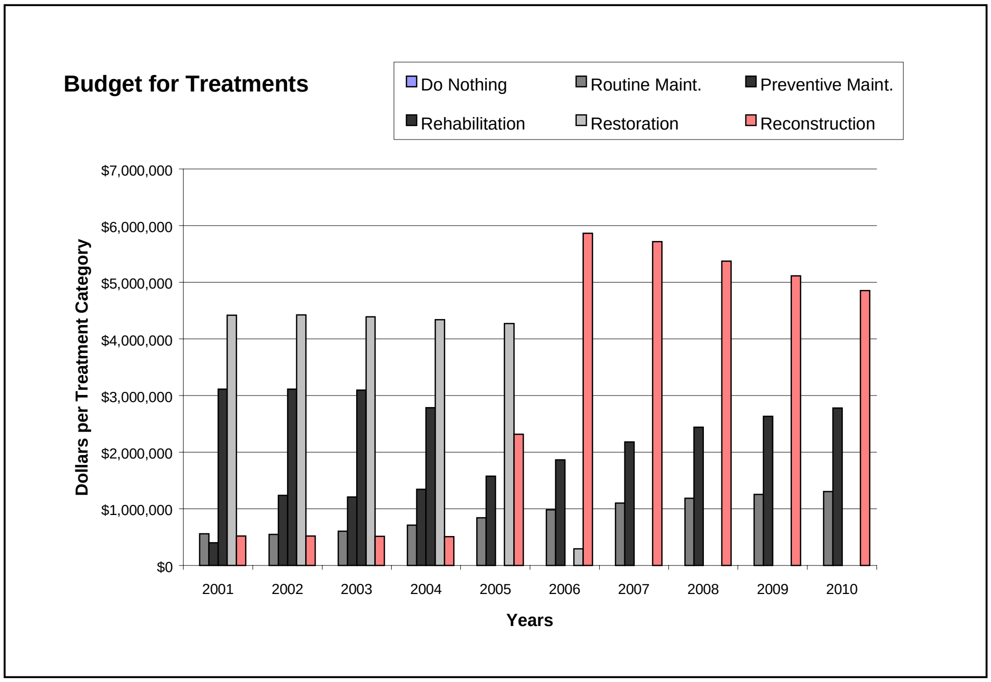


Figure 4.2 Budget for Treatments – Proposed

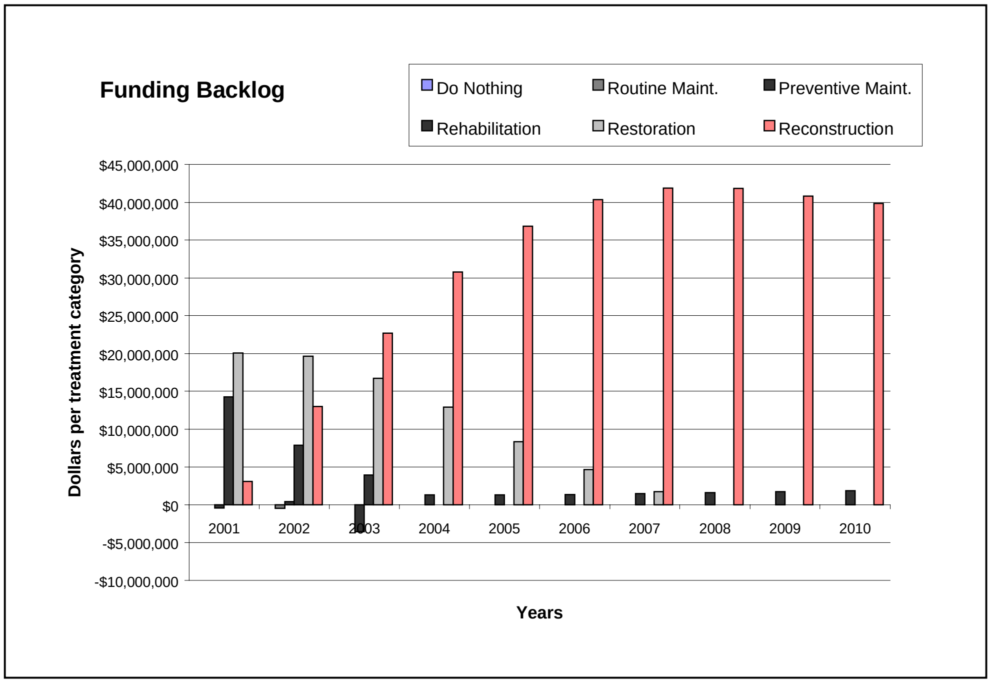


Figure 4.3 Funding Backlog – Current D-5 practices

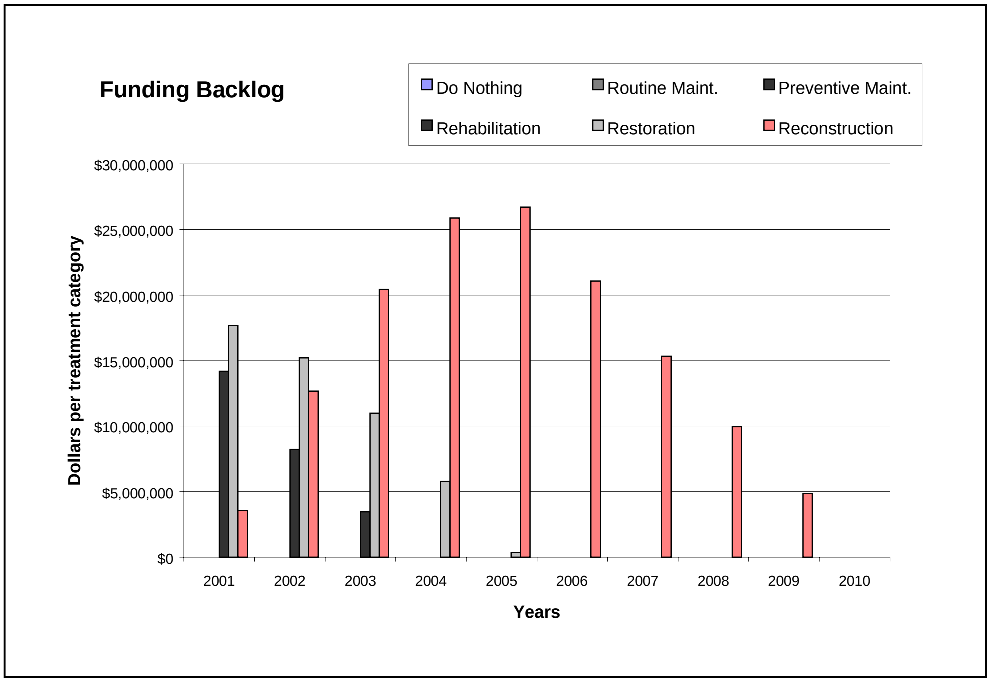


Figure 4.4 Funding Backlog – Proposed

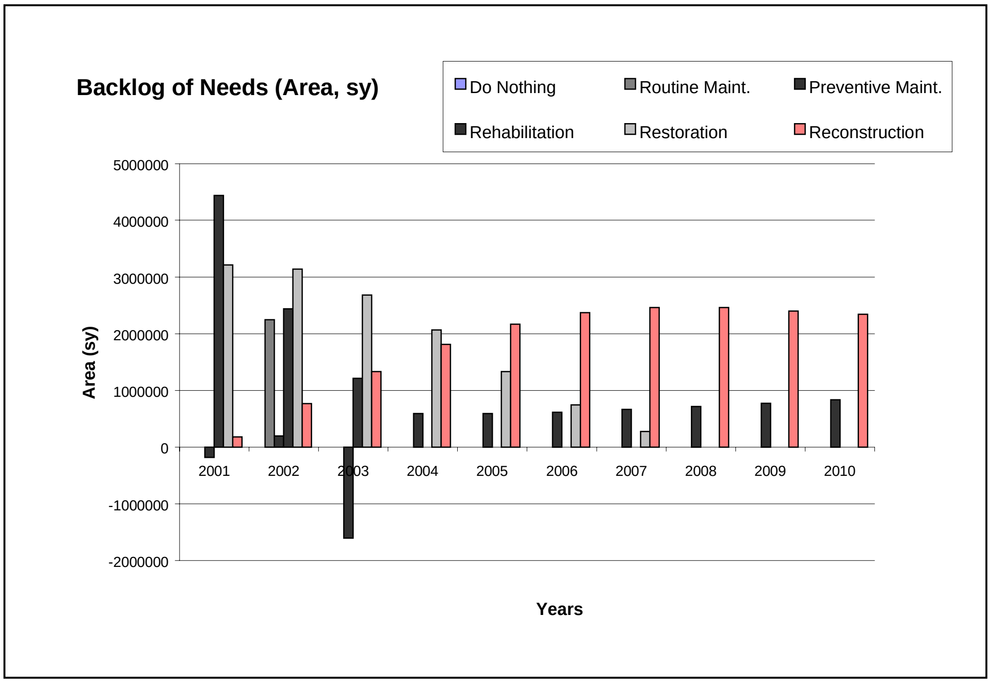


Figure 4.5 Backlog of Needs (Area) – Current D-5 practices

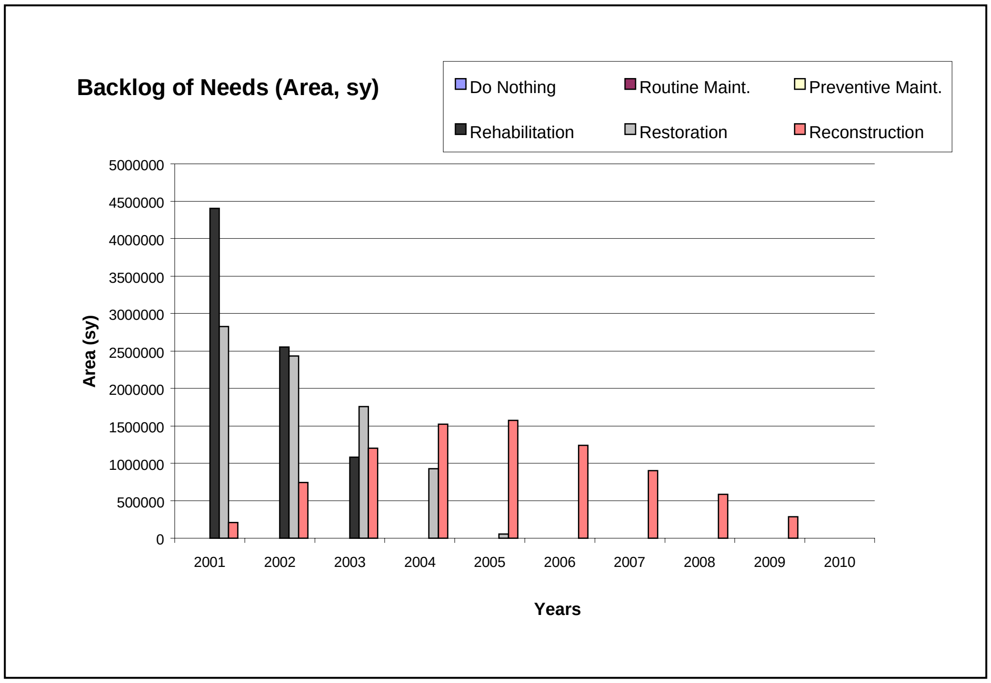


Figure 4.6 Backlog of Needs (Area) – Proposed

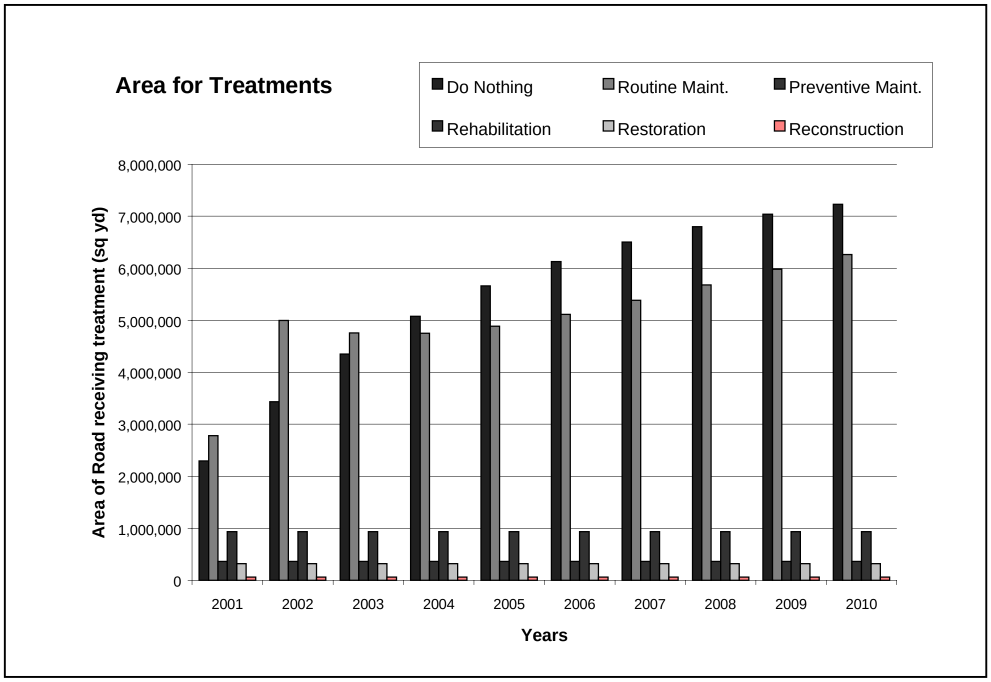


Figure 4.7 Area for Treatments -- Current D-5 practices

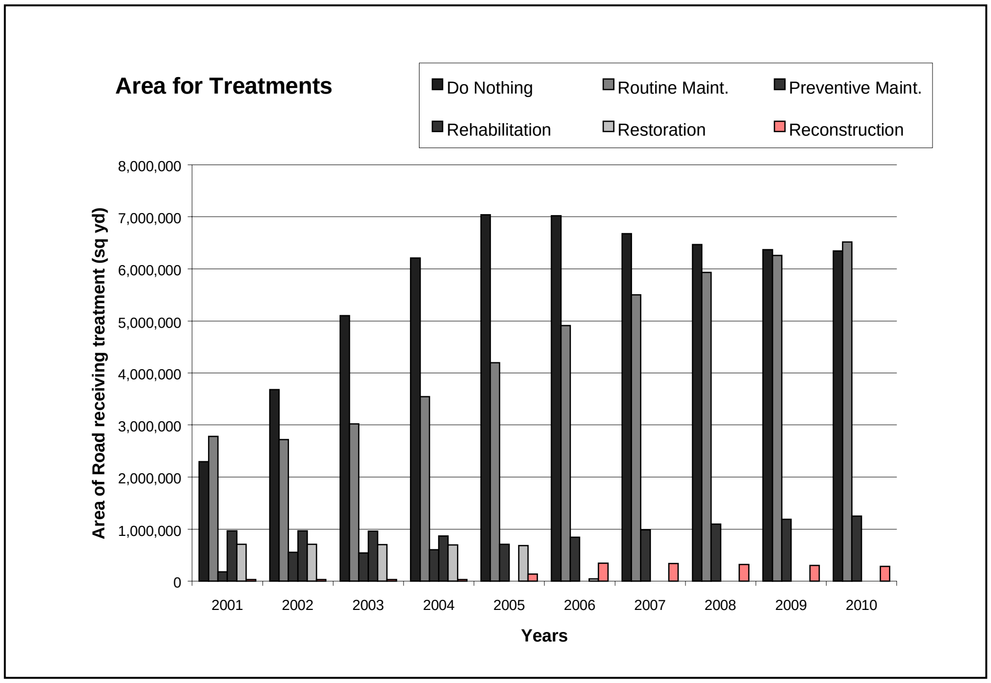


Figure 4.8 Area for Treatments -- Proposed

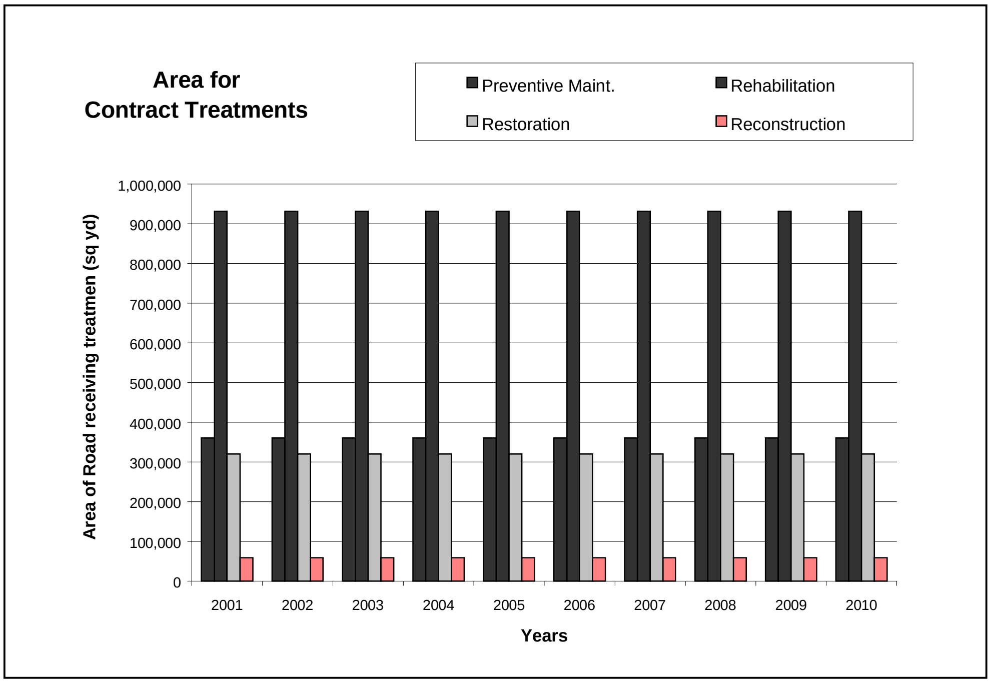


Figure 4.9 Area for Contract Treatments -- Current D-5 practices

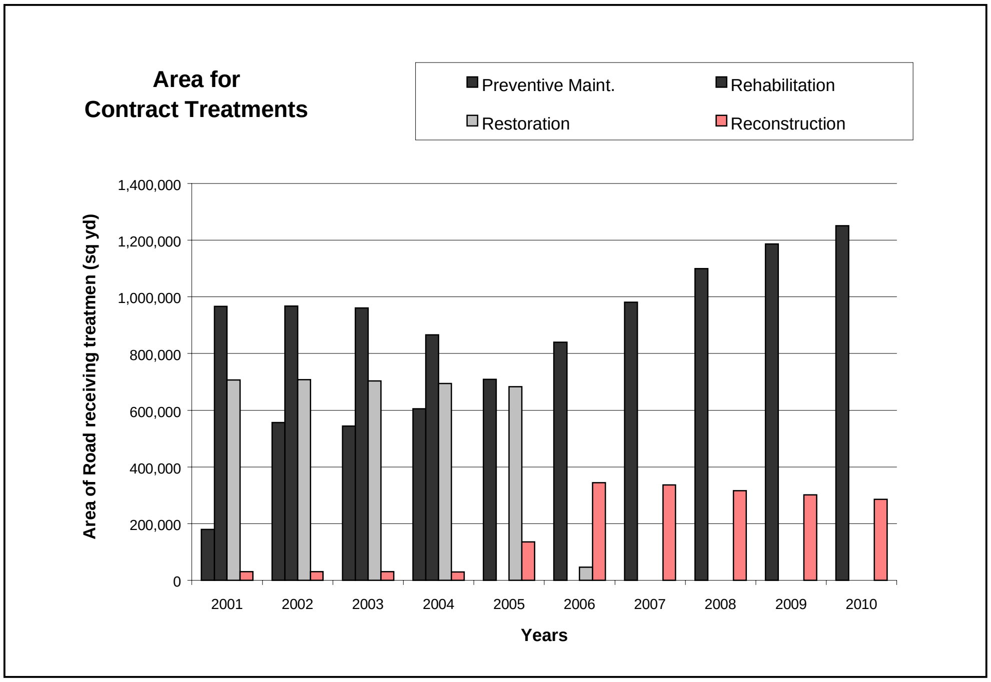


Figure 4.10 Area for Contract Treatments -- Proposed

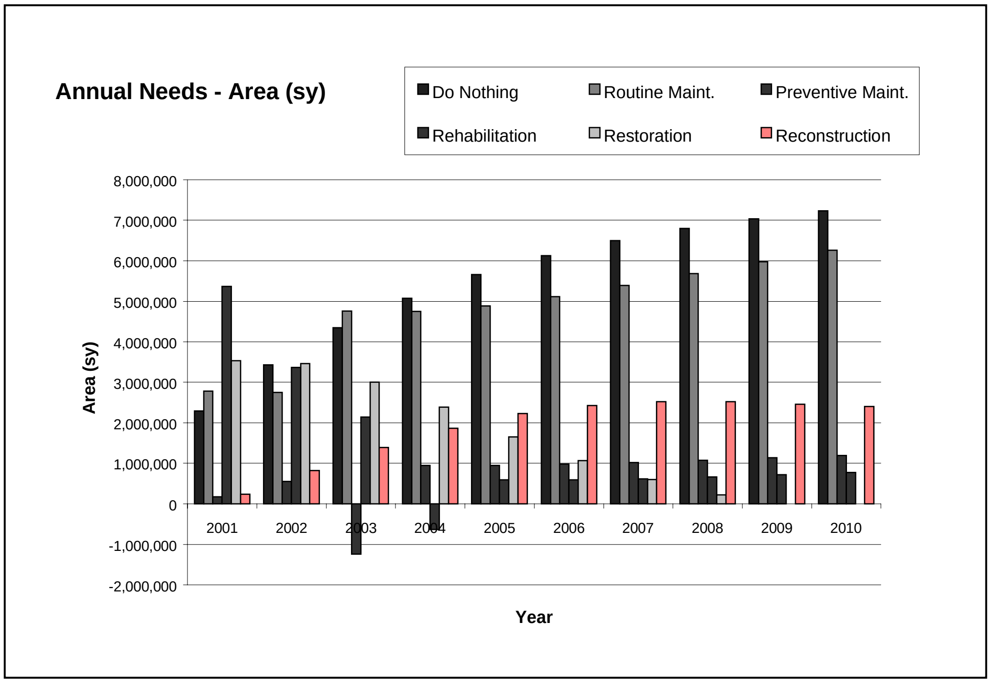


Figure 4.11 Annual Needs (Area) -- Current D-5 practices

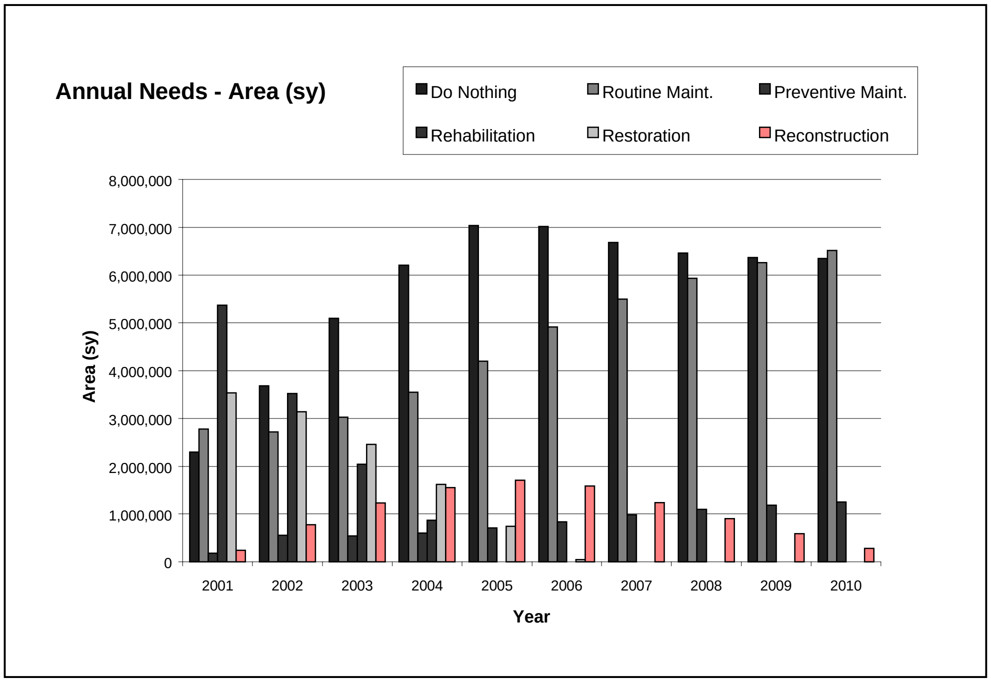


Figure 4.12 Annual Needs (Area) -- Proposed

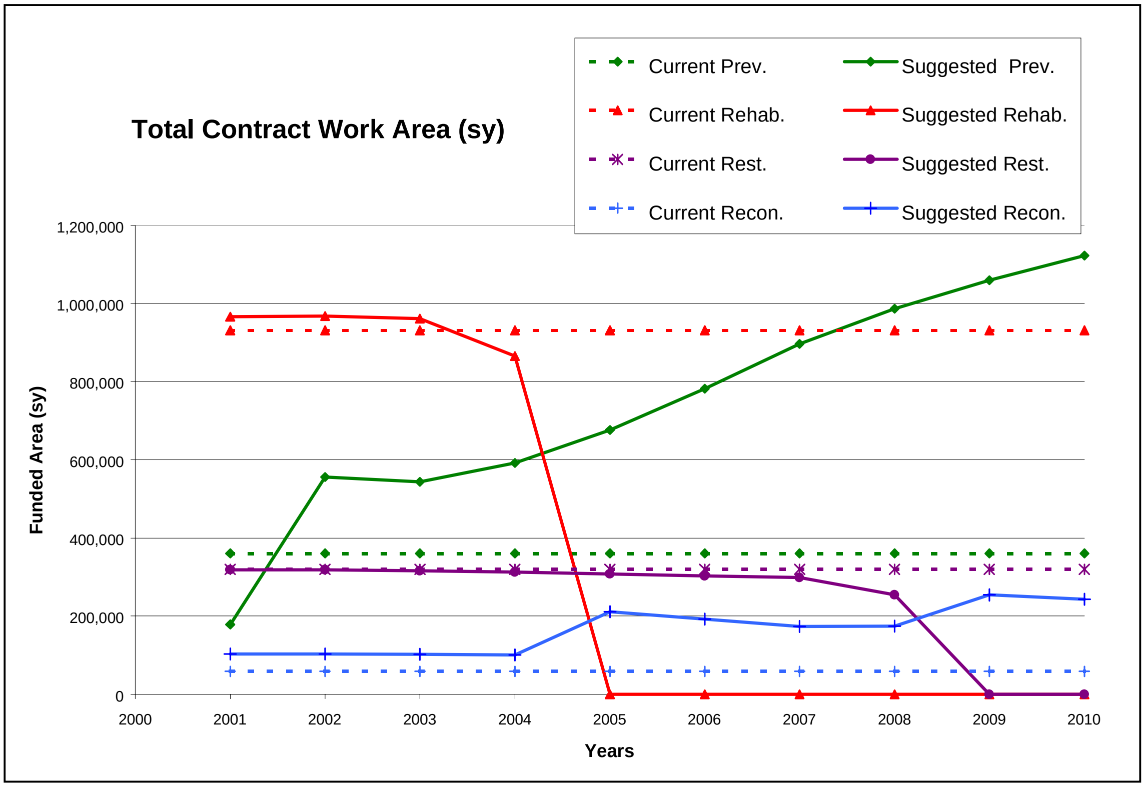


Figure 4.13 Changes to Contract Work

CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS

The nation’s economy depends heavily on its infrastructure, specifically its roads. New roads are being added and existing roads are aging and deteriorating. As those pavements degrade, repair costs are increasing exponentially. Responsible agencies with insufficient funds are being asked to manage and maintain these roads at a high level that is acceptable to motorists. One solution to this problem is pavement management. PMS are a rational, systematic approach to making decisions and managing budgets, maintenance programs, and so forth, to maximize the taxpayer’s dollars. WV DPMS was created to help WV DOH district personnel make better decisions, spend their money cost-effectively, and preserve the condition of their roads.

5.1 SUMMARY AND CONCLUSIONS

A detailed literature search was conducted and presented in Chapter 2. The review focused on the PMS experiences and recommendations of other agencies, among other things. Those recommendations were considered in the development of WV DPMS.

Chapter 3 presented the overall design and methodologies of WV DPMS. The data collection procedures, analytical methods, and details of the new management system are provided.

The steps of implementation and the details of the District 5 case study were presented in Chapter 4. The proposed budget and funding scenarios are only for illustration purposes. District personnel must review their spending practices, determine if they can increase their overall budget, and identify and enter the correct performance model parameters and unit costs to accurately generate a ten year budget and maintenance program plan. Care must be taken to determine the most accurate information available and to use this data for calculations and projections.

If there is no effect on how the district manages their roads and available funds, the PMS is not working. However, WV DPMS has been developed to address the concerns of WV DOH personnel and the disadvantages of other PMS. WV DPMS must be accepted by district personnel, implemented, and correctly used following the procedures presented herein to be of value to the district. If the district fully implements WV DPMS they could spend their funds cost-effectively and preserve their roads at a reasonable cost, rather than deferring maintenance and having to reconstruct or replace their roads. They will have a rational, systematic approach to selecting "*the right treatment, for the right road, at the right time*", and may be able to present their results and receive additional funding in future years.

The intent of the researchers was to provide a PMS that can be adopted by all WV DOH districts. It is believed that once the other districts in West Virginia see the benefits of WV DPMS and understand how to implement it for themselves, they will follow District 5's lead in utilizing WV DPMS and adapt the system to meet their needs.

5.2 RECOMMENDATIONS

5.2.1 Inventory and Data Collection Crews

The most cost-effective method of collecting inventory data would involve using present DOH employees during their down time. The workers in the maintenance or construction division may experience a decrease in the amount of work to be performed during the winter months when the construction season is at a very slow pace. The personnel could be trained and perform the work at this convenient time. This method was utilized by District 5 in collecting the inventory data used in WV DPMS.

Another option for potential data collectors is using summer interns. This would primarily be engineering students who are hired as part-time staff for the summer months. Proper and consistent training must be provided to the interns every year to maintain continuity and quality.

The West Virginia Transportation Technology Transfer Center (T^2 Center) could provide the initial training of the system and provide technical assistance, as it is needed. Training must be uniform and be provided on a consistent basis. Making sure that everyone involved with the management system is following the same rules and procedures is crucial to the effectiveness of the system.

5.2.2 Tools for Measuring Severity of Distresses

It is mentioned in *Appendix C, Method of Collecting Pavement Condition Surveys,* that the condition data collection teams should be provided with a tool to measure the extent and severity of the distresses. The crew will use the tools to determine the extent and severity of the pavement distress by gauging crack lengths, measuring the distance between cracks, measuring rut depths, and/or measuring slopes. Some of the tools that are recommended are steel rulers, measuring wheels, templates, and a digital electronic level. The steel rulers would be used to measure the width of cracks, distance of edge cracks from the pavement edge, rut depths, and edge drop-offs. The measuring wheels should be used to measure the distance between transverse cracks. The templates or digital electronic levels can be used to spot-check the slope of the shoulder. The template can be made out of wood or some other material and should be made to meet the standards set forth by the *WV DOH 2000 Typical Sections and Related Details*. However, to achieve more accuracy, survey crews may want to consider using the digital electronic levels. The Macklanburg-Duncan company manufactures a digital electronic level called SmartLevel. The WV DOH already uses this tool in construction inspection, therefore the survey crews should already be experienced in the tool's operations and uses. This digital electronic level can read and display measurements in the angle, slope, and pitch modes. The SmartLevel should also be used in conjunction with the steel ruler to measure the depth of ruts in the sections. The SmartLevel's sensor module is attached to a 4-foot rail. This tool can be laid across the wheel path, perpendicular to the traveled way, and the steel ruler can be used to measure the depth of the rut. Of course, all of these tools should be used in conjunction with the *Condition Survey Worksheet* and the *Flexible Pavement Condition Survey*.

5.2.3 Consideration of Additional Treatments

Presently, the WV DOH applies an overlay of hot mix asphalt to the majority of the roads requiring repair. Consequently, most of the treatments included in the treatment selection decision tree of WV DPMS are overlays of hot mix asphalt. Many treatment strategies were described in the *Literature Review* of this report. Of those that were explained, only about half are presently used by the WV DOH and are implemented into the treatment selection process. The treatments that are not utilized are in the preventive maintenance category. It is apparent form the analyses presented in Chapter 4 that the district's decisions on when to apply preventive maintenance treatments differ from those recommended in WV DPMS. Preventive maintenance, under the district's current methodologies, is overfunded. Pavements currently selected for Preventive Maintenance have too much distress to fully benefit from the thin treatments. The WV DPMS decision tree and treatment selection processes are guidelines the districts may use to select treatments that will preserve the roads in the network. The users of this system should consider using other available preventive maintenance treatment strategies such as Fog Seals, Chip Seals, Slurry Seals, and Microsurfacing. The processes and benefits of these treatment strategies are explained in the *Literature Review*, Chapter 2.

There are a number of factors to consider before implementing a preventive maintenance program. The type, time, and quality of the maintenance procedure that is used affect the pavement performance. A well-developed preventive maintenance program extends pavement service life by slowing the rate of deterioration. It is imperative to recall that preventive maintenance treatments only *preserve* a pavement surface. These treatments do *not* improve the structural integrity of the pavement. As a result, preventive maintenance should only be performed on pavements in good structural condition. In addition, preventive maintenance treatments should be applied before significant environmentally induced surface distresses (such as raveling and block cracking) have developed. Delays in maintenance increase the severity and extent of defects, and therefore the treatment cost is greater (Zaniewski and Mamlouk, 96).

5.2.4 Additional Recommendations

There are a number of additional recommendations that have been identified at the conclusion of this project. The first one would be to take full advantage of the tools and capabilities of the Microsoft Access software program that runs WV DPMS. There are a large variety of reports that can be generated, numerous queries that can be written and viewed, and other data manipulation features. The type and amount of decision making tools that the user gets out of WV DPMS depends on their creativity and desires.

Along those same lines, it is recommended that the users continue to build and maintain the historical database. This includes the inventory data and condition survey data. This information can be used to keep track of the district's infrastructure and to measure the "health" of the roads in the district. The performance model should also be refined through the years as better historical data is gathered and examined. Once precise funding scenarios are determined, the model should be calibrated to generate more accurate budget and maintenance plans.

The term, "health" of the roads, was previously mentioned in the recommendations. To obtain a better grasp on this idea, the district may consider developing a Pavement Condition Index (PCI). These values would not serve a purpose in the treatment selection process, but would help to monitor the condition of the pavements. Deduct values could be assigned to distresses and subtracted from a certain value, say 100, as the distresses are encountered in a road section. The PCI would aid in tracking the road's health over time and possibly be used to create informative graphs.

Another recommendation would be to change the WV DPMS program to accept and handle metric units. The WV DOH currently uses English units for their design and construction projects. However, this practice may change in the future and the WV DPMS should be altered accordingly. The WV DPMS is presently programmed to calculate the Repair Costs and Budget based on feet and miles for road width and length, respectively. Modifications to the software program could easily accommodate the switch to metric units.

An additional suggestion would be to get input from some of the other districts about the ease of data entry and customization. Some other pavement management systems allow very easy modifications to such things as the decision tree. However, this can prove detrimental to the decision making process. If an untrained, inexperienced individual makes unwise alterations to the decision tree, the entire treatment selection and budget proposal process can be negatively affected. The modification of the WV DPMS decision tree was intentionally made somewhat involved to deter a sabotage of the system. Input from some of the other districts should be gathered to see if they would like this customization process made easier or to remain the same as it presently is.

A further proposal for WV DPMS would be to extend the use of the program to smaller communities and municipalities, not just the other districts in the WV DOH. Some West Virginia communities, such as Morgantown and Fairmont, have expressed interest in customizing WV DPMS for use on their roads. Discussions have been held with representatives from these towns to determine how WV DPMS could be modified for their use. It was resolved that the following items had to be altered. The beginning and ending mileposts for the road section should be changed to intersecting streets. The classification should be changed from "US, WV, CO, and HA" to arterial collector, minor artery, major artery, no outlet, and so on, to accommodate the town. The traffic volume data should be replaced or added to the number of residents per road section. Finally, the available treatments and respective unit costs should be examined and changed accordingly.

Another recommendation would be to use a Geographical Information System (GIS) to display the results of WV DPMS. For instance, the user could present the reports and recommendations of WV DPMS through the creation and displaying of maps. The Access software allows data to be exported to GIS software, such as ArcView. The compatibility of the software programs permits creation of detailed maps of the district that present the treatments recommended for application on each section. The maps may be advantageous to the maintenance crews who can see exactly where they need to perform a specific treatment. The maps will also be beneficial in informing the general public and elected officials of the current condition of their roads and future work that will be done. If the agency decides to undertake this recommendation, they should consider using PMS data export. This approach involves exporting the WV DPMS data and then importing it into the GIS software for display or querying. This approach has the advantage of not placing restrictions on the development environment used for the PMS, since the PMS and GIS communicate through file transfer and can use different software. The major disadvantage with this approach is that it requires the user to use two separate systems -- creating data on the PMS, but then having to perform data transfer to do graphical querying each time the PMS data is modified. Initially, WV DPMS was to include exportation of data to ArcView, a GIS program, for displaying the recommendations of the program. However, it was concluded that this was an unnecessary procedure at this time because the WV DOH has not fully implemented any GIS program. It is highly recommended that the districts that use WV DPMS link this program to a GIS program as soon as the GIS is fully adopted and functional.

If the choice is made in the future to utilize GIS, the agency may also consider using a Global Positioning System (GPS) for section identification and inventory and condition data collection. GPS can accurately and efficiently provide the GIS systems with location/reference points and is an excellent interface for the mapping system. The agency must keep the costs of such systems in mind when making decisions of this sort.

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APPENDIX A - INVENTORY DATA COLLECTION AND CONDITION ASSESSMENT FORMS

WV DPMS
District Level
Pavement Management System

West Virginia DOH

Inventory Data Collection Form

Date:____________________________ Completed by:_________________________

---

*County:*________________________*Road Name:*_________________________

*Route #:*_________ *Ref. #*__________

*Begin MP:*_____ *End MP:*_____ *Direction of MP:* E-W S-N

*Road Length:*_________mi. *Road Width:*________ft.

Number of Lanes: (circle one) 1 2 3 4 5 6 *Road Surface:* ☐ HMA ☐ other

Shoulder Type: ☐ paved ☐ gravel ☐ earth ☐ curb and gutter

Shoulder Width:_________ft. *Drainage/Utility Features:* ☐ manholes
☐ drop inlets
☐ other

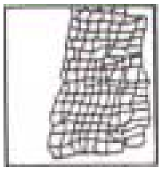
Classification: ☐ US ☐ WV *Traffic*:_________AADT
☐ CO ☐ HA

Last Surface Year:_________

WV DPMS
District Level
Pavement Management System
West Virginia DOH

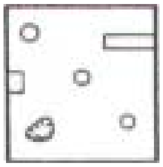
Flexible Pavement Condition Survey

FATIGUE CRACKING



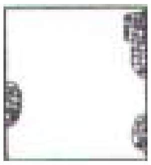
SEVERITY	0 No Defect	EXTENT Percent of Road Surface <10%	10-30%	>30%
Low		1	2	3
Mod.		4	5	6
High		7	8	9

PATCHING



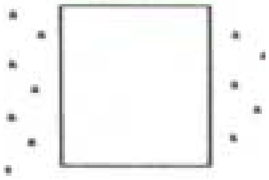
SEVERITY	0 No Defect	EXTENT Percent of Road Surface <10%	10-30%	>30%
Low		1	2	3
Mod.		4	5	6
High		7	8	9

EDGE CRACKING



SEVERITY	0 No Defect	EXTENT Percent of Road Surface <10%	10-30%	>30%
		1	2	3
0-2ft		4	5	6
>2ft.		7	8	9

DRAINAGE CONDITION



CONDITION	
GOOD	1
FAIR	3
POOR	6

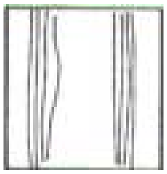
RIDE COMFORT

Check Road for
Presence of Following:

- Uneven Surface
- Corrugations
- Sags
- Humps
- Frost Heaves

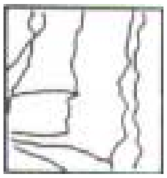
CONDITION	
GOOD	1
FAIR	3
POOR	6

RUTTING



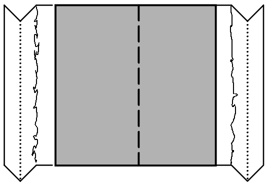
0 No Defect	SEVERITY
Low (<1/4” Rut)	2
Med. (1/4”-3/4” Rut)	4
High (>3/4” Rut)	7

LONGITUDINAL/ TRANSVERSE CRACKING



SEVERITY	0 No Defect	EXTENT Low	Med.	High
Low		1	2	3
Mod		4	5	6
High		7	8	9

SHOULDERS



0 NON -EXISTENT	CONDITION
GOOD	2
FAIR	4
POOR	7

County:_________________________ Road Name:________________________________
Route #:_______________ Ref. #:_________________________
Begin MP:_________ End MP:_________ Direction:_______
Date of Survey:____________ Surveyed By:_______________________________

WV DPMS

District Level

Pavement Management System

West Virginia DOH

Condition Survey Worksheet

Pace Counter

# of boxes checked = 25

Fatigue Cracking

1 Pace

Avg. crack width for test section = ________ in.

# of boxes checked ______ X 4 =

______ % of test section exhibiting distress

Edge Cracking

Distance of cracks from pavement edge = ________ in.

# of boxes checked ______ X 4 =

______ % of test section exhibiting distress

Long./Trans. Cracking

L T

Avg. crack width for test section = ________ in.

Distance between trans. cracks = ________ ft.

# of boxes checked (L/10 + T) ______X 4 =

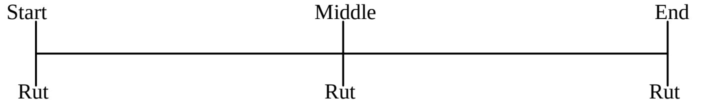
______ % of test section exhibiting distress

Patching

# of boxes checked ______X 4 =

______ % of test section exhibiting distress

Rutting: measure at 3 points throughout the 25-pace test section. Note maximum rut depth.



______ ______ ______

Drainage Condition: Good Fair Poor

Shoulder Condition: Good Fair Poor

County:________________________ Road Name:______________________________

Route #:______________ Begin MP:_________ End MP:_________

Distance from beginning of section:_____________ Direction of travel:_________

Date of Survey:____________ Surveyed By:_____________________________

WV DPMS
District Level
Pavement Management System
West Virginia DOH

Immediate Maintenance Report Form

Date:______________ Completed by:__________________________
*County:*_______________________ *Road Name:*_________________________ *Route #:*_________
*Begin MP:*_____ *End MP:*_____ *Direction of MP:* E-W S-N

Potholes:___________ Distance from beginning of section __________ Direction of travel

___________ Distance from beginning of section __________ Direction of travel

___________ Distance from beginning of section __________ Direction of travel

Drainage:___________ Distance from beginning of section __________ Direction of travel

___________ Distance from beginning of section __________ Direction of travel

___________ Distance from beginning of section __________ Direction of travel

Edge drop-off:___________ Distance from beginning of section __________Direction of travel

___________ Distance from beginning of section __________ Direction of travel

___________ Distance from beginning of section __________ Direction of travel

Shoulders:___________ Distance from beginning of section __________ Direction of travel

___________ Distance from beginning of section __________ Direction of travel

___________ Distance from beginning of section __________ Direction of travel

Comments:____

____

____

Notes:

Report ***potholes*** if they are present in the section;
Report ***edge drop-offs*** if greater than 1 ½” drop-off from edge of pavement;
Report ***drainage*** if ditches, gutters and other drainage structures are not functioning;
Report ***shoulders*** if water is ponding on edge of pavement.

APPENDIX B – INVENTORY DATA COLLECTION PROCEDURES

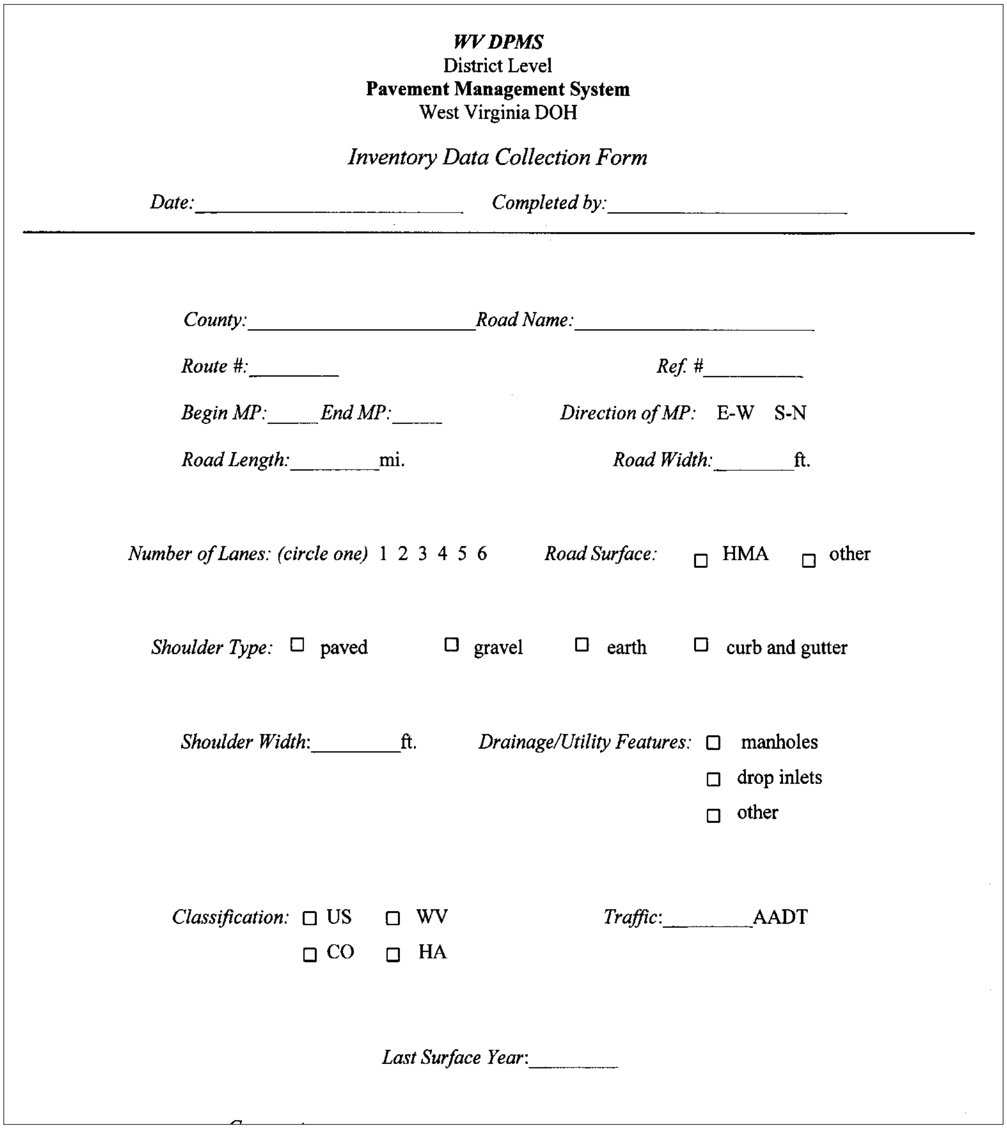
METHOD OF COLLECTING INVENTORY DATA

A two-person team should perform the road inventory data collection. The accuracy and quality of the data are maintained by having each team member check and validate the data. The team will need a vehicle and a device to accurately measure distance. A distance-measuring device that can be mounted on the dash of a vehicle is a good tool to perform this task. The crew will also need a district map showing the road section boundaries that have been established for WV DPMS and forms for recording the inventory data. The recommended inventory data form is found in Appendix A. The completed forms should be taken back to the district office and the data should be entered into the Access database.

The actual survey of the road inventory will be a riding survey conducted at slow speeds. However, the driver of the vehicle must be aware of blind curves and poor sight distances and drive accordingly. When the driver decides to stop and get out of the vehicle, flashing lights should be turned on and the vehicle should be completely off the road. For example, a team member wearing a reflective safety vest may get out of the vehicle to measure the width of each road section at the section boundary. The other categories included in the inventory such as number of lanes, surface types, shoulder characteristics, and drainage features can be determined from the vehicle.

FILLING OUT INVENTORY DATA COLLECTION FORMS

The forms should be filled out according to the methods described in this section to provide continuity and accuracy. All members of the team should read this section before collecting the inventory data and filling out the form. Each line of the form, as seen in Figure B.1, is explained.



WV DPMS
District Level
Pavement Management System
West Virginia DOH

Inventory Data Collection Form

*Date:*____________________ *Completed by:*____________________

*County:*____________________*Road Name:*____________________

*Route #:*________ *Ref. #*________

*Begin MP:*_____*End MP:*_____ *Direction of MP:* E-W S-N

*Road Length:*________mi. *Road Width:*_______ft.

Number of Lanes: (circle one) 1 2 3 4 5 6 *Road Surface:* ☐ HMA ☐ other

Shoulder Type: ☐ paved ☐ gravel ☐ earth ☐ curb and gutter

Shoulder Width:________ft. *Drainage/Utility Features:* ☐ manholes
☐ drop inlets
☐ other

Classification: ☐ US ☐ WV *Traffic*:________AADT
☐ CO ☐ HA

Last Surface Year:________

Figure B.1 Inventory Data Collection Form

Date: the date of the actual collection of inventory data should be noted on the first line of the form.

Completed by: the person(s) that complete the form should print their name legibly so that they can answer any questions that may arise.

County: the county that the road section is located in.

Road Name: the specific name of the road that the section is located on.

Route #: the designated route number that is assigned to the road section; it can be found on county maps or posted signs.

Ref. #: this number can be assigned at a later time to coordinate the road section between relational databases. The field is not currently needed. It was provided to facilitate future upgrades to WV DPMS if a GIS program is implemented.

Begin MP & End MP: the assigned mile posts for the beginning and end of the section as designated by straight-line diagrams or signs.

Direction of MP: circle the direction that the survey crew travels from the beginning of the section to the end.

Road Length: this value can be determined from the straight line diagrams. It can also be measured using the distance measuring devices found in the team’s vehicle and can be measured while traveling at slow to normal speeds. If the value from the distance measuring device varies from the length found in the straight-line diagrams, note the measured length and then determine where the discrepancy lies. The correct length must be entered into the database because this value is used in calculating section repair costs.

Road Width: the crew will have to get out of their vehicles at the beginning of each new section to measure the road width. The crew should take care to be safe and not to disrupt traffic. This measurement can be done with a measuring wheel. If the width of the surveyed road section appears to change by more than 2 feet within the section, the varying road widths should be averaged and the mean road width should be reported.

Number of Lanes: the appropriate number of lanes of the road section should be circled on the form.

Road Surface: the crewmember should check the correct box. “HMA” is short for hot mix asphalt and the “other” category can be concrete pavement, chip seal, and other surface types.

Shoulder Type: a check should be placed in the pertinent box according to the shoulder type found in this section of road.

Shoulder Width: the crew will have to carefully stop the vehicle and get out to measure the width. The shoulder width of each new road section will have to be determined and reported. This measurement can be done concurrently with the road width measurement. If the shoulder width changes within the section, an average value should be estimated and noted.

Drainage/Utility Features: a check should be made in the appropriate box, depending on what features are located within the road section.

Classification: mark the appropriate box to indicate road classification. WV and US routes are considered primary roads and the CO (County Routes) and HA (Orphan Roads) are considered secondary roads.

Traffic: the average annual daily traffic, AADT can be retrieved from previous records or a new traffic count can be performed. The value can be determined before or after the field data collection occurs.

Last Surface Year: write in the year of the last resurfacing or reconstruction job that occurred on this road section. If good maintenance records are not available, ask personnel that may have worked in the district when the section was last repaired. If the section has not been resurfaced, write down the year the section was built.

The crewmembers should agree on the values that are entered onto the collection form. If there is a discrepancy, the difference should be resolved.

APPENDIX C – CONDITION DATA COLLECTION PROCEDURES AND DISTRESS RATING CRITERIA

METHOD OF COLLECTING PAVEMENT CONDITION SURVEYS

The WV DPMS pavement condition survey requires a visual inspection of the distresses. WV DPMS involves identifying road distress characteristics, estimating the severity of the distress, and assessing the extent of the severity. Severity applies to the degree of deterioration of the distress. Extent refers to the frequency or amount of the distressed road surface area. Both the severity and extent are rated on a pre-established scale. The criteria for determining the severity and extent are explained in detail in this Appendix. The crewmembers should read and understand the criteria before rating the distresses. Following this procedure will ensure that the crews are recording data according to the same criteria and that the quality of data is enhanced.

The condition survey should be a windshield survey with four stops within the road section. The driver should drive at a slow speed and get off of the traveled way when possible, making sure the vehicles lights are flashing to warn passing motorists. The surveyors should stop four times in a road section, and measure the distresses in a 25-pace segment of roadway (approximately a 60 to 75 foot test section). The condition survey worksheet should be filled out at each test section to identify the extent, severity, and condition of the distresses. Using the condition survey worksheets will give the surveyors a good idea of the type, extent, and severity of distresses occurring in the whole section. The distress values for the entire section are manually recorded on the supplied data forms.

The survey should be done by a 2-person team that has been trained to recognize pavement distresses and to record the data. Two-person teams are used to ensure quality and accuracy and to reduce any bias or subjectivity that may exist.

The team will a vehicle to transport them to the survey site and to perform the survey. They will also need a district map showing the established section boundaries and what roads they need to survey. The crew should also be given a measuring tool to determine the severity and extent of the pavement distresses. The surveyor may use a ruler or template to determine the severity of the pavement distress by gauging crack widths or measuring rut depths. The extent can be measured with aid of the condition survey worksheet.

USING THE CONDITION SURVEY WORKSHEETS

Procedures are presented herein to determine the severity and extent levels of distresses. Survey crewmembers should use the provided worksheets during their periodic stops to help measure and calculate the distress characteristics. The condition survey worksheet is supplied in Appendix A so that it can be reproduced and distributed to the appropriate personnel.

The distresses that are analyzed with the aid of the worksheet are Fatigue Cracking, Edge Cracking, Longitudinal/Transverse Cracking, Patching, Drainage Condition, Rutting, and Shoulder Condition. Ride Comfort is not included on the worksheet because it is a subjective condition that is best measured after the crew has driven over the road section. The distresses that are on the worksheet, except for Drainage Condition, Rutting, and Shoulders, are rated based on severity and extent levels. The severity levels are measured directly with specific tools such as levels, straight edges, rulers, and others. However, extent levels are based on a percentage and could be harder to accurately determine. This condition survey worksheet enables the surveyor to accurately evaluate the extent, or percentage of road surface exhibiting distresses, on the test section. The worksheet also provides a means of recording the various measurements used in determining a severity rating. At the end of a section and the completion of the four test sections, the surveyor can review the measurement data for the section and report the most severe rating observed in the section. Knowing the condition of the test sections will determine the condition of the entire road section.

A condition survey worksheet should be filled out each time the crew stops within the road section. To use the worksheet, a crewmember exits the vehicle and locates a safe place to survey. The surveyor will take 25 paces along the paved surface. The surveyor should pace, stop, look, and record, 25 times in the test section. The pace should be a normal stride covering approximately 2 to 3 feet. As each pace is made, the surveyor should stop and look for Fatigue Cracks, Edge Cracks, Longitudinal/Transverse Cracks, or Patches within the pace length and road width. If one of these distresses is encountered on the pavement within the pace length, a check should be placed in the corresponding box. If no distress is observed in the respective pace, the corresponding box should be left blank. The pace counter column is used to help the surveyor keep track of the number of paces they have completed. At the end of the 25-pace test section the number of checked boxes for each distress should be counted. This value should be multiplied by 4 to yield the percentage of the 25-pace test section that is exhibiting the distress.

For example, if there are 5 checks in the Edge Cracking portion of the worksheet after completing the 25 pace analysis, 20% of the test section is exhibiting Edge Cracking. After completing four test sections within the road section, the extent levels for each distress should be examined. If the extent levels for Edge Cracking for all four test sections within an entire road section are 20%, the surveyor can determine that the extent of Edge Cracking for the entire road section is 20%, or Medium Extent. Therefore, the entire road section should be designated as Medium Extent Edge Cracking. If the test sections are exhibiting drastically different extent levels for each respective distress, the highest extent level should be noted on the condition survey form.

The extent rating for Longitudinal/Transverse Cracking is handled slightly different from the other distress surveys. Both types of distresses are considered in the same survey because they are treated and repaired in the same manner. However, there is a difference in the measurement of the extent of the distress. A longitudinal crack may extend the entire length of the test section at a construction joint. Although this is not a drastic distress, it would be reported as 100% cracking for the test section and an inappropriate treatment may be selected. Transverse cracking may be more severe than the longitudinal cracking but would only be counted and checked a few times in the pace-check box using the procedures of the other distresses. A 24-foot transverse crack may only be counted once in a test section because of its orientation and the way the survey is conducted; whereas, a 24-foot longitudinal crack may be recorded as 10 checks. To compensate for these possible problems and to balance out the significance of each distress in the treatment selection process, the worksheet has been created to equalize the distresses. The equation, $L/10 + T$, is used for the Longitudinal/Transverse Cracking portion of the condition survey worksheet. The surveyor will observe the two types of cracking within each pace and check the box accordingly, L for longitudinal crack and T for transverse crack. At the end of the test section the surveyor will add up the longitudinal, L, boxes checked and divide that number by 10. They will also sum the number of transverse, T, boxes checked. These two values will be added together and multiplied by 4 to determine the total percentage of the test section exhibiting longitudinal and transverse cracks. For example, 20 “L” boxes were checked and 4 “T” boxes were checked. Therefore, 20 would be divided by 10 and then added to 4. The resulting value, 6, would be multiplied by 4 to determine the percentage of the test section exhibiting longitudinal and transverse cracking.

The severity ratings should be made concurrently with the extent ratings. A representative sample of the observed distress should be selected. Specifically, measure the width of the fatigue cracks, the distance of edge cracking from the edge of pavement, the width of the longitudinal or transverse cracks and the distance between transverse cracks in the test section. When all of the test sections have been analyzed, the most extreme severity rating exhibited in the test sections should be used to rate the entire road section. For example, if the largest longitudinal/transverse crack measured in any one of the test sections was $^1/_8$ inch wide, the severity rating would be Low for the entire road section.

Rutting is measured on each test section to accurately determine what is occurring in the entire road section. This distress can be measured by using a straight edge, such as a four-foot piece of wood, and a ruler. The surveyor should measure rutting depths at three distinct points within the test section. The various points include the area preceding the first pace of the test section, a point after the twelfth pace, and a point after the twenty fifth pace. This should give a representative sample of the rutting depths within the test section. After completing assessment at the four stops and subsequent test sections, the severity of Rutting for the whole road section can be determined. The largest rut depth that is measured in the test sections should be the reported value for the entire section on the condition survey form. For example, the largest rut depth that was measured at any of the points in the various test sections of a road section was ½ inch. Therefore, the severity rating would be Medium for the road section and the number 4 would be highlighted or circled on the condition survey form.

The remaining two distresses are Drainage Condition and Shoulder Condition. The condition of these categories should be circled on the form at the end of the test section after observations of the test section have been made. When the entire road section is completed, the worst rating on any one of the test sections should be the rating for the entire road section. For example, if the drainage condition for one of the test sections was determined to be Poor, the entire section would be rated Poor and the number 6 would be highlighted or circled on the condition survey form.

At the bottom of the condition survey worksheet are spaces to note the county, road name, mileposts, and other characteristics of the section that is being examined. This information is needed to match the worksheets to the condition survey form for the respective road section. The distance from the beginning of the section and the direction of travel should also be noted in case future investigations of the test sections are necessary.

The worksheets should be archived along with the condition survey forms for future review should any problems arise.

FILLING OUT FLEXIBLE PAVEMENT CONDITION SURVEY FORMS

The flexible pavement condition survey forms have been created to facilitate quick surveys and swift data entry. The forms are supplied in Appendix A and should be copied and distributed to the survey teams. Pertinent information such as Road Name, Route Number, and Mileposts should be entered first, so as to coordinate with the sections identified in the inventories. Then the assessment of distresses in each test section can begin. At the end of the road section and the completion of the worksheets for the four test sections, the distress rating values can be noted on the condition survey form. The surveyor should record the worst severity and extent level they observe in the section. The surveyor can either highlight or circle the appropriate field for each distress type, as determined by the criteria. For example, for a section exhibiting low extent, moderate severity longitudinal/transverse cracks, the surveyor would circle or highlight the number 4. Then when the condition survey data is entered into the Access database, the number 4 is entered into the appropriate field.

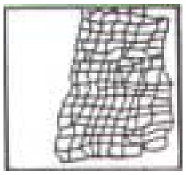
DISTRESS RATING CRITERIA

The design for the WV DPMS flexible pavement condition survey form is based on the *Road Surface Management System 1992 (RSMS)* manual and system. Similarly, some of the rating criteria explanations were reviewed and borrowed from the same publication (New Hampshire T^2 Center, 92). WV DOH personnel and other engineers reviewed the RSMS forms and criteria and submitted input on the layout and content of the WV DPMS forms and criteria. The revised rating criteria are explained herein. The extent and severity of the distresses are determined using the WV DPMS procedures and condition survey worksheet.

C.1 Fatigue Cracking

Fatigue cracking, or alligator cracking, refers to interconnected crack patterns that resemble alligator skin. The irregular pieces of pavement vary in size but are typically less than 12 inches across.

FATIGUE CRACKING



0 No Defects

		EXTENT Percent of Road Surface		
		<10%	10-30%	>30%
SEVERITY	Low	1	2	3
	Mod.	4	5	6
	High	7	8	9

NO DEFECT:		The road section has no visible alligator cracking or the total area exhibiting cracking comprises less than 1% of the entire length of section.
SEVERITY:	**LOW**	Crack pattern is just beginning to appear. Cracks are less than ¼" in width.
	MODERATE	Easily discernible cracking with measurable crack widths between ¼" and ¾".
	HIGH	Wide cracking (> ¾") has resulted in major pavement breakup with loose pieces actually displaced.
EXTENT:	**LOW <10%**	The total section length exhibiting alligator cracking is less than 10% of the length of roadway section.
	MOD. 10–30%	The total section length exhibiting alligator cracking is between 10% and 30% of the length of roadway section.
	HIGH >30%	The total section length exhibiting alligator cracking is greater than 30% of the length of roadway section.

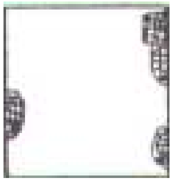
Notes:

1. Alligator cracking is generally related to traffic loading. As such, alligator cracking will be found primarily in wheel paths.
2. It is important that surveyors be aware of the distinction between alligator cracking and the other primary distresses of edge cracking, longitudinal/transverse cracking, and rutting. This is critical to the program for selecting viable repair strategies.
3. The highest observed severity present should determine the entire section's severity ranking.

C.2 Edge Cracking

Edge cracking refers to cracks adjacent and parallel to the edge of the pavement. While generally confined to the outer one to two feet of pavement, edge cracking can progress into the travel lane.

EDGE
CRACKING



EXTENT

Percent of Road Surface

	0 No Defects	<10%	10-30%	>30%
SEVERITY		1	2	3
0-2ft		4	5	6
>2ft.		7	8	9

NO DEFECT:		The roadway does not exhibit edge cracking.
SEVERITY:	**LOW**	Parallel, unconnected cracking is evident near edge of pavement; however, no breakup.
	MOD. 0-2 ft.	Interconnected cracking occurring with some breakup or raveling. Cracks extend up to 24” from pavement edge.
	HIGH >2 ft.	Extensive cracking beyond 24” from edge of pavement; breakup. This condition closely resembles alligator cracking.
EXTENT:	**LOW**	The total section length affected by cracking is less than 10% of the section length.
	MOD.	The total section length affected by cracking is between 10% and 30% of the section length.
	HIGH	The total section length affected by cracking is more than 30% of the section length.

C.3 Ride Comfort

Ride comfort is evaluated subjectively. The category includes irregularities in the roadway surface that adversely affect the comfort of the ride.

RIDE COMFORT

Check Road for
Presence of Following:

Uneven Surface
Corrugations
Sags
Humps
Frost Heaves

CONDITION	
GOOD	1
FAIR	3
POOR	6

CONDITION:	**GOOD**	Road has even surface – ideal for smooth, undisturbed travel. New roads and recent resurfacing generally fall into this category.
	FAIR	Acceptable ride quality; not as good as newly paved road, but vehicle may travel safely at posted speeds.
	POOR	Pavement surface is very uneven, causing a possible safety hazard for vehicles traveling at the posted speed limit. Overlay needed due to poor ride quality.

Notes:

1. Assessment of ride comfort *should be determined while the survey vehicle is traveling at posted speeds.*
2. This category comprises conditions which are not included in other categories – such as corrugations, waves, frost heaves, settlement, and so forth.

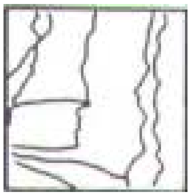
C.4 Longitudinal/Transverse Cracking

Longitudinal cracks are cracks that run parallel to the roadway centerline. Longitudinal cracks are usually found at construction joints and between lanes.

Transverse cracks run perpendicular to the roadway centerline. Transverse cracks are generally spaced at regular intervals and caused by expansion and contraction of the road surface material.

Both types of cracks can also be reflective, appearing above joints and cracks in underlying pavements.

LONGITUDINAL/
TRANSVERSE
CRACKING



	0 No Defects	EXTENT		
		Low	Med.	High
SEVERITY	Low	1	2	3
	Mod	4	5	6
	High	7	8	9

NO DEFECT:		The road section has no visible signs of longitudinal/transverse cracking.
SEVERITY:	**LOW**	Cracks less than ¼” in width; little or no spalling.
	MODERATE	Crack widths between ¼” and ¾” with some spalling evident. Also includes parallel cracks that are not in the wheel path.
	HIGH	Well-defined cracks (> ¾”); cracks may be filled with foreign material (sand, stones, and other materials). Extensive spalling and breakage.
EXTENT:	**LOW**	The overall percentage of longitudinal and transverse cracking is less than 10%; and/or transverse cracks are 50’ apart.
	MEDIUM	The overall percentage of longitudinal and transverse cracking is between 10% and 30%; and/or transverse cracks are between 25’ and 50’ apart.
	HIGH	The overall percentage of longitudinal and transverse cracking is over 30%; and/or transverse cracks are less than 25’ apart.

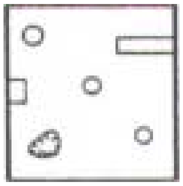
Notes:

1. Spalling refers to the physical relocation and/or displacement of pieces of original pavement.
2. Transverse cracks must extend across at least one full lane width to be counted as transverse.
3. Parallel cracks limited to wheel paths should be categorized as alligator cracks.

C.5 Patching

Patching refers to areas where the original pavement has been removed and subsequently replaced but is showing deterioration. Failed patches may be potholes in the road surface.

PATCHING



0
No
Defects

EXTENT

Percent of Road Surface

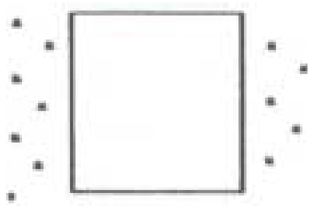
SEVERITY	<10%	10-30%	>30%
Low	1	2	3
Mod.	4	5	6
High	7	8	9

NO DEFECT:		No patches detected in the rated section.
SEVERITY:	**LOW**	Patch appears to have been applied correctly and recently. Patch does not affect ride quality.
	MODERATE	Cracks appear at edges of patch and/or throughout the patch.
	HIGH	Patch is distorted (was not properly applied or has deteriorated), affecting ride quality.
EXTENT:	**LOW**	The total area of patching is less than 10% of the total section area.
	MEDIUM	The total area of patching is between 10% and 30% of the total section area.
	HIGH	The total area of patching is greater than 30% of the total section area.

C.6 Drainage Conditions

Drainage severities are judged by the ability for run-off to flow from the paved area to a location that does not influence roadway conditions. Visual indicators of drainage problems include accumulation of debris and sand and high water marks. Evaluation during or just after a rainfall event can be extremely beneficial.

DRAINAGE
CONDITION



CONDITION	
GOOD	1
FAIR	3
POOR	6

CONDITION:	**GOOD**	There is no evidence of water accumulation on the pavement surface. Roadway has good crown. Positive drainage can be visually confirmed. Ditches, gutters, and other drainage structures are clear, clean, and functioning.
	FAIR	There is evidence of occasional water accumulation on the pavement surface. Road crown is minimal, nearly 0%. Ditches, gutters, and other drainage structures are functional but may need cleaned or repaired.
	POOR	There is evidence of recurring and extensive ponding of water on the pavement surface. Roadway has no crown. Ditches, gutters, and other drainage structures are not functioning or non-existent.

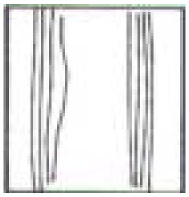
Notes:

Signs of poor drainage:

1. Road shoulders above the edge of pavement;
2. Standing water; and
3. Outwashes or accumulations of sand along the edge of the roadway.

C.7 Rutting

Rutting refers to channels in the wheel paths. Rutting causes water to drain along the road surface rather than drain to the edge of the road.

RUTTING	0 No Defects	SEVERITY	
		Low (<1/4” Rut)	2
		Med. (1/4”-3/4” Rut)	4
		High (>3/4” Rut)	7

SEVERITY:	**NO DEFECTS**	There is no evidence of rutting in the section.
	LOW	Rutting is present; less than ¼” rut.
	MEDIUM	Visible rutting between ¼” and ¾”.
	HIGH	Rutting greater than ¾”.

Notes:

1. Tire path wear caused by studded snow tires or tires with chains is not the same as rutting, but should be recorded in this category.

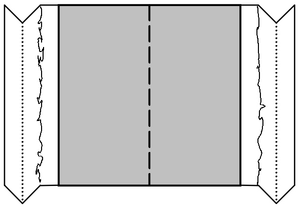
2. The severity of rutting is measured during the four condition assessment stops in each road section.

C.8 Shoulders

This category refers to the condition of the shoulders. It includes cross section template considerations, drop-off conditions, surface material, and water handling capabilities.

SHOULDERS

0
NON-EXISTENT



CONDITION	
GOOD	2
FAIR	4
POOR	7

CONDITION:	**NON-EXISTENT**	Shoulder is less than 2 ft. wide
	GOOD	Appropriate cross section template (3/4” : 1’); shoulders are even with paved surface; shoulder material is intact.
	FAIR	Shoulder is still driveable; water can flow to ditchline; edge drop off < 1 ½ inch.
	POOR	Shoulder material is gone and potholes exist on shoulder; water drains back towards pavement rather than to ditchline; edge drop off > 1 ½ inch.

Note:

1. Edge drop-offs and non-existent shoulders should also be noted on the immediate maintenance report so that the problem can be remedied soon.

APPENDIX D – DISTRESSES AND CAUSES MANUAL

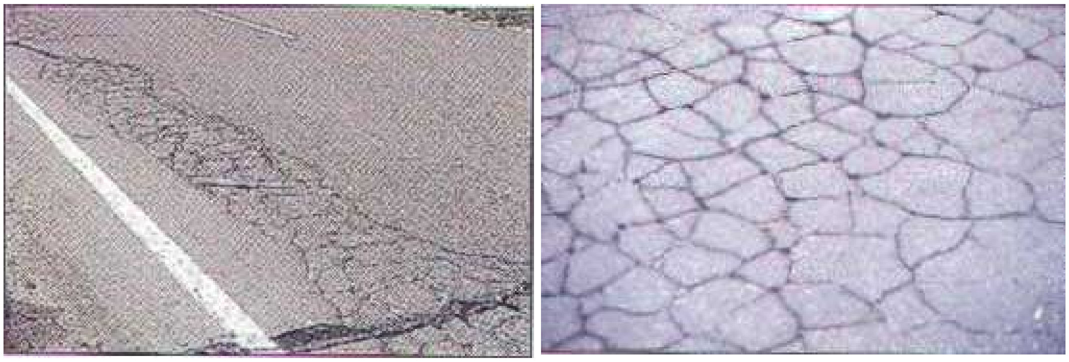
D.I. INTRODUCTION

There were a number of distresses presented and explained in the literature survey. The eight distresses that were chosen to be included in WV DPMS are presented herein. This appendix should be copied and distributed to the survey crews.

D.1 Fatigue Cracks

Fatigue cracking is also commonly known as alligator cracking. Fatigue cracking starts with individual longitudinal cracks developing in wheel paths. With time and traffic, additional longitudinal and transverse cracks develop and the cracks become interconnected. This results in a closely spaced crack pattern that resembles the pattern on an alligator’s back. The irregular pieces of pavement vary in size, but are typically less than 12 inches across. If pavement areas with alligator cracking are not treated, potholes eventually develop.

As the name fatigue cracking suggests, the primary cause of this pavement distress is repeated traffic loading which stresses the pavement to its fatigue life limit. Alligator cracking is also associated with loads that are too heavy for the pavement structure. Fatigue and alligator cracking formation is accelerated by insufficient pavement drainage because the cracks allow the pavement layers to become saturated and lose strength. Inadequate pavement thickness due to poor design or quality control during construction combined with repetitive passes with overweight trucks can also induce alligator cracking. The cracking starts at the bottom of the asphalt concrete layer where the tensile stresses are the greatest. With continued traffic loading, the cracks migrate to the surface. Figure D.1 presents typical alligator cracking (Strategic Highway Research Program, National Research Council, 93). Figure D.1(a) depicts the cracking in the wheel path and Figure D.1(b) is a close-up view of the cracking.



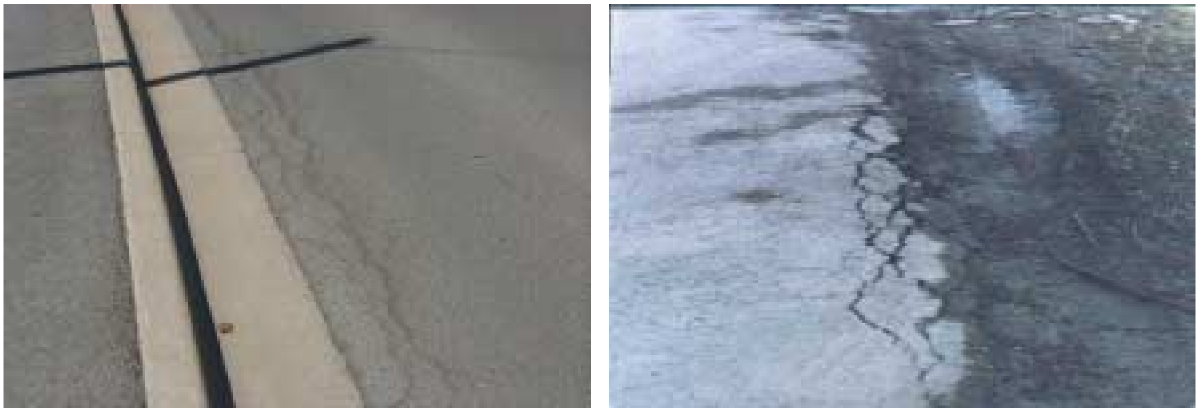
(a) (b)

Figure D.1 Fatigue/Alligator Cracks

Depending on the extent, repair strategies for alligator cracking typically include patching, overlays, or reconstruction techniques. Alligator cracking that occurs infrequently in a particular section can be corrected with patching. Overlays are often used to correct alligator cracks that cover an extensive area but the thickness of the overlay must be sufficiently designed to carry the number of expected loads. Removal and replacement of material with patching techniques may be needed to repair localized areas of alligator cracking. Pavements with alligator cracking require careful investigation to determine the cause of alligator cracking. If poor subgrade drainage is the root cause, drainage improvements are necessary. If the pavement structure is fatigued due to repetitive loading alone, a stronger pavement structure is needed to carry the anticipated traffic (Roberts, et al, 96).

D.2 Edge Cracks

Edge cracking occurs along the shoulders of the pavement and look similar to longitudinal cracks. Edge cracking typically occurs within 1 to 2 feet of the pavement edge. Cracking can occur as a result of poor shoulder support, excessive traffic loads, or a high percentage of heavy trucks on an insufficiently designed road. Depending on the severity and extent, edge cracking is usually repaired with either preventive maintenance (thin overlays, chip seal, and others), routine maintenance (patching), rehabilitation (thick overlay), or reconstruction techniques. If the problem is lack of edge support, material must be added to the shoulders to bring it up to the road level and the material should be properly compacted (Roberts, et al, 96). Figure D.2 presents examples of edge cracking; Figure D.2(a) exhibits cracking at a curb and gutter and Figure D.2(b) exhibits cracking along a gravel and earth shoulder.



(a) (b)

Figure D.2 Edge Cracking

D.3 Ride Comfort

Pavement roughness is produced by surface deviations that create a response in the suspension system of the travelling vehicles. Pavement roughness is important because this is the pavement property that is most noticeable to the travelling public. Devices used to measure pavement roughness include response type road roughness meters and inertial profilometers (Roberts, et al, 96).

Pavement roughness can be evaluated subjectively by determining the comfort of the driver, or ride comfort. Ride comfort is defined as a user perceived reduction in ride quality due to pavement surface irregularities. Ride comfort is an encompassing term because it includes conditions that are not accounted for in the other categories, such as corrugations, sags, humps, frost heaves, and settlement, to name a few. A subjective opinion made by the motorists/surveyor can be used to estimate pavement roughness.

The causes for loss of ride comfort are varied. They include poor drainage, insufficient design and material, and inferior base. Subsequently, the corrective procedures are many and should be based on the specific causative mechanism (N H T^2 Center, 92). There is no one picture that can visually represent roughness. Therefore, one is not provided for this section.

D.4 Longitudinal/Transverse Cracks

Longitudinal cracks are individual cracks, parallel to the roadway centerline. Longitudinal cracks most frequently occur at the joint between adjacent lanes or at the edges of the wheel paths in a rutted pavement. These cracks can start as hairline cracks and widen with age and wear. Longitudinal cracks provide a path for water to enter the subsurface layers and subgrade resulting in the development of fatigue cracking at the joint between lanes and raveling. Longitudinal cracks, when found in the wheel paths, can also signify the beginning of alligator cracking.

The density of the asphalt concrete at construction joints is typically lower than the rest of the pavement. The lower density of the asphalt concrete results in lower tensile strengths. As surface temperatures drop to a level such that the thermally induced shrinkage stresses exceed the tensile strength of the asphalt concrete at the joint, longitudinal cracking will develop. Longitudinal cracking can develop at any place in the pavement if shrinkage stresses exceeds the tensile strength of the pavement; however, it will usually first occur at a construction joint due to the lower tensile strength. In addition, the higher voids in the asphalt concrete at the joint also allows for increased oxidation hardening, which makes the pavement more susceptible to cracking and raveling.

The longitudinal cracks that develop at the edges of rutted wheel paths are often caused by heavy loads, especially when combined with high tire pressures. Residual stresses develop in the asphalt concrete adjacent to the wheel path as asphalt concrete in the wheel path compacts due to the excessive loads and/or tire pressures. When the residual stresses exceed the tensile strength of the pavement, longitudinal cracks develop. Figure D.3 is a typical representation of longitudinal cracking (Strategic Highway Research Program, National Research Council, 93).

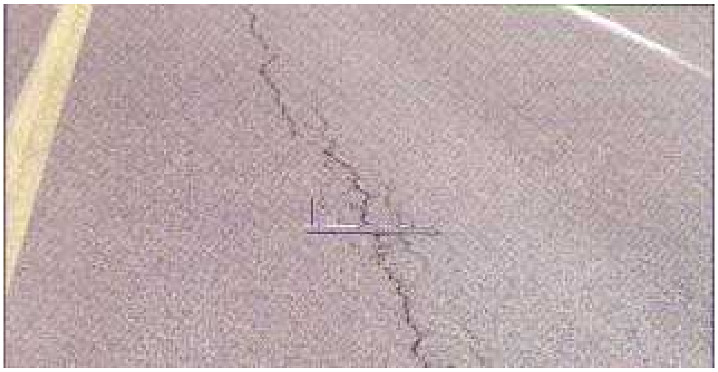


Figure D.3 Longitudinal Cracking

Sealing can repair longitudinal cracks, provided the treatment is made in the early stages of crack development. If the cracks are less than ¼ inch wide, fog seals can be used. Cracks wider than a ¼ inch must be filled with crack sealant. Once raveling develops at the crack edges, the needed repair is more extensive, sometimes requiring an overlay. In general, longitudinal crack repair typically involves a variety of maintenance techniques, depending on the severity of the crack (Roberts, et al, 96).

Transverse cracking is also referred to as low temperature or thermal cracking. Transverse cracks are perpendicular to the roadway centerline. The cracks are often approximately equally spaced. Transverse cracks develop when the surface temperature drops to a level such that thermally induced shrinkage stresses exceed the tensile strength of the asphalt concrete. Presented in Figure D.4 is an example of transverse cracking (Strategic Highway Research Program, National Research Council, 93).

Transverse crack repair is similar to longitudinal crack repair. Small transverse cracks can be fog sealed and crack sealant can be used for wide cracks. Milling can eliminate the difference in elevation of the road surface in cases where the sides of the cracks are at different elevations. In advanced stages of transverse crack development, overlays may be required (Roberts, et al, 96).

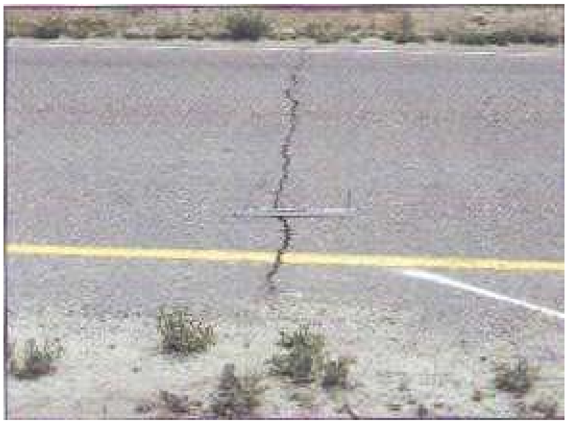


Figure D.4 Transverse Cracking

D.5 Patching

Patches are sections of pavement that have been removed and replaced. Patches are typically used to repair localized pavement defects or to cover utility trenches. A patch failure can lead to a widespread pavement distress problems. Patches are defects relative to the original pavement. Even patches in good condition can accelerate the rate of pavement distress development because it can permit the intrusion of water into the subsurface layers and subgrade if the patch is not constructed and sealed properly (Kercher, 99).

Patch cracking and distortions typically occur when the root cause of a pavement defect was not properly corrected before the patch was placed. Patches over utility trenches typically fail when the trench was not adequately back-filled and compacted. Figure D.5 exhibits a patch over a utility cut.

Patches that have minor cracking can be repaired with preventive maintenance techniques so that surface water does not enter the subsurface. Pavement sections with a high extent of severely cracked and distorted patches will need reconstruction (Roberts, et al, 96). Extensive settlement in utility trenches may require additional repair to the utility trench prior to pavement repairs (Kercher, 99).

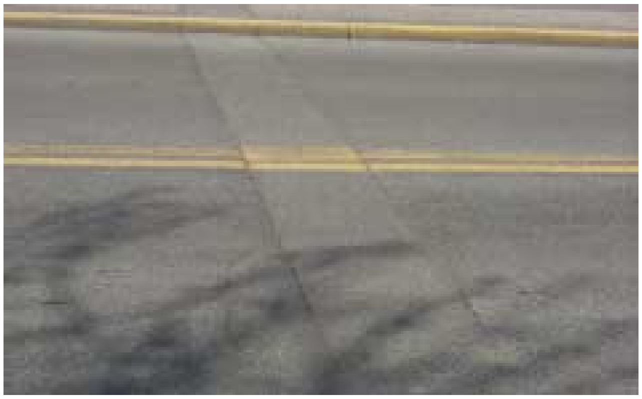


Figure D.5 Patch Over Utility Cut

D.6 Drainage Condition

Drainage condition is not a pavement distress per se. However, water can be very detrimental to the pavement and must be considered and analyzed. The severity of a poor drainage condition is judged by the ability for run-off to flow from the road surface to a location that does not influence roadway travel or surface conditions. Visual indicators of drainage problems include accumulation of debris and sand on the traveled road surface. Other directives of poor drainage include road shoulders that are above the edge of pavement, standing water, and outwashes or accumulations of sand along the edge of the road. Evaluation during or just after a rainfall can be very beneficial in assessing drainage conditions. Figure D.6 exhibits typical drainage conditions that a surveyor may encounter. Notice the standing water on the road surface and the outwashes near the edge of the pavement.

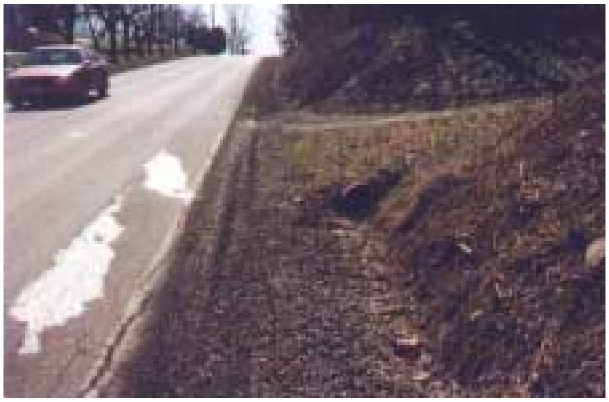


Figure D.6 Drainage Conditions

The lack of, or poor performance of, ditches, gutters, drop inlets, and other drainage structures results in poor drainage. Lack of a crown in the pavement surface also promotes water-induced damage. The crown aids in shedding water from the traveled way so that water does not stand on the surface.

Repairs for poor drainage include reestablishing or creating a crown in the road and/or maintaining or creating the necessary drainage features (NH T^2 Center, 92).

D.7 Rutting

Rutting is a depression of asphalt concrete in vehicle wheel paths. The surface depressions created in the wheel paths result from either continued consolidation or lateral displacement of the asphalt concrete under traffic. Some of the factors that cause rutting are insufficient compaction during construction, poor mix design (high asphalt content, excessive mineral filler, rounded aggregate, etc.), inadequate drainage, and poor subgrade strength. The pavement section must be carefully examined to determine the cause of the rutting before a specific treatment is selected. Figure D.7 presents an example of rutting in the wheel path of travel (Strategic Highway Research Program, National Research Coucil, 93).

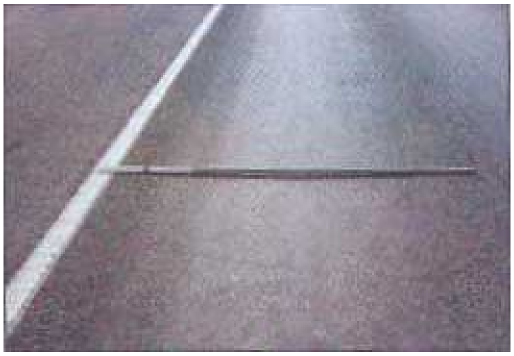
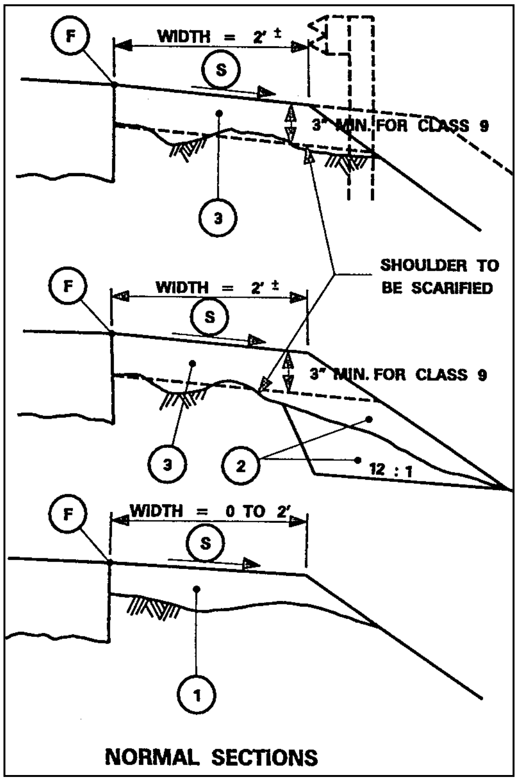


Figure D.7 Rutting

Minor rutting can be repaired with surface milling and preventive maintenance techniques, such as rut filling with microsurfacing. Major rutting requires surface milling and rehabilitation (thick overlay). Sections with poor drainage conditions also require drainage improvements to increase subgrade strength (Roberts, et al, 96).

D.8 Shoulder Condition

Water is one of a road's worst enemies. Therefore, adequate drainage is essential to a road (Kercher, 99). The Shoulders category refers to the condition of the shoulders and the how they facilitate roadside drainage. Included in this distress category is the presence of adequate shoulder material, water handling capabilities of the shoulder, edge drop-offs, and cross section template considerations. The considerations of the template include drop-offs, shoulder widths, and minimum slopes of the shoulder. The cross section templates, Figure D.8, were taken from the *WV DOH 2000 Typical Sections and Related Details.*


F
WIDTH = 2' ±
S
3" MIN. FOR CLASS 9
3
SHOULDER TO BE SCARIFIED
F
WIDTH = 2' ±
S
3" MIN. FOR CLASS 9
3
2
12 : 1
F
WIDTH = 0 TO 2'
S
1
NORMAL SECTIONS

Ⓢ SHOULDER SLOPE

Normal Sections : 6 %.

Superelevated : Match rate of superelevation or reduce as shown above. Minimum slope to be 3/4" per foot, on low side of superelevation.

Paved Shoulders : 4 % or superelevated.

Figure D.8 Shoulders (Cross section templates)

Inadequate shoulders are caused by improper construction techniques or poor maintenance procedures (Kercher, 99). Shoulder material can be removed as vehicles travel on the shoulders in curves or as they leave the pavement. Non-existent shoulders were either not installed at the time of construction or have been decreased by pavement widening projects.

To resolve the problem of poor shoulder condition, material should be added to the shoulders and compacted to the specified density. Care should be taken to meet the cross section template requirements. All edge drop-offs and non-existent shoulders should be corrected as soon as possible due to the possible safety hazard.

APPENDIX E – WV DPMS MICROSOFT ACCESS USERS MANUAL

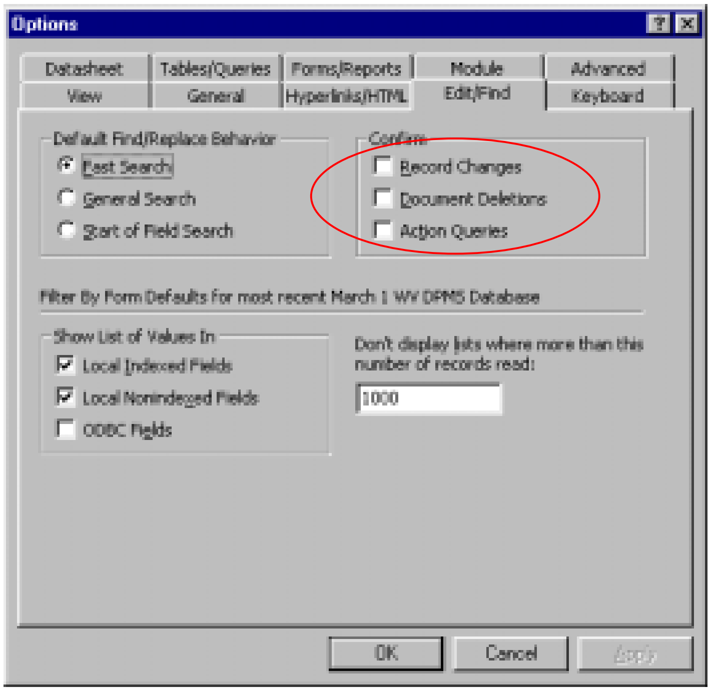
This section explains the specific steps needed to use the WV DPMS software program. The analysis is performed and the reports are generated within the Microsoft Access program. This manual is provided to guide the user through the Access program for general use and analysis, generation of reports, and procedures to update or customize the program.

E.1 GENERAL USE AND ANALYSIS

The user should initially save the WV DPMS program to the hard drive of their computer. The Microsoft Access program should be placed in an easily accessible file. To start the program, the user should locate the file and then double-click on the file icon.

The WV DPMS program was created using Microsoft Access 97. If the user has the same version of the software program, there will not be a problem. However, if the user has a later version of the software program, say Access 2000, a message will appear notifying the user of the discrepancy. The user should convert the file to Access 2000 when given the option to convert.

First, the user should turn off the confirmation messages that Microsoft Access provides. This pop-up window appears every time an update is made to the database and can be annoying for the user. To avoid seeing this message, the user should go to "***Tools***" on the menu bar and select "*Options*" and then click the "Edit/Find" tab. The user should un-check or click "off" the buttons for "*Confirm*" including "Record Changes, Document Deletions, and Action Queries". If this function has not been turned off before the WV DPMS program is opened, the user will see the Update pop-window when the program begins. The user should just check "OK" to update the data records. Once the initial update is performed, the user should locate and turn off the confirmation messages to avoid seeing them again. Figure E.1 exhibits the screen that the user must locate to turn off the confirmation messages.


Options
Datasheet
Tables/Queries
Forms/Reports
Module
Advanced
View
General
Hyperlinks/HTML
Edit/Find
Keyboard
OK
Cancel
Apply

Default Find/Replace Behavior
● Fast Search
○ General Search
○ Start of Field Search

Confirm
☐ Record Changes
☐ Document Deletions
☐ Action Queries

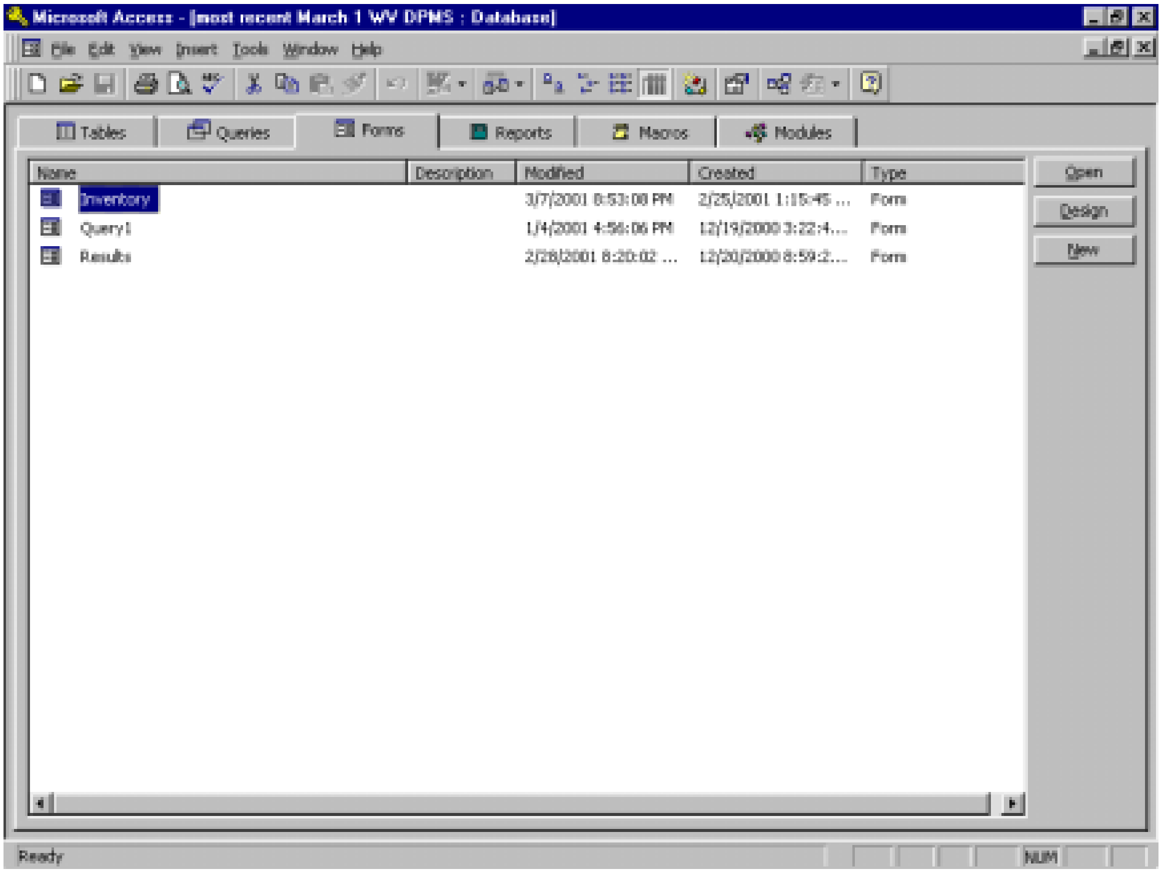
Filter By Form Defaults for most recent March 1 WV DPMS Database

Show List of Values In
☑ Local Indexed Fields
☑ Local Nonindexed Fields
☐ ODBC Fields

Don't display lists where more than this number of records read: 1000

Figure E.1 MS Access Screen to turn off Confirmation Messages

To begin the data entry or analysis, the user should click on the "***Forms***" tab. Then double-click the "*Inventory*" form or highlight it and click "*Open*", Figure E.2. Once the "*Inventory*" form is open, the user will see two tabs – "*Inventory Data*" and "*Condition Data and Treatment Selection*". First, click on the "*Inventory Data*" tab. The inventory data that is collected is entered on this part of the form. The following steps should be taken when entering data on the "*Inventory Data*" part of the "***Inventory***" form, Figure E.3.


Microsoft Access - [most recent March 1 WV DPMS : Database]
File
Edit
View
Insert
Tools
Window
Help
Tables
Queries
Forms
Reports
Macros
Modules
Open
Design
New
Ready
NUM

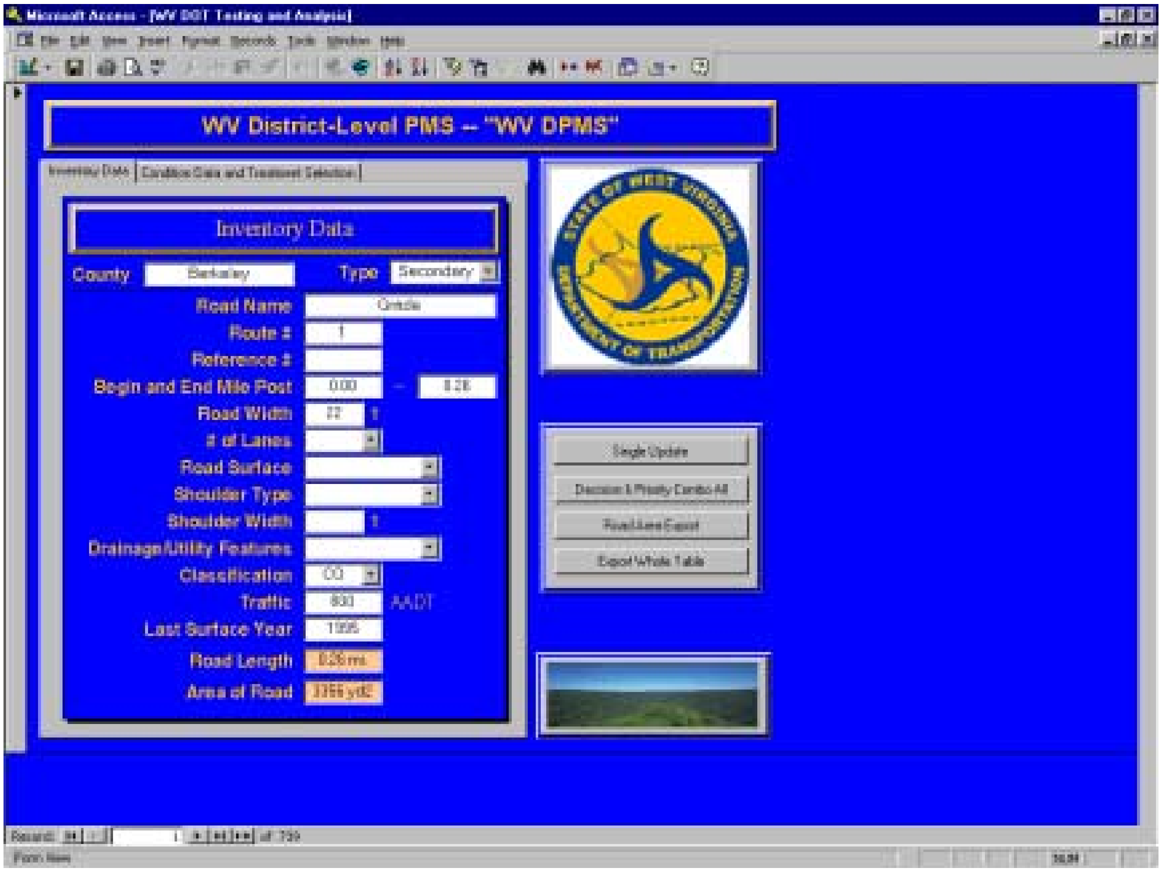
Name	Description	Modified	Created	Type
Inventory		3/7/2001 8:53:08 PM	2/25/2001 1:15:45 ...	Form
Query1		1/4/2001 4:56:06 PM	12/19/2000 3:22:4...	Form
Results		2/28/2001 8:20:02 ...	12/20/2000 8:59:2...	Form

Figure E.2 Opening up the WV DPMS Data Entry Forms

- The first thing that is entered is the name of the county the road section is located in.
- Next, click on the arrow of the selection box for the type of the road section and choose primary or secondary.
- Then type in the road name and route number of the road section in the appropriate boxes.
- The next box is open to enter the reference number for the road section. The reference number will be used when the database is linked to a GIS program. This data entry can be neglected if the users are not using and linking to a GIS program.
- Following this step, the beginning and end mileposts should be typed into the respective boxes, with the beginning mileposts entered first.

- The width of the road surface in feet should be typed into the appropriate box next.
- Then click on the arrow of the selection box for the road surface and the shoulder type or simply type in the appropriate text. The default for the road surface is HMA, hot mix asphalt, and the defaults for shoulder type are paved, gravel, earth, and curb and gutter. The user can enter text other than the default choices if they encounter a type that is not shown in the drop down box.
- The next data entry is the shoulder width in feet. This value is typed into the appropriate box.
- Next, click on the arrow of the selection box for drainage/utility features. The defaults for this category are manholes and drop inlets, but the user can type in other text if needed.
- Click on the arrow of the selection box for classification and choose the appropriate one. The options are “US”, “WV”, “CO”, and “HA”. The user must choose one of these four options.
- Enter the traffic volume (AADT) for the road section into the appropriate box.
- Finally, enter the last year the road section was repaired. This value should be typed into the correct box.

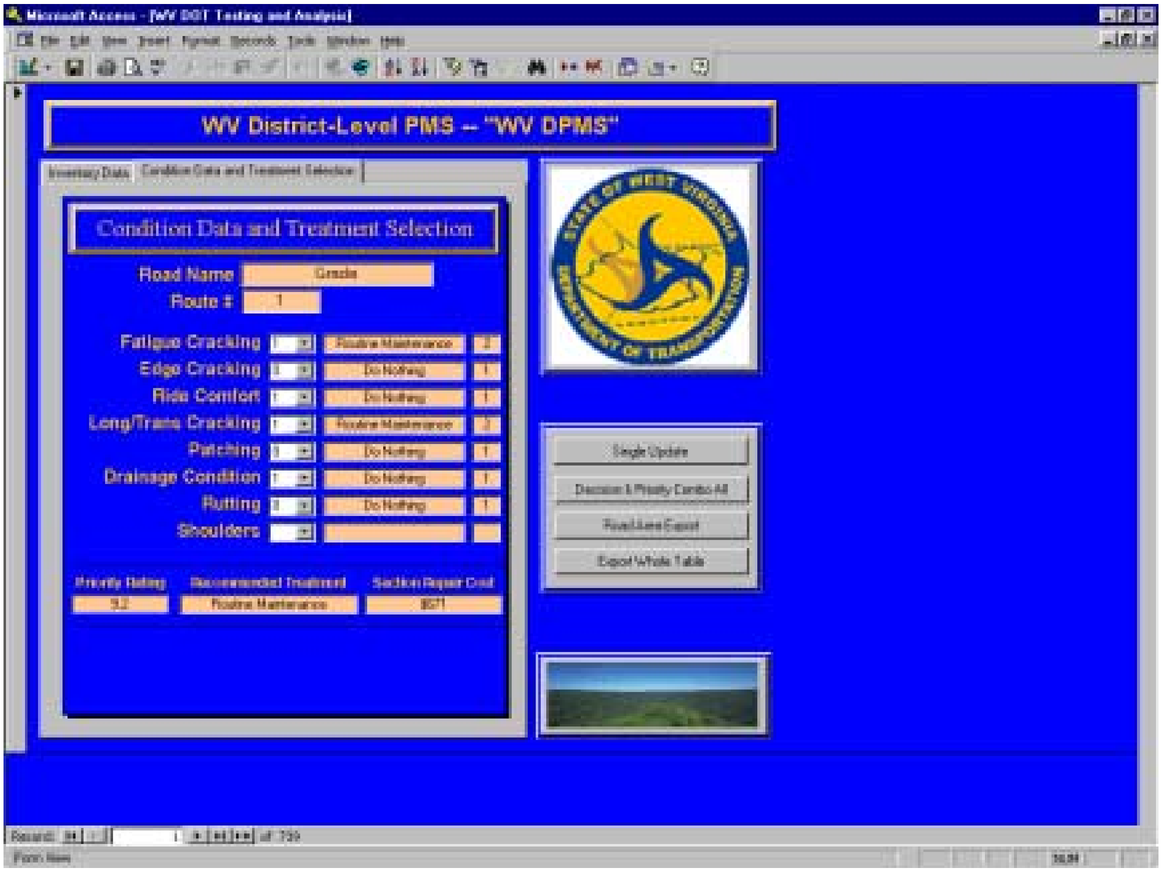
The program calculates the road length and area.


Microsoft Access - [WV DOT Testing and Analysis]
File Edit View Insert Format Records Tools Window Help
WV District-Level PMS -- "WV DPMS"
Inventory Data
Condition Data and Treatment Selection
Inventory Data
Single Update
Decision & Priority Combo All
Road Area Export
Export Whole Table
Record: 1 of 759
Form View

County: Berkeley
Type: Secondary
Road Name: [illegible]
Route #: 1
Reference #:
Begin and End Mile Post: 0.00 – 0.26
Road Width: 22 ft
# of Lanes:
Road Surface:
Shoulder Type:
Shoulder Width: ft
Drainage/Utility Features:
Classification: CO
Traffic: 800 AADT
Last Surface Year: 1995
Road Length: 0.26 mi
Area of Road: 3356 yd2

Figure E.3   WV DPMS Inventory Data Entry Form

Next, click on the "*Condition Data and Treatment Selection*" tab. The condition data that is collected is entered and the recommendations for each section are displayed on this part of the form. The user does not need to enter data in the gold colored boxes of the form. They are for informational purposes and to display calculated values. The following steps should be taken when entering data and performing the analyses on the "*Condition Data and Treatment Selection*" part of the form, Figure E.4.


Microsoft Access - [WV DOT Testing and Analysis]
File Edit View Insert Format Records Tools Window Help
WV District-Level PMS -- "WV DPMS"
Inventory Data
Condition Data and Treatment Selection
Single Update
Decision & Priority Combo All
Road Area Export
Export Whole Table
Record: 1 of 759
Form View

Condition Data and Treatment Selection

Road Name: Grade

Route #: 1

Fatigue Cracking	1	Routine Maintenance	2
Edge Cracking	3	Do Nothing	1
Ride Comfort	1	Do Nothing	1
Long/Trans Cracking	1	Routine Maintenance	2
Patching	3	Do Nothing	1
Drainage Condition	1	Do Nothing	1
Rutting	3	Do Nothing	1
Shoulders			

Priority Rating	Recommended Treatment	Section Repair Cost
5.2	Routine Maintenance	$571

Figure E.4   WV DPMS Condition Data and Treatment Selection Form

- Click on the arrow of the selection boxes for each of the eight distresses and select the appropriate distress values. The values can be typed in directly but the program will only accept the default values.
- Next, to run the analysis on the individual road section under, click on the "Single Update" button, Figure E.5. The recommended treatment, section repair cost, and priority rating are calculated and displayed on the form. Two pop-up windows will appear on the screen that notify the user of the section's recommended treatment and which distress(es) triggered the recommended treatment. The user can see which is the most dominant, severe distress encountered on the road section. Simply close the

windows by clicking on the "OK" button on the first pop-up window and by clicking on the "Close Form" button (looks like a door shutting) on the second window.

- To run the analyses on all of the road sections at once, click on the "Decision & Priority Combo All" button, Figure E.5. The function is utilized if the user changes the priority weighting factors, unit cost values, or some other values and wants to re-analyze all of the data at once. Clicking this button will run the analyses and select a recommended treatment, section repair costs, and priority rating for all road sections being managed.

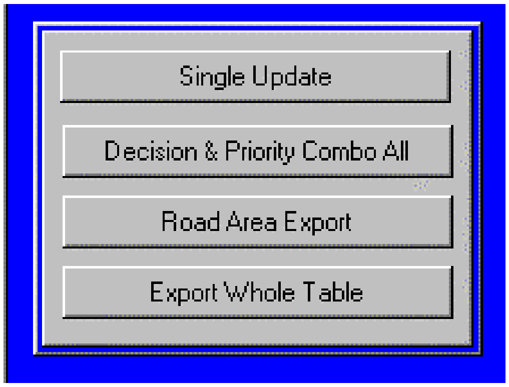


Figure E.5 Buttons on WV DPMS Data Entry Forms

- Two optional buttons, "Road Area Export" and "Export Whole Table", have been added to the "***Inventory***" form, Figure E.5. These buttons should be clicked after all of the sections have been analyzed and a treatment, section repair cost, and priority rating has been designated for each section. Clicking on "Road Area Export" will query the data and sum the area of the road surface for each of the six recommended treatments. *Please note that the treatments are presented in alphabetical order and may not be in the order you have seen them in before.* A pop-up window will appear when the button is "Road Area Export" is clicked. Select the option to save the Road Area Query to an external file or database and then click "OK". When given the option, change the “Save as Type” to Microsoft Excel (*.xls) and select where the file should be saved. This Excel file will be accessed later for use in the performance model.

The second optional button “Export Whole Table” sends the entire database to an external file. This button could be clicked after the analyses are performed on all of the road sections. The raw data could be e-mailed to someone or used to manipulate the data in another format, say Microsoft Excel. Presently, the file is saved and exported to the C: drive of the computer in an Excel file. The file name and location is C:\table.xls. This can be changed if so desired by going to the design view of the “Export Whole Table” macro under the “***Macros***” tab, Figure E.6 and Figure E.7. The “File Name” can be changed to whatever is desired.

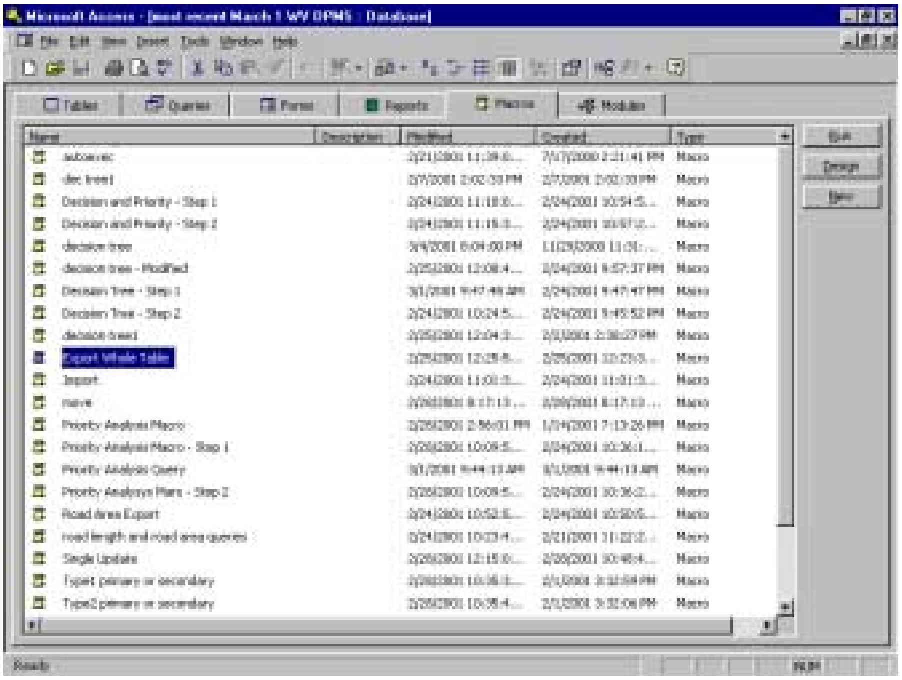
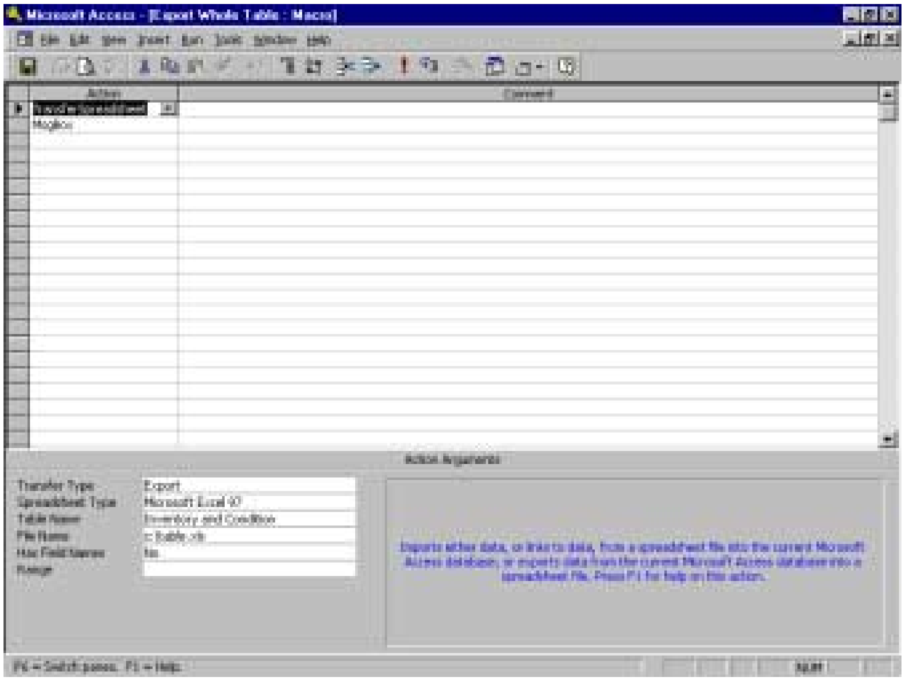


Figure E.6 WV DPMS Macros Selection Screen


Microsoft Access - [Export Whole Table : Macro]
File Edit View Insert Run Tools Window Help
Action
Comment
Action Arguments
F6 = Switch panes. F1 = Help.
NUM

TransferSpreadsheet
MsgBox

Transfer Type: Export
Spreadsheet Type: Microsoft Excel 97
Table Name: Inventory and Condition
File Name: c:\table.xls
Has Field Names: No
Range:

Imports either data, or links to data, from a spreadsheet file into the current Microsoft Access database, or exports data from the current Microsoft Access database into a spreadsheet file. Press F1 for help on this action.

Figure E.7 WV DPMS screen to change file export

In subsequent years, the same WV DPMS Access program file can be copied as used as a template for the next year's data. Right-click on the previous year's file and select Copy. Then right-click on another area in the file/directory and select Paste. The existing WV DPMS will be copied in the same folder/directory as the previous year's file. The copy will be named "Copy of *name*.mdb". The user should right-click on the copy and choose to rename the file. The new file should follow the proposed naming process. The file name should be D (district number) (current year) WV DPMS.mdb. For instance, if District 5 was preparing to enter their 2003 condition data, the new file would be D5 2003 WV DPMS.mdb. This new file should be used to input the current condition data and to perform the analyses.

The user should *not* delete the previous years' WV DPMS. The files should be archived and retained to build a historical database. The database is relatively small, approximately 670 kilobytes, and will not use much space on the computer's hard drive.

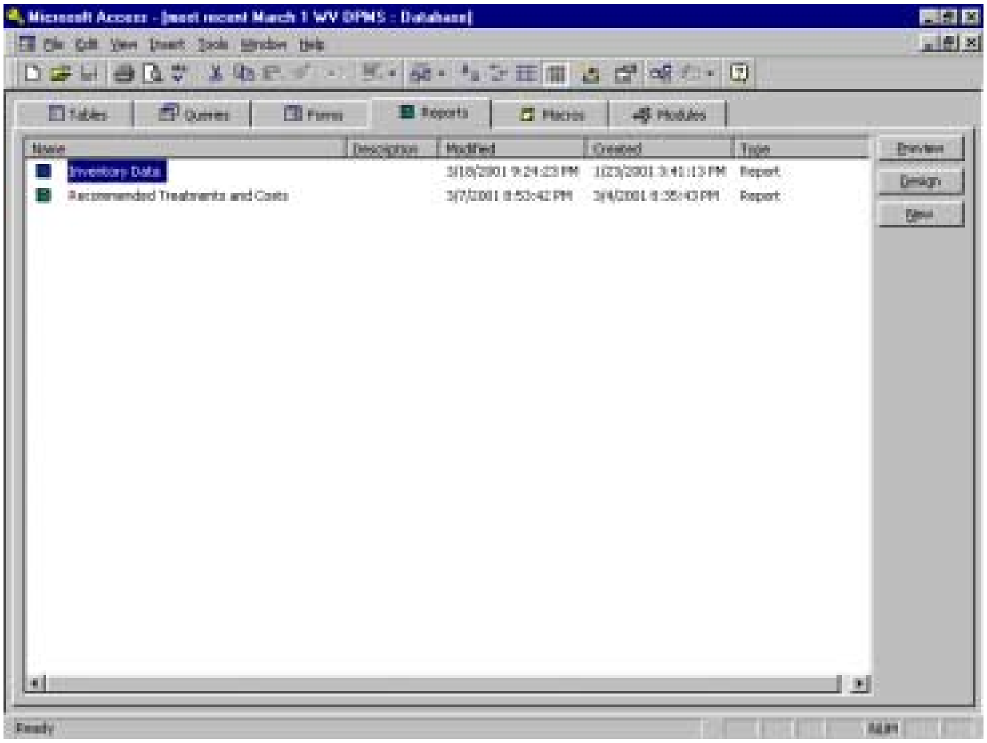
The user should back up the WV DPMS on a floppy disk for precautionary measures. If something should happen to the computer's hard drive, the user will have a copy of the database. The backup copies may also be necessary in future years if the hard drive is reaching capacity and the user wants to maintain the archival of the data.

E.2 GENERATION OF REPORTS

The essential reports have already been designed and created for the users. It is not necessary to manually create a new report each time that the user changes data in the database. Microsoft Access gathers the most current data from the database to create the new report. This ensures that the report always displays the most current information. The following steps should be taken to access and print out the reports.

To view or print out the inventory data, the user should click on the "***Reports***" tab, Figure E.8. Then double-click the "*Inventory Data*" report or highlight it and click "*Preview*". Once the "*Inventory Data*" report is open, the user can view the reports and/or print them. To print the files, choose File from the tool bar and then select Print.

The same process is performed to view/print the report containing the recommended treatments and repair costs. Click on the "***Reports***" tab and then double-click on the "*Recommended Treatments and Costs*" report. The user could also highlight the report by clicking on it once and clicking "*Preview*". Choosing Print from the File option on the tool bar can print the report.

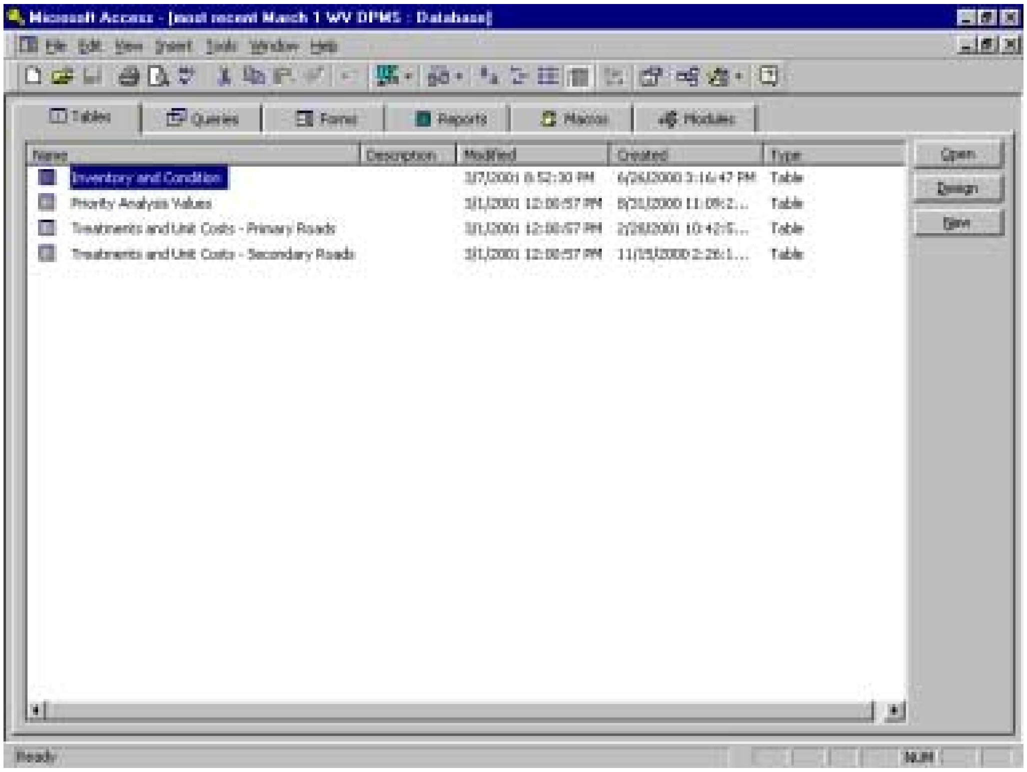

Microsoft Access - [most recent March 1 WV DPMS : Database]
File
Edit
View
Insert
Tools
Window
Help
Tables
Queries
Forms
Reports
Macros
Modules
Preview
Design
New
Ready
NUM

Name	Description	Modified	Created	Type
Inventory Data		3/18/2001 9:24:23 PM	1/23/2001 3:41:13 PM	Report
Recommended Treatments and Costs		3/7/2001 8:53:42 PM	3/4/2001 8:35:43 PM	Report

Figure E.8 WV DPMS Report Selection Screen

E.3 UPDATING AND CUSTOMIZING WV DPMS

The WV DPMS has been created to be easily customizable and updated. If the user decides to change factors or values, the program can accommodate the changes. For instance, if the user wants to change the weights assigned to each of the factors included in the priority rating calculation, the following steps should be performed. First, click on the "***Tables***" tab, Figure E.9, and then double-click on the "*Priority Analysis Values*" table. The user can then alter the traffic weighting factor, the classification weighting factor, or the distress index weighting factor. After changing these values, the user should re-analyze the data to calculate the new priority rating value.


Microsoft Access - [most recent March 1 WV DPMS : Database]
File Edit View Insert Tools Window Help
Tables
Queries
Forms
Reports
Macros
Modules
Open
Design
New
Ready
NUM

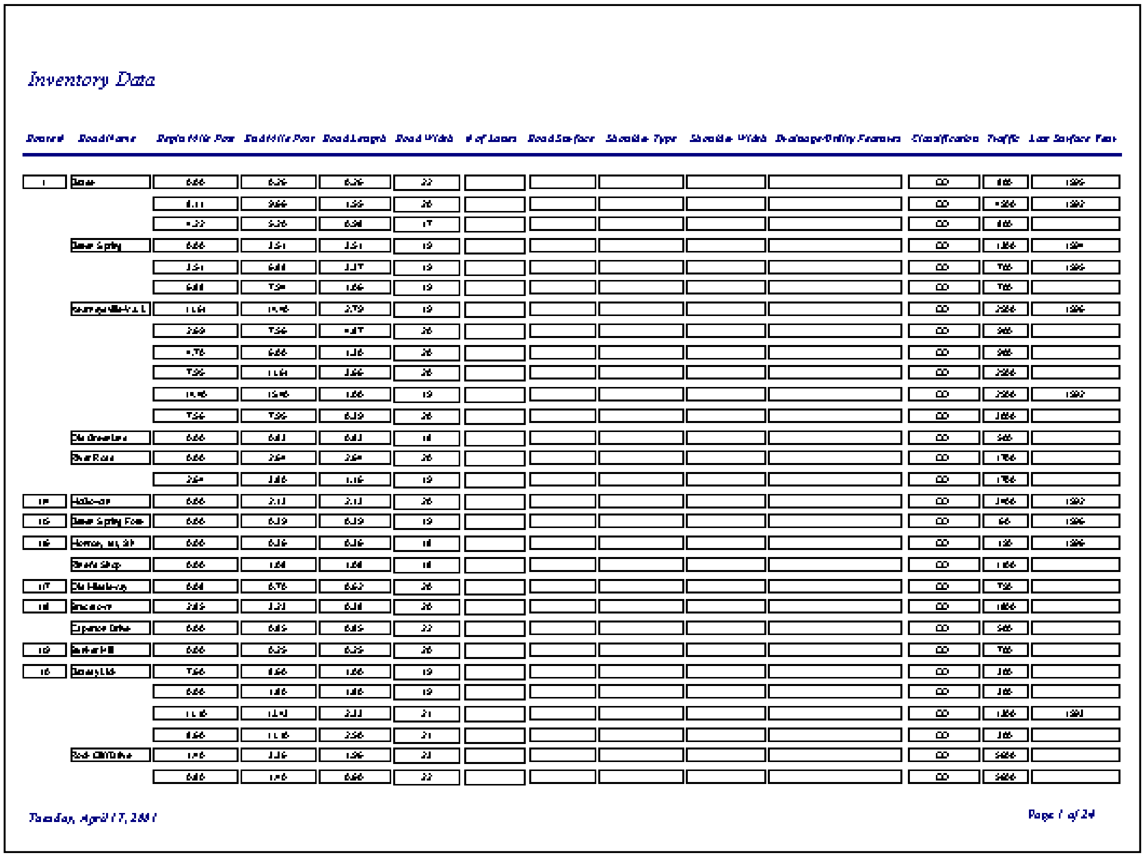
Name	Description	Modified	Created	Type
Inventory and Condition		3/7/2001 8:52:30 PM	6/26/2000 3:16:47 PM	Table
Priority Analysis Values		3/1/2001 12:00:57 PM	8/31/2000 11:09:2...	Table
Treatments and Unit Costs - Primary Roads		3/1/2001 12:00:57 PM	2/28/2001 10:42:5...	Table
Treatments and Unit Costs - Secondary Roads		3/1/2001 12:00:57 PM	11/15/2000 2:26:1...	Table

Figure E.9   WV DPMS Table Selection Screen

The user can also easily change the unit costs for the treatments. This would be necessary in future years if the costs fluctuate from what is presently in the program or if another district uses WV DPMS and has different unit cost values for the treatments. The user should click on the "***Tables***" tab and then double-click on either the "*Treatments and Unit Costs – Primary Roads*" or the *"Treatments and Unit Costs – Secondary Roads"* table, depending on which unit costs they want to change. The user can then alter the unit costs values by clicking the cell of the value they want to change and then typing in the new value. After changing these values, the user should re-analyze the data to calculate the new section repair costs. The user may also want to create new reports with the new data. The unit costs used in the Performance Model should also be changed accordingly to remain consistent and to create accurate models. The unit costs for the Performance model exist in a Microsoft Excel file and are not linked to the WV DPMS Access program.

Another customization of the program that may be necessary is changing the decision tree properties. This will involve modifying the decision tree macros by clicking on the "***Macros***" tab, Figure E.6, and then highlighting the "decision tree" and "decision tree – Modified" macros and clicking "Design". Once the macro is open in the design view, the user can change the treatment type that corresponds with the distresses. For example, if the user feels that Rehabilitation should be recommended when Fatigue Cracking is given a value of 6, the user will set the Number value to 4 and set the Word value to Rehabilitation. The changes should be saved when prompted to do so. It is recommended that only experienced Access users attempt to alter the decision tree macros. The macros can be altered, but errors can result and make the decision process inoperable. The user should make a backup copy of the program before changing these parameters. Along the same lines, the user should not delete any queries or macros that have already been created for WV DPMS or change the names of tables, queries, forms, or reports.

APPENDIX F – SAMPLE INVENTORY AND CONDITION DATA REPORTS FOR DISTRICT 5 FROM WV DPMS ACCESS PROGRAM



Inventory Data

Tuesday, April 17, 2001

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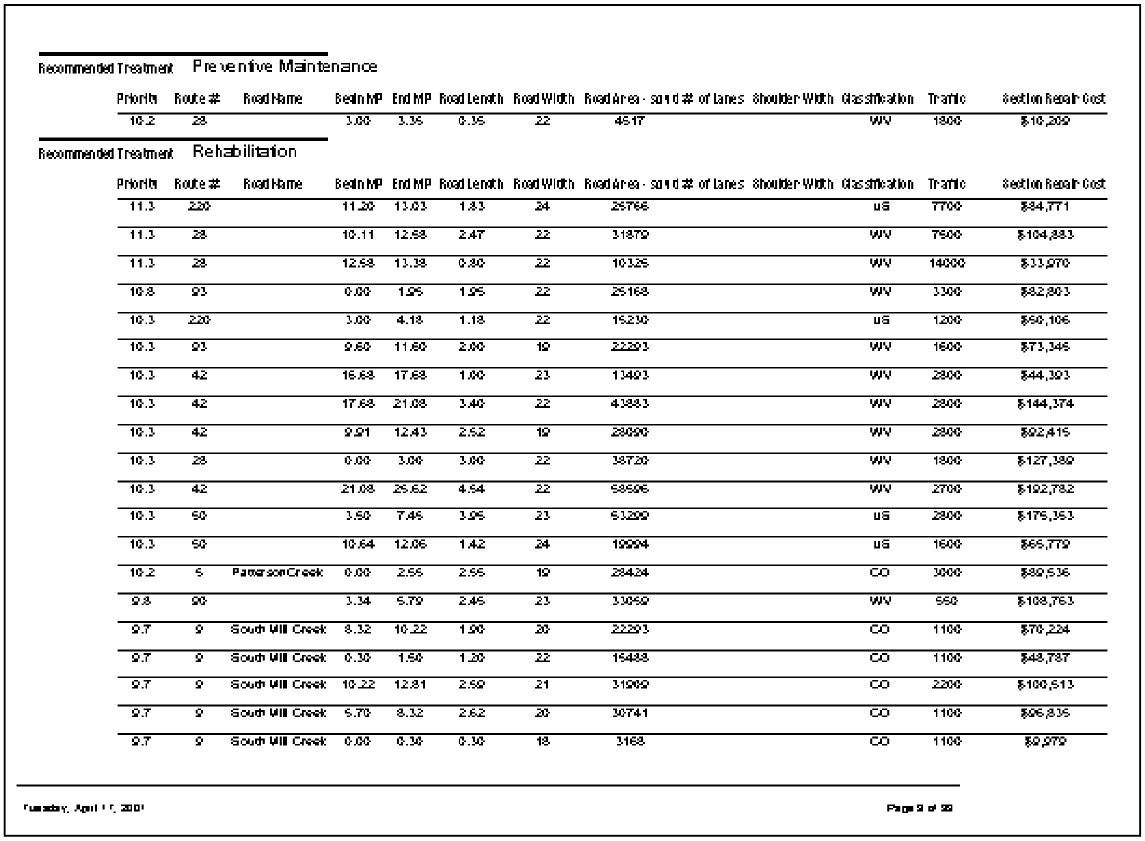

Recommended Treatment **Preventive Maintenance**

Priority	Route #	Road Name	Begin MP	End MP	Road Length	Road Width	Road Area - sq yd	# of Lanes	Shoulder Width	Classification	Traffic	Section Repair Cost
10.2	28		3.00	3.36	0.36	22	4517			WV	1800	$10,209

Recommended Treatment **Rehabilitation**

Priority	Route #	Road Name	Begin MP	End MP	Road Length	Road Width	Road Area - sq yd	# of Lanes	Shoulder Width	Classification	Traffic	Section Repair Cost
11.3	220		11.20	13.03	1.83	24	25766			US	7700	$84,771
11.3	28		10.11	12.58	2.47	22	31879			WV	7500	$104,883
11.3	28		12.58	13.38	0.80	22	10326			WV	14000	$33,970
10.8	93		0.00	1.95	1.95	22	25168			WV	3300	$82,803
10.3	220		3.00	4.18	1.18	22	15230			US	1200	$50,106
10.3	93		9.60	11.60	2.00	19	22293			WV	1600	$73,346
10.3	42		16.68	17.68	1.00	23	13493			WV	2800	$44,393
10.3	42		17.68	21.08	3.40	22	43883			WV	2800	$144,374
10.3	42		9.91	12.43	2.52	19	28090			WV	2800	$92,415
10.3	28		0.00	3.00	3.00	22	38720			WV	1800	$127,389
10.3	42		21.08	25.62	4.54	22	58596			WV	2700	$192,782
10.3	50		3.50	7.46	3.96	23	53299			US	2800	$175,353
10.3	50		10.64	12.06	1.42	24	19994			US	1600	$65,779
10.2	5	Patterson Creek	0.00	2.56	2.56	19	28424			CO	3000	$89,536
9.8	90		3.34	5.79	2.45	23	33059			WV	550	$108,763
9.7	9	South Mill Creek	8.32	10.22	1.90	20	22293			CO	1100	$70,224
9.7	9	South Mill Creek	0.30	1.50	1.20	22	15488			CO	1100	$48,787
9.7	9	South Mill Creek	10.22	12.81	2.59	21	31909			CO	2200	$100,513
9.7	9	South Mill Creek	5.70	8.32	2.62	20	30741			CO	1100	$96,835
9.7	9	South Mill Creek	0.00	0.30	0.30	18	3168			CO	1100	$9,979

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VITA

Anthony W. Ford was born in Fairlea, West Virginia on September 17, 1976. He was raised in Union, West Virginia and graduated from Union High School in June 1994. In May 1999, Anthony received his bachelor of science degree in Civil Engineering from West Virginia University in Morgantown, West Virginia. He then focused his studies on Transportation Engineering and obtained his master of science degree in Civil Engineering from West Virginia University in May 2001.

Throughout his years as a college student, Anthony was employed by the West Virginia Department of Transportation Division of Highways. While in graduate school, he was employed by the West Virginia Transportation Technology Transfer Center. Anthony also fulfilled the first step to becoming a Professional Engineer by passing the Fundamentals of Engineering Exam to become an Engineer Intern.