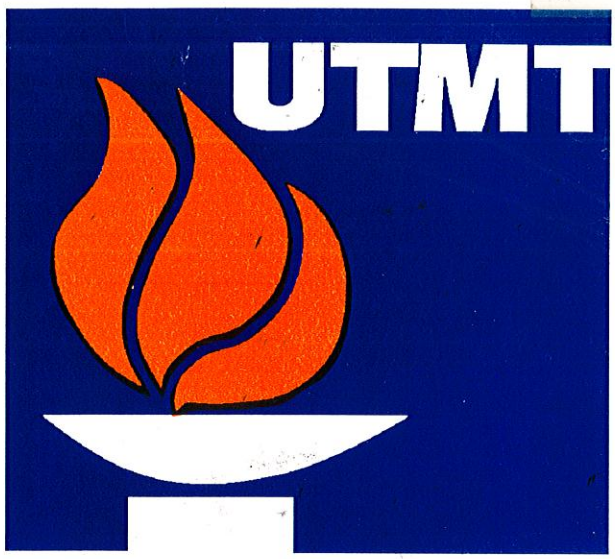

The University of Tennessee Municipal Training

Pavement Management

Sponsored by The University of Tennessee's Center for Government Training
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In cooperation with Tennessee Municipal League and its affiliate groups

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LETTER TO PARTICIPANTS

Municipal governments are under constant pressure to deliver services more efficiently. As a municipal government professional you must continually evaluate your performance in terms of productivity and effectiveness to keep pace with today's demands as well as to prepare for tomorrow's challenges. You must keep up with new trends, sharpen old techniques and acquire new skill. Your participation in *The University of Tennessee Municipal Training Program* (UTMT) will help prepare you for the challenges of public service.

The UTMT program is a comprehensive certificate program focusing on six major functions necessary for the smooth operation of municipal government. The courses included in each functional area are carefully tailored to meet the needs of municipal professionals. Courses are developed and delivered through a cooperative effort with The University of Tennessee's Municipal Technical Advisory Service, the Tennessee Municipal League, its affiliate organizations and state and national resources. In addition to the knowledge and management insights you will acquire, UTMT courses provide an opportunity for you to discuss issues and share ideas with other municipal professionals. I encourage you to learn more about the UTMT program.

Today's course materials were developed by Mr. Alex B. Moore, Associate Professor of Civil Engineering, The University of Tennessee, Knoxville. Today's program is sponsored in cooperation with The University of Tennessee's Transportation Center, Dr. Stephen H. Richards, Program Director; Mr. Don Jones, Assistant Director; and Ms. Mary Ann Gregory, Program Director of the Training Division. Our sincere thanks is extended to these individuals.

On behalf of the staff of the Center for Government Training. I welcome you to *The University of Tennessee Municipal Training Program*. By your participation in this course, you are joining an outstanding group of municipal professionals who realize that education is a life-long process. We applaud your commitment to public service and professional development.

Sincerely,

Patricia Davis

Patricia C. Davis
Executive Director

PAVEMENT MANAGEMENT

THE UNIVERSITY OF TENNESSEE
CENTER FOR GOVERNMENT TRAINING

TRANSPORTATION CENTER

and
MUNICIPAL TECHNICAL ADVISORY SERVICE

in cooperation with the
TENNESSEE MUNICIPAL LEAGUE

PARTICIPANT MANUAL
February 1992

PAVEMENT SURFACE MANAGEMENT

Table of Contents

ACKNOWLEDGEMENTS

Much of the information contained in this course was taken directly from two sources: 1) "Road Surface Management System", developed through the Technology Transfer Center, The University of New Hampshire, Sept. 1989, and 2) "Road Surface Management for Local Governments", prepared by ARE Inc.-Engineering Consultants, for FHWA, December 1999. The author expresses gratitude to these sources as well as the University of Tennessee's Center for Government Training and the Transportation Research Center.

COURSE SCHEDULE [PLATE 3]

9:00 - 9:30	Introduction
9:30 - 10:00	Slides Showing Important Pavement Surface Conditions.
10:00 - 10:15	BREAK
10:15 - 12:00	Conducting a Surface Condition Inventory
12:00 - 1:00	LUNCH
1:00 - 3:00	Field Experience
3:00 - 3:30	Reporting & Prioritizing
3:30 - 4:00	Summary & Evaluation

INTRODUCTION

Pavement surface management may be defined as the application of pavement management principles to the needs of local governments, including the management of flexible pavements and unpaved surfaces. Most governmental agencies have road and street responsibilities and; therefore, practice road surface management. Many agencies have developed well thought-out programs based upon the judgement and experience of long-term employees. The purpose of this training course is to identify areas where current road surface management practices might be improved. The course emphasizes building upon the best features of current practices rather than changing to dramatically different or sophisticated systems.

A comprehensive surface management program consists of a coordinated set of activities. All are directed toward achieving the best value possible for the available public funds in providing and operating smooth, safe, and economical road surfaces. Typical activities include inventory, condition assessment, selection of maintenance and rehabilitation strategies, predicting needs, requirements, and budgeting necessary funds. **[Plate 4]**

When costs were lower, establishing and adhering to maintenance budgets was easier. Unfortunately, this tradition has given way to sporadic maintenance as tax dollars are stretched further and further to cover other demands for municipal services. The importance of a good road surface management program can, perhaps, be best illustrated by Figure 1. **[Plate 5]** It is easily seen that the penalty for postponing pavements maintenance/rehabilitation is quite severe.

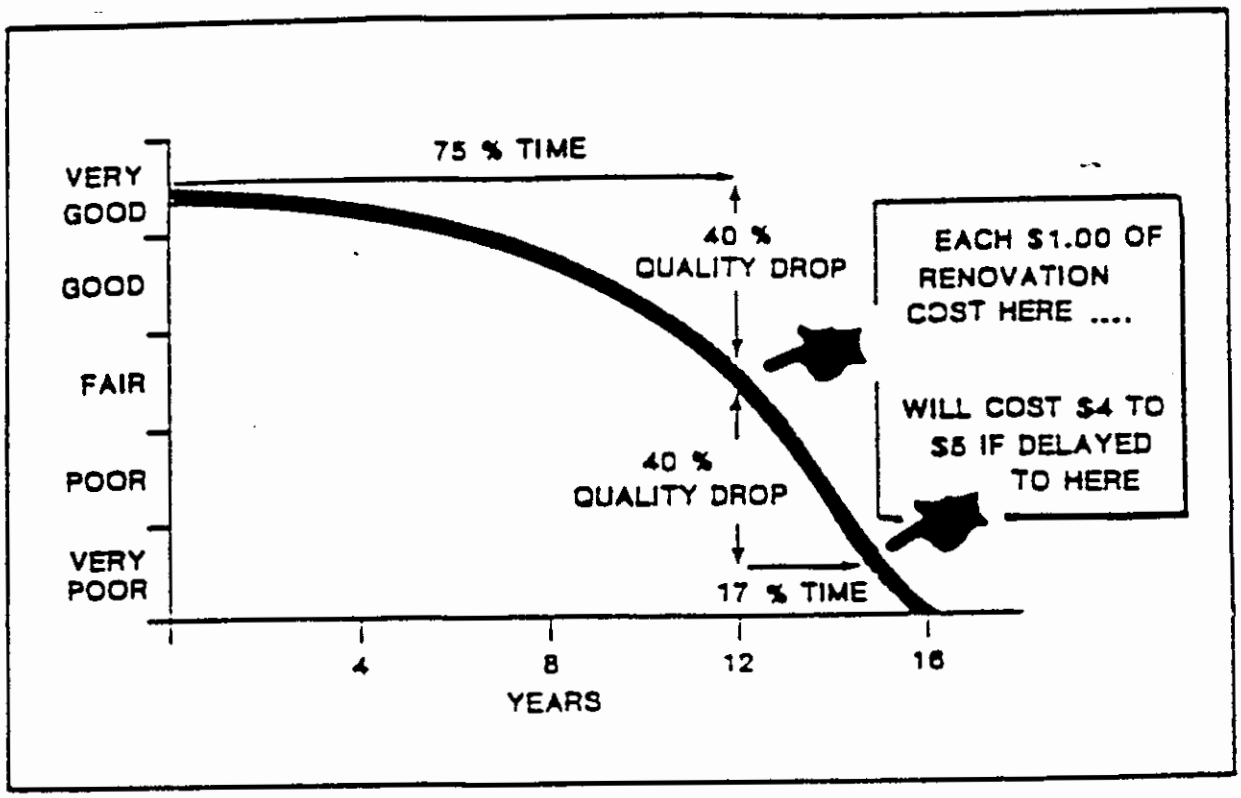


FIGURE 1. COSTS OF DELAYING NEEDED REPAIRS (Plate 5)

Surface Management Concepts

Road and street surfaces represent the largest single share of the transportation investment in most communities. It has been estimated that 40 percent of the public funds spent for roads, streets, and highways are spent on pavements. Agencies must make effective decisions regarding maintenance, repair, rehabilitation, and reconstruction of road surfaces. The concept of road surface management is to improve the efficiency of the way in which these decisions are reached.

Without sufficient information, the following types of decision criteria might be used:

- Budget the same amount of money that was budgeted last year with an arbitrary increase or decrease.
- Establish a program based upon periodic maintenance, such as crack sealing every other year, seal coats every four years, and overlays every 12 years.
- Respond to emergency demands and citizen complaints as they arise.
- Use political considerations to establish programs and budgets.
- Rely on the knowledge, experience, and "gut feel" of managers and experienced employees. [**Plate 6**]

These criteria, individually or in combination, may be satisfactory if there are adequate funds and the majority of surfaces are in satisfactory condition. However, if the road network is in bad shape and getting worse at the same time that funding sources are getting harder to find and pressure exists to lower taxes, then it becomes obvious that a better decision making process is needed. In this environment, questions that might arise are:

- For how many miles of roads and what types of pavement are we responsible?
- Should maintenance effort be used on our best or our worst roads?
- What will happen to our roads if maintenance funds are reduced 10 percent?

- Is it more cost-effective to repair and seal, overlay, recycle, or completely reconstruct a particular road?

- What are our maintenance and rehabilitation requirements over the next five years?

- How can the available money be spent in the most cost-effective way? **[Plate 7]**

The process of performing an inventory of the pavement network, assessing condition of the network, weighing alternatives, and establishing long-term programs and budgets can be much more effective if approached from a road surface management point of view.

Potential Benefits of a Systematic Apporoach

Many experienced local government engineers are already making cost-effective surface management decisions. They recognize the many benefits to approaching the management of road and street surfaces on a systematic basis. These benefits include:

- The ability to gather, organize, and store essential information so that the whole organization benefits. There is a danger to having valuable knowledge and experience locked "in the head" of one individual. Too often, this information is not effectively passed on to others when that key individual leaves the organization. **[Plate 8]**

- Help in understanding the performance of pavements. To make the best possible decisions, an agency must understand the performance of pavements (the term "performance" here is defined as condition deterioration over time), and relate specific maintenance and rehabilitation actions, costs, and performance to each other. **[Plate 9]**

- Long-range plans and annual budgets for labor, equipment, material, and contract requirements can be arrived at logically, with a minimum of guesswork and "gut feel." **[Plate 10]**

- Needs can be communicated to the elected board in a convincing manner. Like most people, elected officials, are more easily convinced with facts and figures rather than opinions. A systematic approach yields enough information so that decision makers know the consequences of their decisions. If a budget is cut or increased, the impact on the road can be described in measurable, understandable terms. **[Plate 11]**

- Provides backup and justification for agency decisions and actions. Individual citizens may criticize road maintenance decisions, operations, and conditions. However, when a manager can express knowledge of a situation, relay the plan to correct a problem, and explain how an individual road fits into the overall needs of the community, then criticism can be minimized. [**Plate 12**]

- Priorities and needs can be defined so that the greatest benefit can be achieved for the available money. In other words, the "greatest bang for the buck". [**Plate 13**]

Features of a Surface Management System

Some of the features of a systematic surface management program are illustrated in Figure 2. [**Plate 14**] These features are described below:

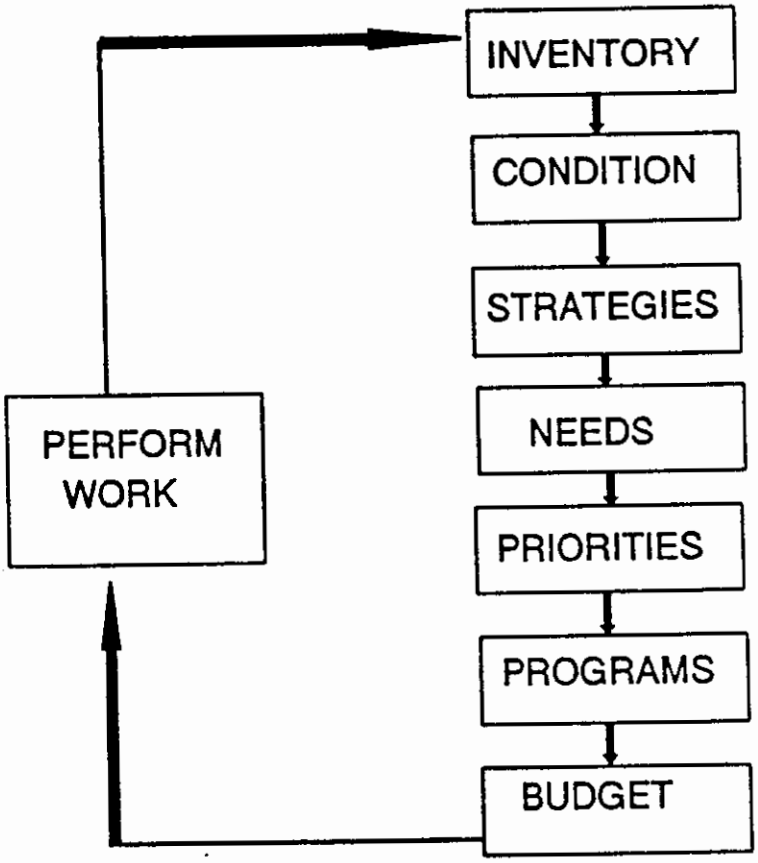


FIGURE 2. SURFACE MANAGEMENT SYSTEM COMPONENTS

Perform Work. First is a need to recognize the importance of sound work practice. Improvements in basic engineering practices can be as important as a systematic program. There are a number of factors that affect the performance of pavements and should be appreciated by local engineers when designing, building, and maintaining pavements. The application of proven techniques will result in engineered pavements rather than pavements that evolved through guesswork. Timing of maintenance and rehabilitation actions can be as important as the action itself. Once a pavement has begun to deteriorate rapidly, the cost to repair can increase dramatically, as illustrated earlier.

Inventory. The first step in systematic management is to obtain an inventory of the road network. It is impossible to adequately plan for maintenance and rehabilitation needs without knowing the size and characteristics of the network. The inventory should be as simple as possible, while still collecting the required information. Types of information that may be needed are:

- Section description/identification
- Functional and administrative classifications
- Pavement structure characteristics
- History, including costs
- Traffic information
- Geometry
- Drainage characteristics [Plate 15)

Condition. The next step is a condition survey. In the past, maintenance personnel relied on experience and personal knowledge of the network to schedule maintenance and rehabilitation. This may work fine as long as there no changes in personnel and as long the elected board does not question opinions.

A systematic condition rating procedure can produce an objective measurement of pavement performance over time, in terms that laymen find easy to understand. A condition rating procedure will not replace good judgement and experience, but rather supplement them.

There are four basic condition rating techniques including distress, skid resistance, roughness, and structural surveys. [Plate 16] Distress surveys are the most common methods used to evaluate pavement condition. Skid resistance is not normally measured by local agencies, but can provide an indication of the safety characteristics of the surface. Roughness measurement and structural testing can be helpful to local agencies.

Of the four condition assessment procedures, however, distress surveys are perhaps the most useful to local governments. In fact, experienced local government engineers already perform distress surveys, although they may be informal and not recorded. A more complete approach to distress

surveys records the type of the distress, the level of severity, and the extent of coverage. By recording this information, a performance record can be established and a quantitative measurement made of what was previously an opinion. **[Plate 17]**

Distress surveys should use standard definitions of distress types and severities. Aggregate surfaces require some special considerations because their condition changes rapidly with traffic and maintenance activities. Distress surveys of aggregate surfaces should include frequency of maintenance as a measure of condition.

Distress surveys can be as simple as a "windshield survey" or very complex, requiring detailed field measurements. To be most useful, distress surveys should record the distress types, severities, and extent. Automated condition surveys are becoming more common. As technology advances, new methods of measuring distress, roughness, and structural capacity faster and accurately will be developed. These automated methods will become more and more cost effective as availability and competition increase.

Strategies. The third step in improved surface management procedures is strategy selection. This process involves evaluating the measured condition of each section and determining the causes of the observed distresses and the cost appropriate corrective measures.

A basic concept of surface management is that maintenance resources are better spent on those pavements that are still in relatively good condition. This preventive maintenance concept emphasizes keeping goods roads in good shape. Given the present condition of a pavement, there is one maintenance and repair strategy that is most appropriate. One should avoid confusing how an activity is funded with strategy at this point. We are using the term "strategy" to refer to an overall approach to maintaining and improving roads over their entire life cycle.

Most pavement strategies consist of a series of activities which are grouped into one of five categories:

- Routine Maintenance
- Preventive Maintenance
- Deferred Action
- Rehabilitation
- Reconstruction

Selection of required current action for a given section depends on the overall condition and the distress present. When using a condition measure such as Pavement Condition Index (PCI) to determine needed current actions, it should be understood that there may be considerable overlap between what action categories should be selected.

The types of distresses present and economic analysis should determine the selection in these cases. See Figure 3. **[Plate 18]**

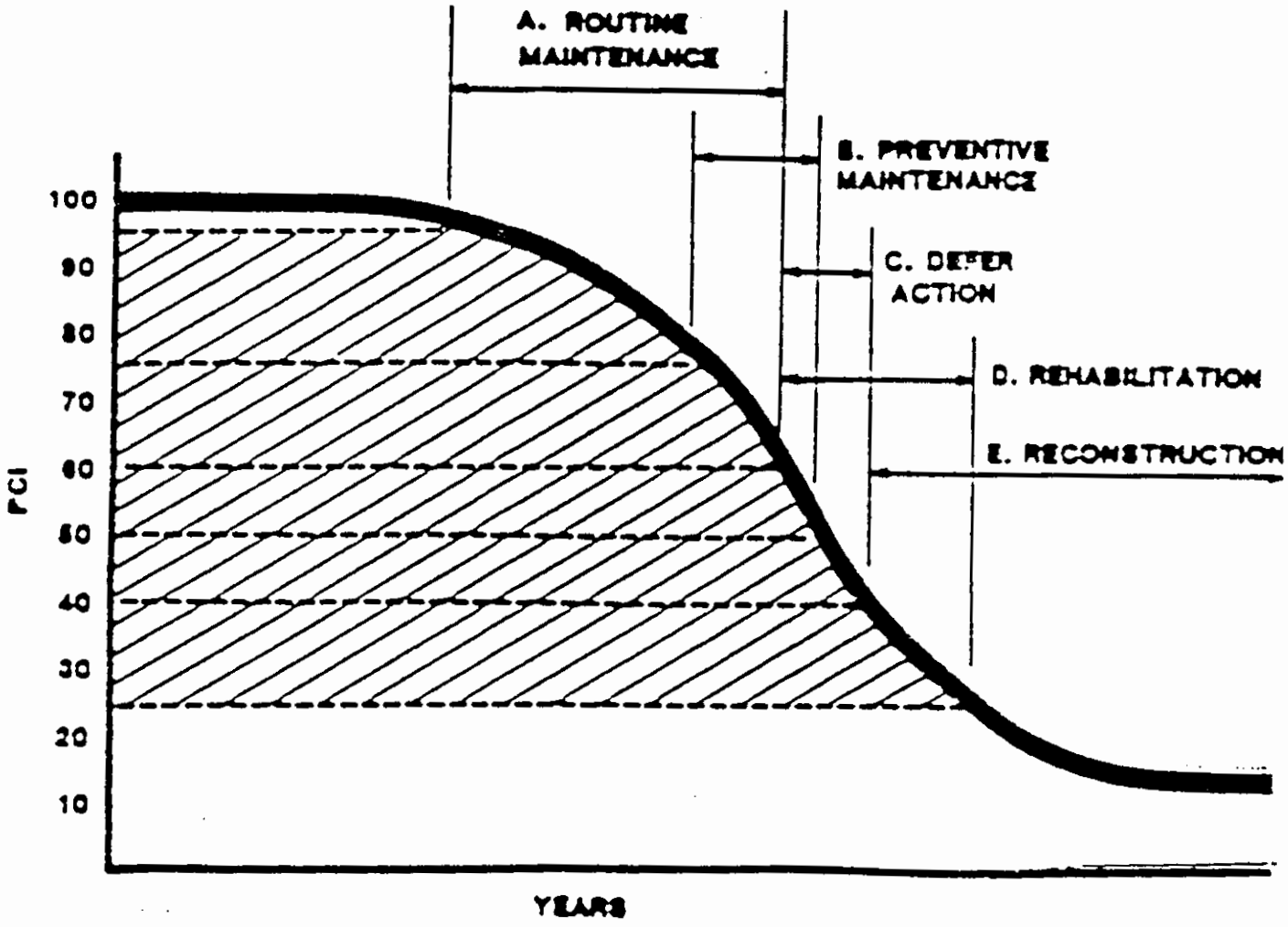


FIGURE 3. MATCHING CONDITION TO REPAIR STRATEGY (Plate 18)

To make the most beneficial and economical maintenance and improvement investments, it is important to examine the long term effects of current actions. A life cycle cost analysis allows a complete picture of current and future costs and benefits. This allows more cost effective maintenance and improvements strategies to be selected for each section in the network.

Needs. Once the appropriate current action of life cycle strategy is selected for each section, the overall network needs can be identified. Using generalized average unit costs for each current action category in the areas determined from the survey, the total present needs, in terms of dollars, can be determined. Since it is unlikely that most communities will be able to afford to address their total needs immediately, long-range goals and objectives should be established, in terms of a target network condition, average annual investment requirements, and years to reach the goal. It is usually easier to justify budget requests if the decision makers are presented with such a "road map".

Priorities. Because total needs cannot always be addressed immediately, priorities must be established. There are actually two priority choices to be made. The first is among the general action categories. Will emphasis be placed on routine maintenance, preventive maintenance, rehabilitation, or reconstruction? This is essentially a "best-first", -- "worst-first", or somewhere in between decision. Next, priorities should be established within the action categories. There are a number of factors that can go into this, including the measured condition, traffic exposure, route classification, and maintenance history. These factors can be combined into a simple formula, but care must be taken to avoid placing too much weight on the results. There may not, in fact, be much difference in sections that are ranked close to each other.

Any procedure should be flexible enough to allow for non-quantifiable factors in these cases.

Economic analysis using life-cycle costing techniques can also be used effectively for priority selection. There are some relatively simple economic analysis techniques available to assist manager in the pave-not pave decision as well.

Programs. Once priorities are set, managers can begin to identify specific needs over a long-range period, usually about 5 years. A long range program should include treatment of the currently identified needs and the projected needs, taking into account future deterioration.

Budget. Year one of the long-range program becomes the budget for the upcoming year. Of course, at this stage, average unit costs are substituted with more accurate estimates and specific actions are addressed. A good condition survey will provide sufficient information to identify the necessary work activities.

Implementation of SMS

Agencies that have made a commitment to an overall systematic approach usually find that a computer is useful to help store and analyze the information collected. There are several ways to approach the implementation of a road surface management system, including the purchase of a "canned" system, the adaptation of an existing system to local needs, and the development of a tailor-made system. Regardless of the approach taken, local agencies should critically analyze their management information needs and carefully evaluate the systems under consideration. The degree to which needs are satisfied and the costs of a system usually involve trade-offs.

The operation of any surface management system will depend upon the quality of the condition survey element. Regardless of the cost associated with computers and software systems, the overriding cost of a management system is the year-in, year-out data collection. Data collection requirements of any system should be carefully analyzed to ensure that the information needed will be gathered and that the costs will be reasonable.

Intergovernmental Cooperation

There are severe pressures on local governments to control or even reduce levels of expenditures in all areas. There are many creative ways to do this without adversely impacting services. By working jointly, local governments can take advantage of savings that can be realized by buying materials, contracting, and performing work in large quantities. This is known as "economy of scale". Creative management in this area is the key to maintaining services with limited resources. Although independence is highly valued by local boards, the financial facts of life seem to dictate some degree of cooperation and compromise.

There are several ways to realize potential savings through inter-governmental cooperation including:

- Piggyback Purchasing
- Joint Purchasing
- Equipment Sharing
- Work Agreements **[Plate 19]**

Summary

This introductory section has described what surface management is and why it' s important. It discussed some of the basic elements of road surface management. Finally, it touched on some implementation issues and ways to realize savings through cooperative efforts with other governmental agencies. The remainder of the course describes the processes of road surface management in more detail.

If a road is divided into two or more sections, each section of the road must be given a different name. For example, if the width of "Main Street" changes from 36 feet to 40 feet, then the first portion should be identified as "MAIN STREET-1" and the second as "MAIN STREET-2."

Customization

The SMS program is generic. By supplying appropriate information, SMS users tune the system to represent local characteristics and parameters. The required information is normally readily available or can be easily obtained. The following are examples of the type of information needed by a SMS.

Traffic Volume. SMS may use five general traffic volume ranges, which may be estimated as follows:

Low	--rural residential roads
Low-Moderate	--urban residential roads
Moderate	--feeder streets
Moderate-High	--collector streets and high importance routes
High	--arterial streets servicing intercommunity traffic

Traffic volume is usually used in prioritizing the order in which roads should be repaired. Community officials can usually provide the traffic volume designation for their roads.

Repair Techniques. The repair techniques traditionally employed by the community may be utilized in SMS. Selection is made from these techniques when determining recommended repair strategies. Approximately twenty flexible pavement and twelve unpaved road repair techniques may be included as default values.

Condition Survey

The condition survey is done by visual inspection of road surface. A condition surveyor travels along the roadway at 5 to 15 mph, recording roadway characteristics using a lightweight digitizing tablet connected to a laptop computer, the laptop computer by itself, or through the use of data collection sheets. The latter method is discussed herein.

As the condition survey is being conducted, the rater may decide to subdivide the road into sections as a function of road surface deterioration. Typical reasons for starting, ending, or changing a section are:

Difference in pavement characteristics
Change in traffic volume
Change in road design (width, curbs, etc.)

Types of distresses for unpaved roads addressed by SMS include:

Primary Distresses
- Cross Section
- Inadequate Roadside Drainage

Traffic-Induced Distresses
- Corrugations
- Dust
- Potholes
- Ruts
- Loose Aggregate [**Plate 24**]

Surface distresses may be recorded using a digitizing tablet, a personal computer, or data collection sheets. In order to facilitate data collection, these all have a pictorial representation of the surface distresses. Typically digitizing tablet overlays and/or data collection sheets for both flexible pavement and unpaved roads are shown in Figures 4 and 5. [**Plates 25 & 26**]

ROAD SURFACE MANAGEMENT SYSTEM

FLEXIBLE PAVEMENT CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ — _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____ TRAFFIC VOL _____ LOW=1, HIGH=5

NO.LANES _____ TOWN MAINT? _____ (Y / N)

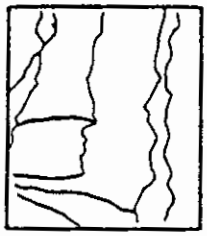
SURF.TYPE _____ 4-SURF.TRT, 5-MISC.ASP

SHLD.TYPE _____ 1-PAVED,2-GRAVEL,3-EARTH 4-CURBED,5-NONE

START MILEAGE _____

END MILEAGE _____

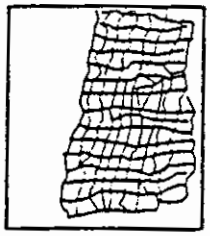
LONGITUDINAL/ TRANSVERSE CRACKING



EXTENT

SEVERITY	NO DEFECTS	LOW (AMOUNT OF ROAD SURFACE)	MED	HIGH
LOW				
MOD				
HIGH				

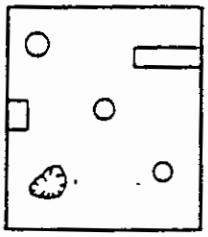
ALLIGATOR CRACKING



EXTENT (PERCENT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	<10%	10-30%	>30%
LOW				
MOD				
HIGH				

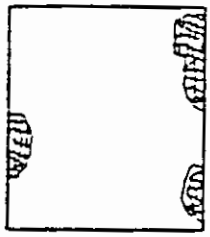
PATCHING/ POTHOLES



EXTENT (AMOUNT OF ROAD SURFACE)

NO DEFECTS	LOW	MED	HIGH

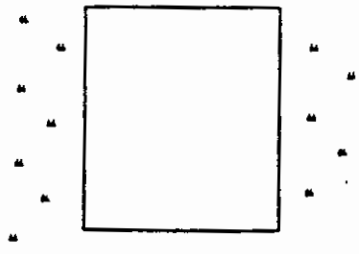
EDGE CRACKING



EXTENT (AMOUNT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	LOW	MOD	HIGH
<1 Ft				
1-2 Ft				
> 2 Ft				

DRAINAGE



CONDITION

SEVERITY
GOOD
FAIR
POOR

ROUGHNESS

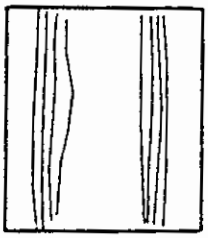
CHECK ROAD FOR PRESENCE OF FOLLOWING:

UNEVEN SURFACE
CORRUGATIONS
SAGS
HUMPS
FROST HEAVES

CONDITION

SEVERITY
GOOD
FAIR
POOR

RUTTING



CONDITION

SEVERITY
NO VISIBLE RUTTING (< 1")
RUTTING VISIBLE (> 1")

FIGURE 4 (Plate 25)

paths, typically alligator cracks, are not included in this category.

3. Multiple (parallel) cracks within 8" of primary crack are considered as part of the primary crack.

Alligator Cracking [Plate 29]

Alligator cracking refers to interconnected crack patterns that resemble alligator skin or chicken wire. Pavement pieces range in size from one to six inches on a side.

NO DEFECT: The road section has no visible alligator cracking or the total area exhibiting cracking comprises less than 1% of the entire section.

SEVERITY: LOW Crack Pattern is just beginning to appear. Cracks have no measurable width and no actual pavement separation is found.

MOD. Easily discernible cracking with measurable crack widths up to 1/8" and some breakup. Pavement pieces, while loose, are still interconnected.

HIGH Wide cracking (1/8") has resulted in major pavement breakup with loose pieces actually displaced.

EXTENT: LOW <10% The total area exhibiting alligator cracking encompasses more than 1% and less than 10% of the roadway section.

MOD. 10-30% The total area exhibiting alligator cracking encompasses between 10% and 30% of the roadway section.

HIGH >30% The total area exhibiting alligator cracking encompasses greater than 30% of the roadway section.

NOTES:

1. When alligator cracking is the primary distress, it 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.

Patching/Potholes [Plate 30 & 31]

Patching refers to areas where the original pavement has been removed and subsequently replaced but is showing deterioration. Potholes are areas where portions of the road pavement have broken and loss of pavement has resulted in a bowl-shaped depression.

NO DEFECT: No patches or potholes detected in the rated section.

EXTENT:

LOW The total area of patching is less than 10% of the total section area and/or there are fewer than 5 potholes per 100′ of section length.

MOD. The total area of patching is between 10% and 30% of the total section area and/or there are between 5 and 10 potholes per 100′ of section length.

HIGH The total area of patching is greater than 30% of the total section area and/or there are more than 10 potholes per 100′ of section length.

NOTES:

1. Edge crack, spalling of longitudinal/transverse cracks, and displacement of alligator cracks are not counted as potholes.

2. Only patches that show deterioration should be evaluated. Good patches should be ignored. Frost heaves, including culverts that are protruding and rocks that are coming up through the surface, should be included. Surface area, rather than depth of deterioration, should be used to assess extent.

Corrugations [Plate 39]

Corrugations, or washboarding, are closely spaced ridges and valleys, spaced at fairly regular intervals. These ridges and valleys are perpendicular to the travel direction.

NO DEFECTS:		No corrugations in the rated section.
SEVERITY:	LOW	Corrugations less than 1" deep.
	MOD.	Corrugations between 1" and 3" deep.
	HIGH	Corrugations are deeper than 3".
EXTENT:	LOW	Less than 10% of the total road surface is covered by corrugations.
	MOD.	Between 10% and 30% of the total road surface is covered by corrugations.
	HIGH	More than 30% of the total road surface is covered by corrugations.

NOTES:

1. Corrugations are often caused by traffic and loose aggregate.

2. Corrugations usually form on hills, curves, acceleration or deceleration areas, or in areas where the road is soft or potholed.

Dust [Plate 40]

Dust creates a hazard to trailing or passing vehicles and may cause significant environmental problems. In addition, the loss of fine materials can result in the larger particles becoming unstable.

CONDITION:	LIGHT	Normal traffic produces a thin dust that does not obstruct visibility.
	MEDIUM	Normal traffic produces a moderately thick cloud that partially obstructs visibility and causes traffic to slow down.
	HEAVY	Normal traffic produces a very thick cloud that severely obstructs visibility and causes traffic to slow down significantly or stop.

NOTE:

1. Dust is measured at the posted speed.

Potholes [Plate 41]

Potholes are areas where portions of the road surface have been worn away, and loss of material has resulted in a bowl-shaped depression.

NO DEFECTS:		No potholes detected in the rated section.
SEVERITY:	LOW	Potholes are less than 1" deep and/or are less than one foot in diameter.
	MOD.	Potholes are between 1" and 3" deep and/or are less than two feet in diameter.
	HIGH	Potholes are deeper than 3" and/or are more than two feet in diameter.
EXTENT:	LOW	The total area of potholes is less than 10% of the total road surface area and/or there are fewer than 5 potholes per 100′ of section length.
	MEDIUM	The total area of potholes is between 10% and 30% of the total road surface area and/or there are between 5 and 10 potholes per 100′ of section length.
	HIGH	The total area of potholes is greater than 30% of the total road surface area and/or there are more than 10 potholes per 100′ of section length.

Rutting [Plate 42]

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.

NO DEFECTS: No visible rutting in the rated section.

SEVERITY:
- LOW Depth of rut is less than 1".
- MOD. Ruts are between 1" and 3" deep.
- HIGH Ruts are greater than 3" deep.

EXTENT:
- LOW Less than 10% of the total road surface is covered by rutting.
- MOD. Between 10% and 30% of the total surface is covered by rutting.
- HIGH More than 30% of the total road surface is covered by rutting.

NOTES:

1. Ruts are caused by a permanent deformation in any of the road layers or subgrade. Ruts result from repeated vehicle passes when the road is soft. Significant rutting can destroy a road.

Loose Aggregate [Plate 43]

Traffic loosens aggregate particles and moves these particles into berms along the shoulders or center of the roadway.

NO DEFECTS: No loose aggregate in the rated section.

SEVERITY:

LOW Loose aggregate on the road surface, or a berm of aggregate, less than 2" deep, or on the shoulders or center of the roadway.

MOD. Moderate aggregate berm, between 2" and 4" deep, on the shoulders or center of the roadway. A large number of fine soil particles may be found on the roadway surface.

HIGH Large aggregate berm, greater than 4" deep, on the shoulders or center of the roadway.

EXTENT:

LOW Loose aggregate covers less than 10% of the total road surface.

MOD. Loose aggregate covers more than 10% and less than 30% of the total road surface.

HIGH Loose aggregate covers more than 30% of the total road surface.

ANALYSIS OF DATA/REPAIR STRATEGY

Using the results of a condition survey, recommended repair strategies are selected from a set of decision tables provided in SMS. The repair techniques for flexible pavement fall into seven categories:

1) Deferred Maintenance
2) Crack Sealing
3) Patching Potholes
4) Roadside Drainage Maintenance
5) Surface Coats
6) Overlays
7) Reconstruction [**Plate 44**]

These seven flexible pavement repair categories are associated with surface distresses in decision tables. For example, in the Longitudinal/Transverse Cracking table, a low severity and less than 10% extent points to the Defer category; if the severity is high and the extent is greater than 30%, the repair strategy is Thin Overlay. The decision tables for each of the flexible surface distress characteristics are given in Figures 6a and 6b. [**Plates 45 and 46**]

The unpaved roads repair techniques fall into the following categories:

1) Deferred Maintenance
2) Dust Control and Stabilization
3) Spot Addition of Surface Material
4) Roadside Drainage Maintenance
5) Reshape (Smoothing by Dragging or Blading)
6) Regrade Existing Material
7) Reconstruction [**Plate 47**]

These repair categories are also associated with surface distresses in decision tables. For example, in the distress Cross Section, a low severity rating points to the Routine Maintenance category, where a moderate rating points to the Rehabilitate category. The decision tables are used in combination with one other; if one distress points to a higher repair than another, the higher repair is given. The decision tables for each of the unpaved surface distress characteristics are given in Figures 7a and 7b. [**Plates 48 and 49**]

The user should check each of the techniques for cost and life span; if there is a difference between what the program suggests and what the user feels is appropriate, then the user should make the change. Changing SMS to represent user-defined techniques, costs, and life spans is what is referred to as "customization". This should be done each year to keep SMS up to date with current practices and costs.

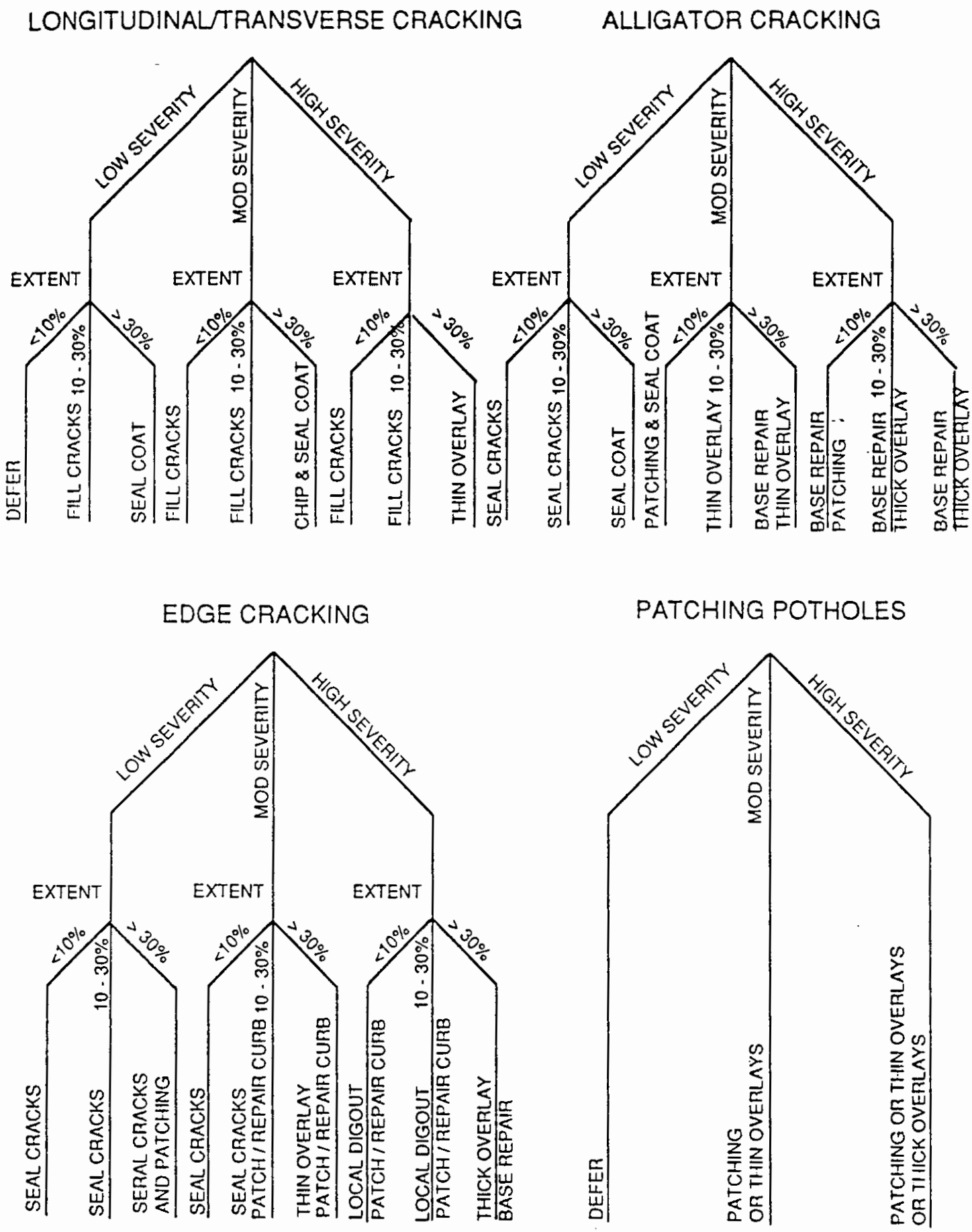


FIGURE 6a: FLEXIBLE PAVEMENT DECISION TABLE

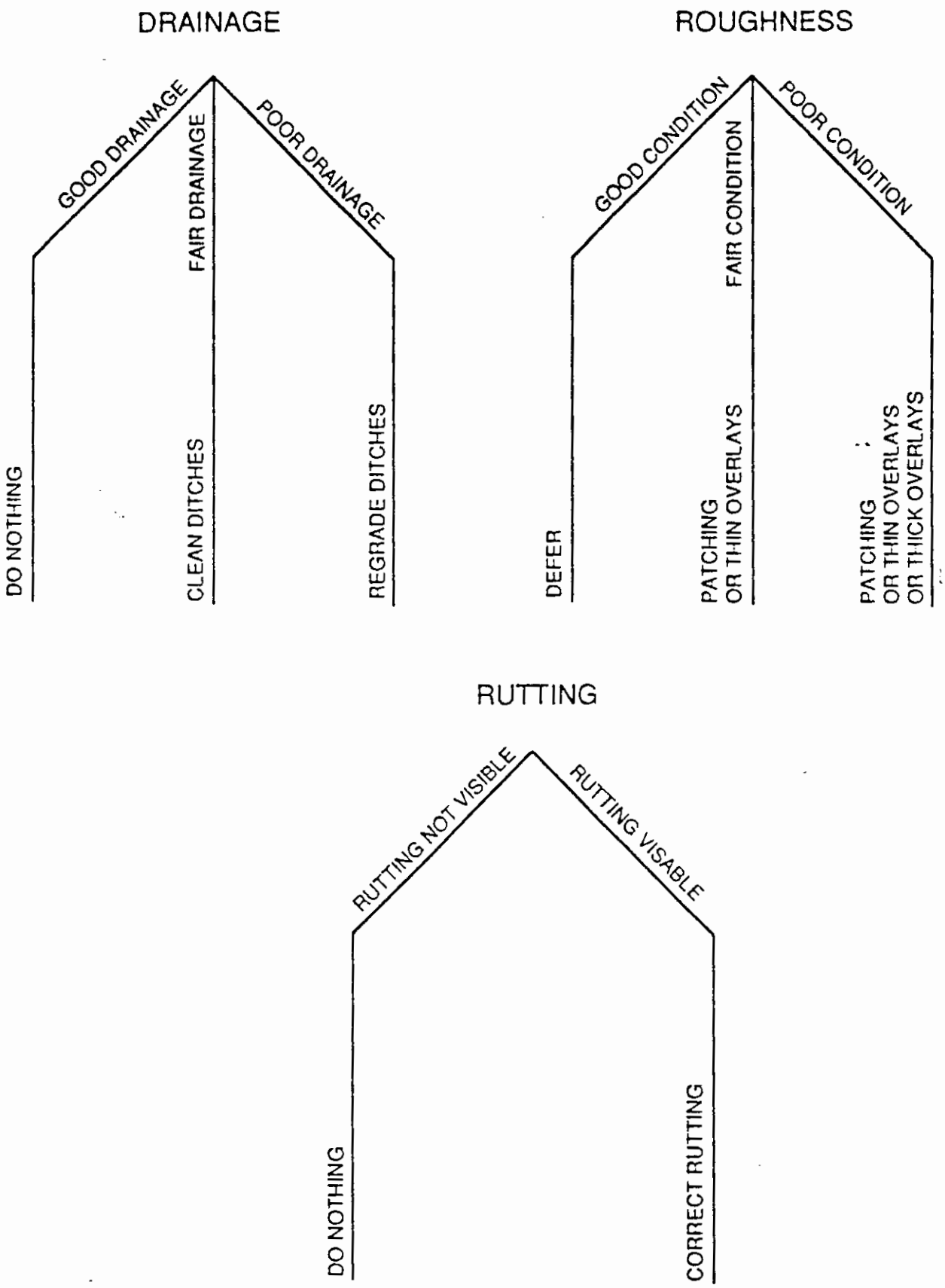


FIGURE 6b: FLEXIBLE PAVEMENT DECISION TABLE

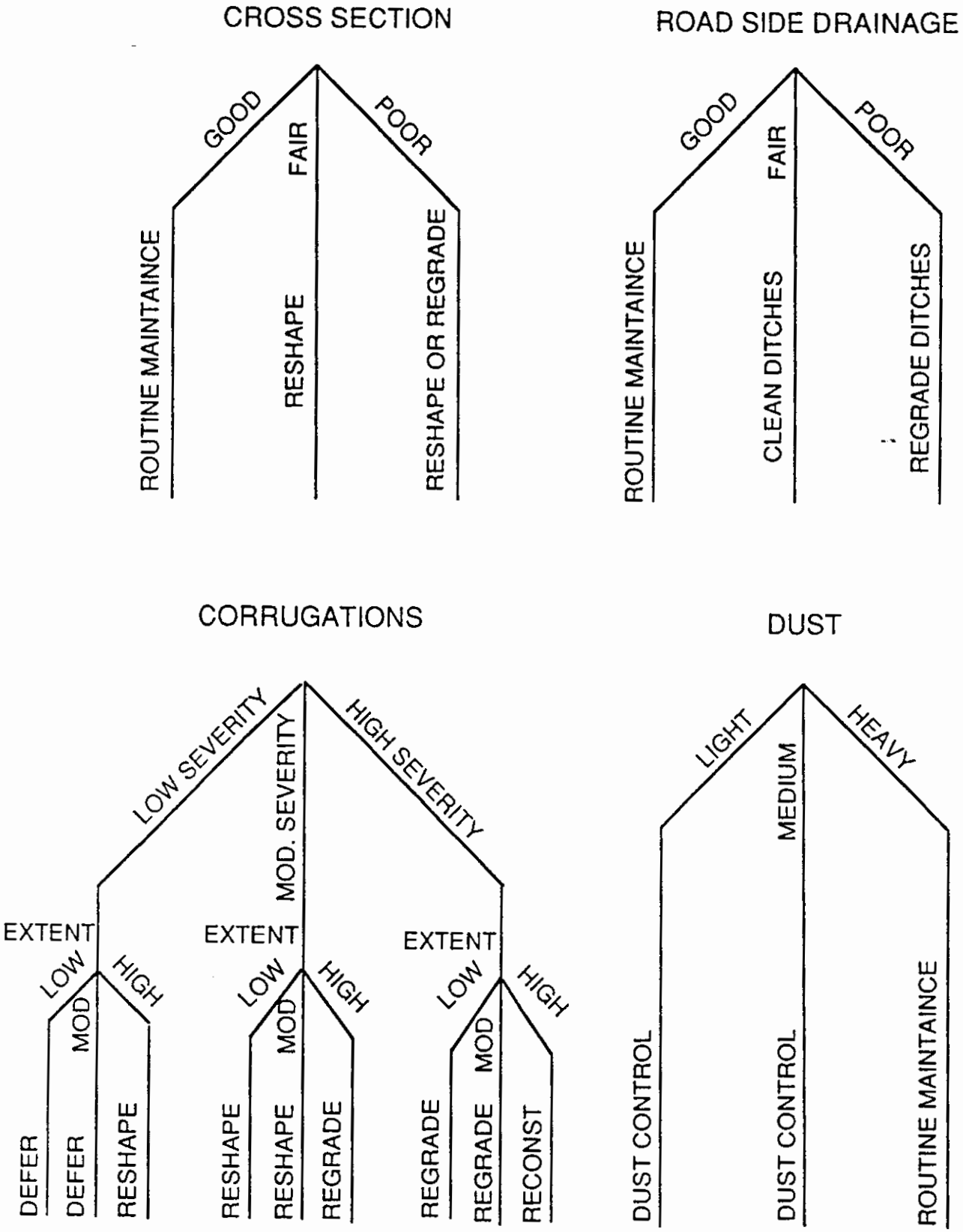


FIGURE 7a: UNPAVED ROAD - DECISION TABLE

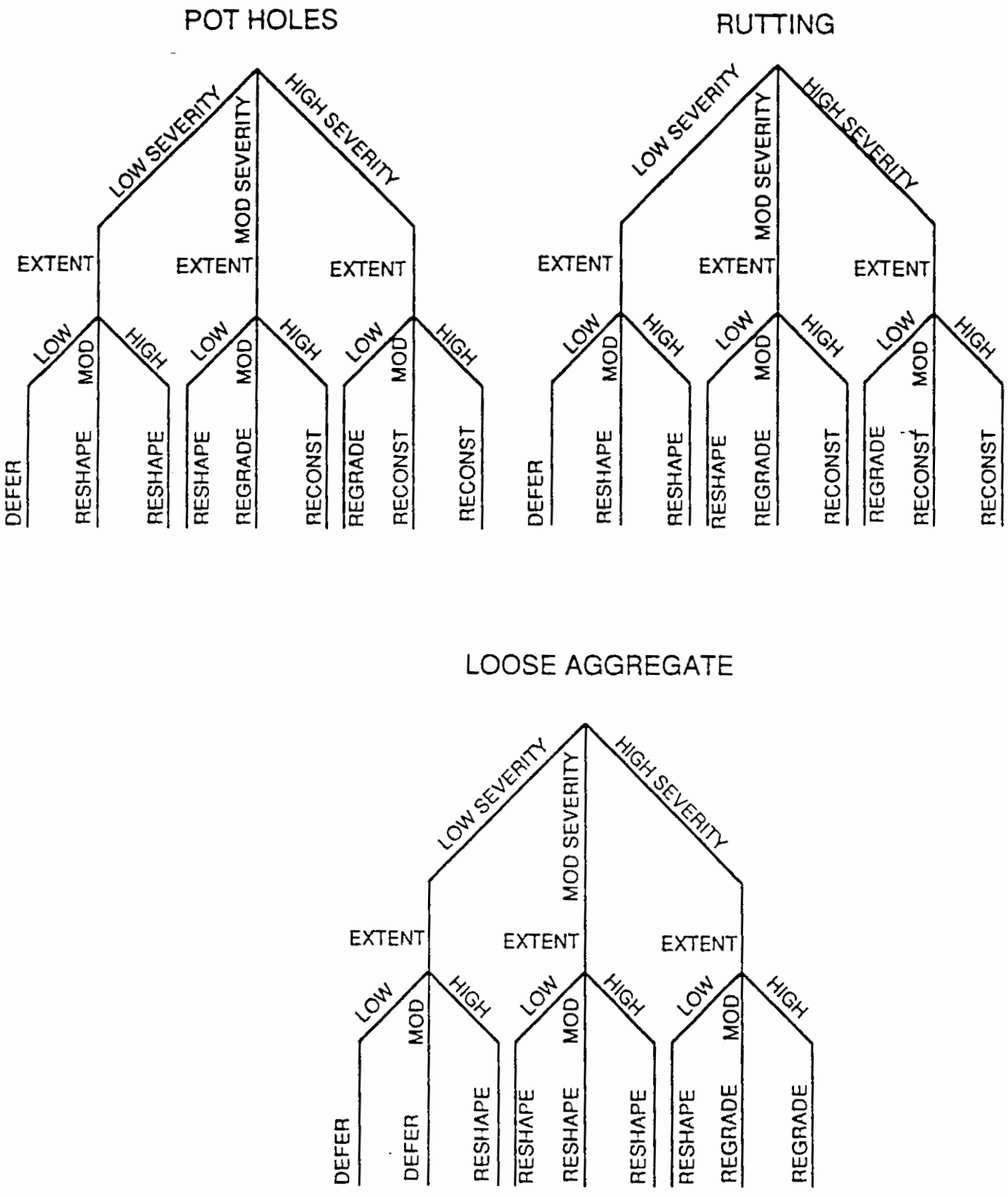


FIGURE 7b: UNPAVED ROADS DECISION TABLE

REPORTS

Reports may be generated to tabulate the road inventory data, condition survey results, and user-and SMS-supplied repair strategies using a computerized system. The types of reports which might be produced include:

1) Road Inventory List
2) Repair Techniques List
3) Road Survey Sequence List
4) Road Surface Condition Survey Results

The road inventory list would consist of the attributes which identify the road segment, i.e. road name, road width, etc., which can be presented in either alphabetical order by road name or ascending order by road inventory number. Report options would include those that allow the user to view or print the entire road inventory or an individual road.

The repair techniques list could contain information concerning which maintenance and repair techniques will be used in the analysis of the road surface conditions. There would be one list for unpaved roads, and one list for flexible pavement.

Specific repair alternative reports list the repair techniques appropriate for each road section. Unit type, quantity, and cost per unit are used to generate an estimated repair cost for each repair technique presented.

SMS repair strategy reports present all the stored repair techniques associated with a particular surface distress characteristic. Users must use good engineering judgement to select the best strategy for their needs. SMS should not be thought of as a design program or facility; it is not! It is a tool for managing information. To determine the correct repair normally requires a lot more investigative work than a windshield survey; subsurface investigation, for example. A windshield survey serves to identify problem areas - not the specific problem. SMS should be used by road agents as a tool for planning and scheduling repair work as well as preparing a repair budget; it should not be thought of as a design program.

The road survey sequence list could be used to identify the order in which roads will be surveyed, and to specify the direction of travel in which the survey will be conducted.

The road surface condition survey results could be presented in the following formats:

1) Summary of Road Condition Survey Results
2) Projected Repairs - General Categories
3) Projected Repairs - Specific Repair Alternatives

The road condition survey results may be tabulated in alphabetical order or in prioritized order. Prioritization may be based upon the following factors: Traffic Volume Group could account for 33% of the prioritization value, Road Surface Roughness could account for 33%, and the Road Condition, represented by the projected required repair category, could account for the remaining 34%.

SUMMARY

This course has provided a basic general introduction to pavement surface management. Those communities in need of this or a similar tool to aid in managing a roadway system will find additional assistance available through UT's Technology Transfer Program. In particular, the process is much more efficient when computerized data analysis and reporting is available. Training required in this area is not expensive, and the benefits derived are numerous.

The backbone of a local government surface management is the surface performance history provided by periodic surface distress evaluations. This history will provide the data necessary to determine the appropriate maintenance strategy. But, most importantly, it will be the tool used to justify a well conceived and planned program of improvements needed to maintain a good and safe local road system.

APPENDIX

ROAD SURFACE MANAGEMENT

Short Course

Course Evaluation Questionnaire

So that we may continue to improve the content and presentation of this course, we ask that you take a moment to respond to the questions shown below. For each topic, indicate whether more or less time should be given to it by circling "L"-less, "S"-same, "M"-more. Rate the material presented on a scale from "1"-very poor, "3" satisfactory, or "5"-excellent in the column provided for score. Use "2" and "4" if needed. Add any comments which you feel would be helpful.

NO.	SESSION TITLE	TIME	SCORE	COMMENTS
1	Introduction	L S M	_____	_____
2	Distress Methods	L S M	_____	_____
3	Field Experience	L S M	_____	_____
4	Wrap Up	L S M	_____	_____
5	Slides of Distress	L S M	_____	_____
6	Plates (Overheads)	L S M	_____	_____

ROAD SURFACE MANAGEMENT SYSTEM

FLEXIBLE PAVEMENT CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ - _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____ TRAFFIC VOL _____
LOV=1, HIGH=5

NO.LANES _____ TOWN MAINT? _____ (Y / N)

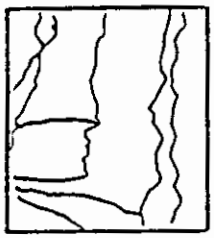
SURF.TYPE _____
4-SURF.TRT, 5-MISC.ASP

SHLD.TYPE _____
1-PAVED,2-GRAVEL,3-EARTH
4-CURBED,5-NONE

START MILEAGE _____

END MILEAGE _____

LONGITUDINAL/ TRANSVERSE CRACKING



EXTENT

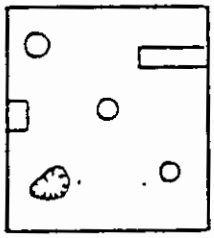
SEVERITY	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

ALLIGATOR CRACKING

EXTENT (PERCENT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	<10%	10-30%	>30%
LOW				
MOD				
HIGH				

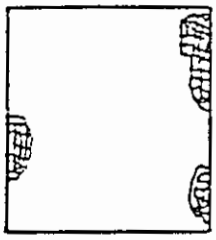
PATCHING/ POTHOLES



EXTENT (AMOUNT OF ROAD SURFACE)

NO DEFECTS	LOW	MED	HIGH

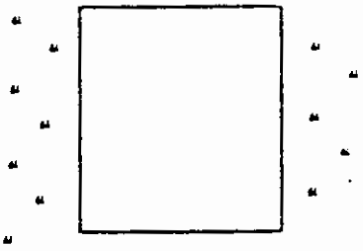
EDGE CRACKING



EXTENT (AMOUNT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	LOW	MOD	HIGH
<1 Ft				
1-2 Ft				
> 2 Ft				

DRAINAGE



CONDITION

SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

ROUGHNESS

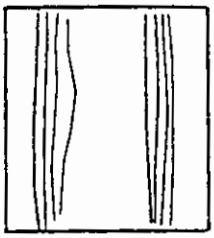
CHECK ROAD FOR PRESENCE OF FOLLOWING:

UNEVEN SURFACE
CORRUGATIONS
SAGS
HUMPS
FROST HEAVES

CONDITION

SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

RUTTING



CONDITION

SEVERITY	CONDITION
	NO VISIBLE RUTTING (< ½")
	RUTTING VISIBLE (> ½")

ROAD SURFACE MANAGEMENT SYSTEM

FLEXIBLE PAVEMENT CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ - _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____ TRAFFIC VOL _____ LOW=1, HIGH=5

NO.LANES _____ TOWN MAINT? _____ (Y / N)

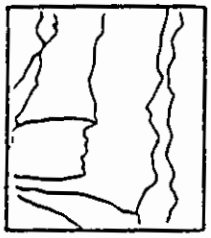
SURF.TYPE _____ 4-SURF.TRT, 5-MISC.ASP

SHLD.TYPE _____ 1-PAVED,2-GRAVEL,3-EARTH 4-CURBED,5-NONE

START MILEAGE _____

END MILEAGE _____

LONGITUDINAL/ TRANSVERSE CRACKING



EXTENT

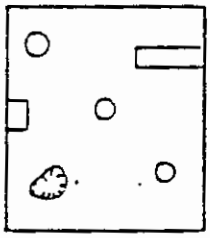
SEVERITY	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

ALLIGATOR CRACKING

EXTENT (PERCENT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	<10%	10-30%	>30%
LOW				
MOD				
HIGH				

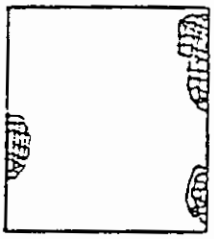
PATCHING/ POTHOLES



EXTENT (AMOUNT OF ROAD SURFACE)

NO DEFECTS	LOW.	MED	HIGH

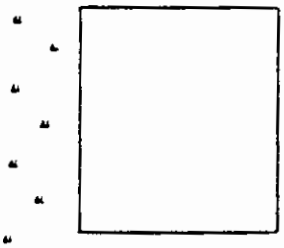
EDGE CRACKING



EXTENT (AMOUNT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	LOW	MOD	HIGH
<1 Ft				
1-2 Ft				
> 2 Ft				

DRAINAGE



CONDITION

SEVERITY
GOOD
FAIR
POOR

ROUGHNESS

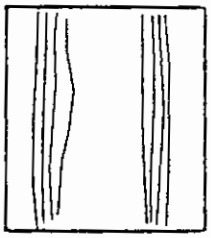
CHECK ROAD FOR PRESENCE OF FOLLOWING:

UNEVEN SURFACE
CORRUGATIONS
SAGS
HUMPS
FROST HEAVES

CONDITION

SEVERITY
GOOD
FAIR
POOR

RUTTING



CONDITION

SEVERITY
NO VISIBLE RUTTING (< 1")
RUTTING VISIBLE (> 1")

ROAD SURFACE MANAGEMENT SYSTEM

FLEXIBLE PAVEMENT CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ - _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____ TRAFFIC VOL _____
LOW=1, HIGH=5

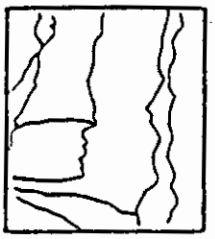
NO.LANES _____ TOWN MAINT? _____ (Y / N)

SURF.TYPE _____ SHLD.TYPE _____
4-SURF.TRT, 5-MISC.ASP 1-PAVED,2-GRAVEL,3-EARTH
4-CURBED,5-NONE

START MILEAGE _____

END MILEAGE _____

LONGITUDINAL/ TRANSVERSE CRACKING



EXTENT

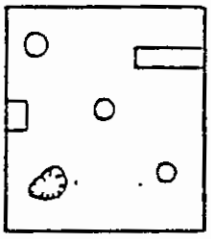
SEVERITY	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

ALLIGATOR CRACKING

EXTENT (PERCENT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	<10%	10-30%	>30%
LOW				
MOD				
HIGH				

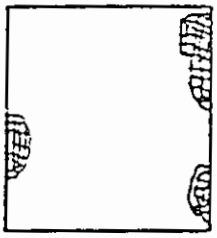
PATCHING/ POTHOLES



EXTENT (AMOUNT OF ROAD SURFACE)

NO DEFECTS	LOW	MED	HIGH

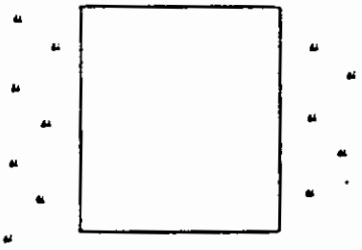
EDGE CRACKING



EXTENT (AMOUNT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	LOW	MOD	HIGH
<1 Ft				
1-2 Ft				
> 2 Ft				

DRAINAGE



CONDITION

SEVERITY
GOOD
FAIR
POOR

ROUGHNESS

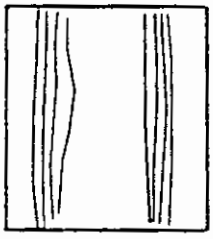
CHECK ROAD FOR PRESENCE OF FOLLOWING:

UNEVEN SURFACE
CORRUGATIONS
SAGS
HUMPS
FROST HEAVES

CONDITION

SEVERITY
GOOD
FAIR
POOR

RUTTING



CONDITION

SEVERITY
NO VISIBLE RUTTING
RUTTING VISIBLE

ROAD SURFACE MANAGEMENT SYSTEM

FLEXIBLE PAVEMENT CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ - _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____ TRAFFIC VOL _____
LOW=1, HIGH=5

NO.LANES _____ TOWN MAINT? _____ (Y / N)

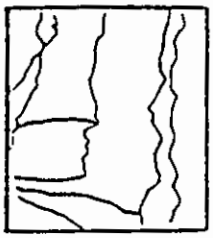
SURF.TYPE _____
4-SURF.TRT, 5-MISC.ASP

SHL.D.TYPE _____
1-PAVED,2-GRAVEL,3-EARTH
4-CURBED,5-NONE

START MILEAGE _____

END MILEAGE _____

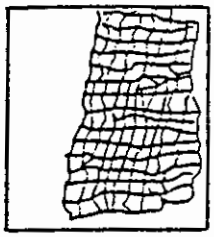
LONGITUDINAL/ TRANSVERSE CRACKING



EXTENT (AMOUNT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

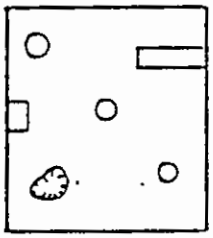
ALLIGATOR CRACKING



EXTENT (PERCENT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	<10%	10-30%	>30%
LOW				
MOD				
HIGH				

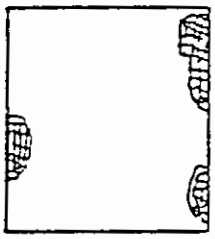
PATCHING/ POTHOLES



EXTENT (AMOUNT OF ROAD SURFACE)

NO DEFECTS	LOW.	MED	HIGH

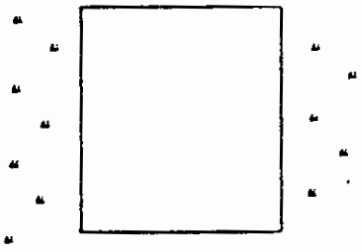
EDGE CRACKING



EXTENT (AMOUNT OF ROAD SURFACE)

SEVERITY	NO DEFECTS	LOW	MOD	HIGH
<1 Ft				
1-2 Ft				
>2 Ft				

DRAINAGE



CONDITION

SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

ROUGHNESS

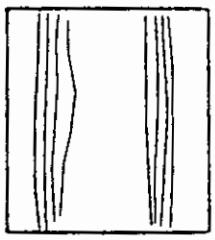
CHECK ROAD FOR PRESENCE OF FOLLOWING:

UNEVEN SURFACE
CORRUGATIONS
SAGS
HUMPS
FROST HEAVES

CONDITION

SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

RUTTING



CONDITION

SEVERITY	CONDITION
	NO VISIBLE RUTTING (< 1")
	RUTTING VISIBLE (> 1")

ROAD SURFACE MANAGEMENT SYSTEM

UNSURFACED ROAD CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ - _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____ TRAFFIC VOL _____ LOW=1, HIGH=5

NO.LANES _____ TOWN MAINT? ___ (Y / N)

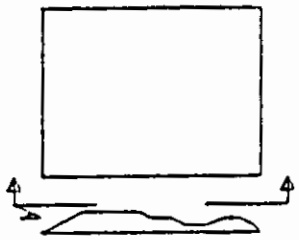
SURF.TYPE _____ SHLD.TYPE _____

1-UNIMP, 2-GRADED, 3-GRAVEL 1-PAVED,2-GRAVEL,3-EARTH 4-CURBED,5-NONE

START MILEAGE _____

END MILEAGE _____

IMPROPER X-SECTION

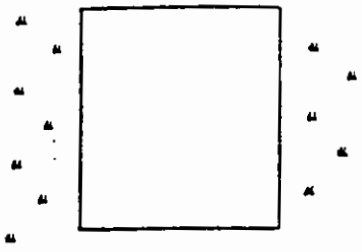


CONDITION

SEVERITY

GOOD
FAIR
POOR

ROADSIDE DRAINAGE

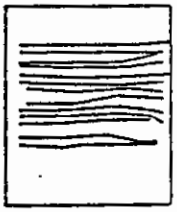


CONDITION

SEVERITY

GOOD
FAIR
POOR

CORRUGATIONS



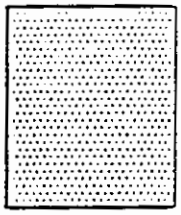
EXTENT

PERCENT OF ROAD SURFACE

SEVERITY

	NO DEFECTS	<10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

DUST

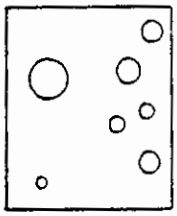


CONDITION

SEVERITY

LIGHT
MEDIUM
HEAVY

POTHOLES



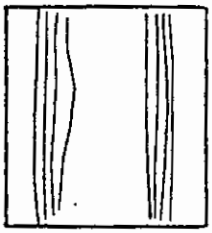
EXTENT

AMOUNT OF ROAD SURFACE

SEVERITY

	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

RUTTING



EXTENT

PERCENT OF ROAD SURFACE

SEVERITY

	NO DEFECTS	<10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

LOOSE AGGREGATE

EXTENT

AMOUNT OF ROAD SURFACE

SEVERITY

	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

ROAD SURFACE MANAGEMENT SYSTEM

UNSURFACED ROAD CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ - _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____ TRAFFIC VOL _____ LOW=1, HIGH=5

NO.LANES _____ TOWN MAINT? ___ (Y / N)

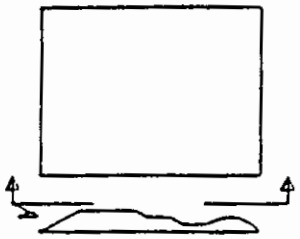
SURF.TYPE _____ SHLD.TYPE _____

1-UNIMP, 2-GRADED, 3-GRAVEL 1-PAVED,2-GRAVEL,3-EARTH 4-CURBED,5-NONE

START MILEAGE _____

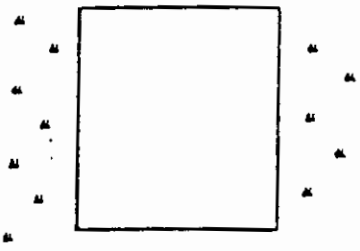
END MILEAGE _____

IMPROPER X-SECTION



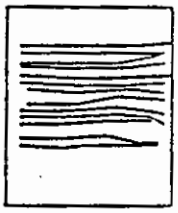
SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

ROADSIDE DRAINAGE



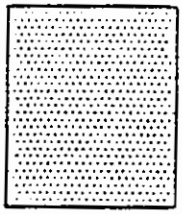
SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

CORRUGATIONS



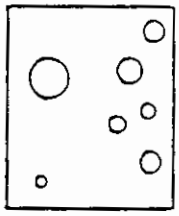
SEVERITY	NO DEFECTS	EXTENT (PERCENT OF ROAD SURFACE) <10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

DUST



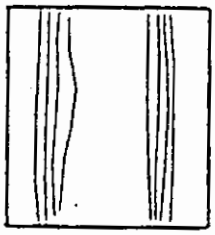
SEVERITY	CONDITION
	LIGHT
	MEDIUM
	HEAVY

POTHOLES



SEVERITY	NO DEFECTS	EXTENT (AMOUNT OF ROAD SURFACE) LOW	MED	HIGH
LOW				
MOD				
HIGH				

RUTTING



SEVERITY	NO DEFECTS	EXTENT (PERCENT OF ROAD SURFACE) <10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

LOOSE AGGREGATE

SEVERITY	NO DEFECTS	EXTENT (AMOUNT OF ROAD SURFACE) LOW	MED	HIGH
LOW				
MOD				
HIGH				

ROAD SURFACE MANAGEMENT SYSTEM

UNSURFACED ROAD CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____ - _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____

TRAFFIC VOL _____
LOW=1, HIGH=5

NO.LANES _____

TOWN MAINT? ___ (Y / N)

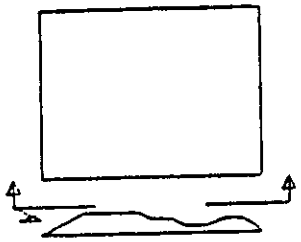
SURF.TYPE _____
1-UNIMP, 2-GRADED, 3-GRAVEL

SHLD.TYPE _____
1-PAVED,2-GRAVEL,3-EARTH
4-CURBED,5-NONE

START MILEAGE _____

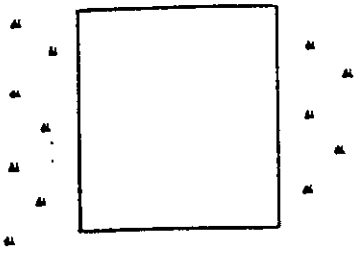
END MILEAGE _____

IMPROPER X-SECTION



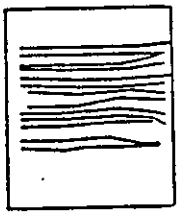
SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

ROADSIDE DRAINAGE



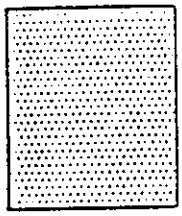
SEVERITY	CONDITION
	GOOD
	FAIR
	POOR

CORRUGATIONS



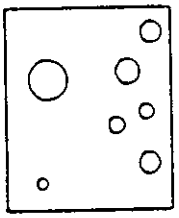
SEVERITY	NO DEFECTS	EXTENT (PERCENT OF ROAD SURFACE) <10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

DUST



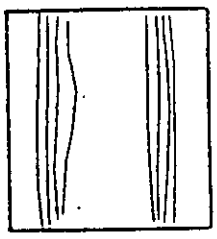
SEVERITY	CONDITION
	LIGHT
	MEDIUM
	HEAVY

POTHOLES



SEVERITY	NO DEFECTS	EXTENT (AMOUNT OF ROAD SURFACE) LOW	MED	HIGH
LOW				
MOD				
HIGH				

RUTTING



SEVERITY	NO DEFECTS	EXTENT (PERCENT OF ROAD SURFACE) <10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

LOOSE AGGREGATE

SEVERITY	NO DEFECTS	EXTENT (AMOUNT OF ROAD SURFACE) LOW	MED	HIGH
LOW				
MOD				
HIGH				

ROAD SURFACE MANAGEMENT SYSTEM

UNSURFACED ROAD CONDITION SURVEY

ROAD NAME _____

SECTION I.D. _____

DATE SURVEYED _____

SURVEYED BY _____

SHEET NO. _____ OF _____

DIRECTION OF TRAVEL

FROM _____ TO _____

WIDTH _____

TRAFFIC VOL _____
LOW=1, HIGH=5

NO.LANES _____

TOWN MAINT? ___ (Y / N)

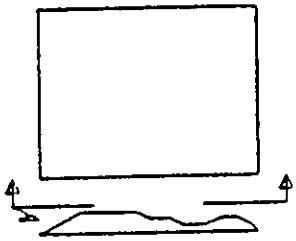
SURF.TYPE _____
1-UNIMP, 2-GRADED, 3-GRAVEL

SHLD.TYPE _____
1-PAVED,2-GRAVEL,3-EARTH
4-CURBED,5-NONE

START MILEAGE _____

END MILEAGE _____

IMPROPER X-SECTION

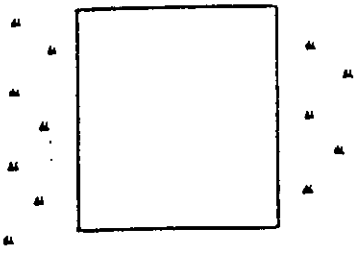


CONDITION

SEVERITY

- GOOD
- FAIR
- POOR

ROADSIDE DRAINAGE

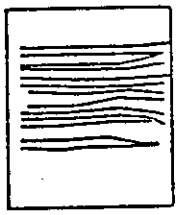


CONDITION

SEVERITY

- GOOD
- FAIR
- POOR

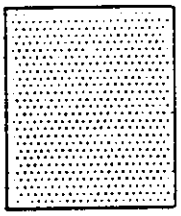
CORRUGATIONS



EXTENT
PERCENT OF ROAD SURFACE

SEVERITY	NO DEFECTS	<10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

DUST

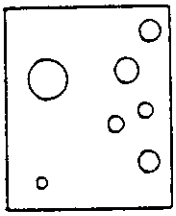


CONDITION

SEVERITY

- LIGHT
- MEDIUM
- HEAVY

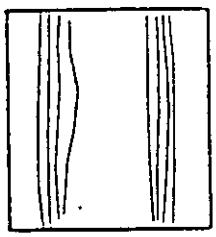
POTHOLES



EXTENT
AMOUNT OF ROAD SURFACE

SEVERITY	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

RUTTING



EXTENT
PERCENT OF ROAD SURFACE

SEVERITY	NO DEFECTS	<10%	10-30%	>30%
LOW <1"				
MOD 1"-3"				
HIGH >3"				

LOOSE AGGREGATE

EXTENT
AMOUNT OF ROAD SURFACE

SEVERITY	NO DEFECTS	LOW	MED	HIGH
LOW				
MOD				
HIGH				

The University of Tennessee does not discriminate on the basis of race, sex, color, religion, national origin, age, handicap, or veteran status in provision of educational opportunities or employment opportunities and benefits.

The University does not discriminate on the basis of sex or handicap in the educational programs and activities, pursuant to the requirements of Title IX of the Educational Amendments of 1972, Public Law 92-318; and Section 504 of the Rehabilitation Act of 1973, Public Law 93-112 and the Americans With Disabilities Act of 1990, Public Law 101-336, respectively. This policy extends to both employment by and admission to the University.

Inquiries concerning Title IX, Section 504, and the Americans With Disabilities Act of 1990 should be directed to Mr. Gary Baskette, Director of Business Services, 109 Student Services and Administration Building, Knoxville, Tennessee 37996-0212, (615)974-6622. Charges of violation of the above policy should also be directed to Mr. Baskette.

INSTITUTE FOR PUBLIC SERVICE

In 1971, the UT Board of Trustees created the Institute for Public Service (IPS) to coordinate and promote public service activities throughout the University system, excluding services provided through the Institute of Agriculture.

The basic goal of the university public service effort continues to be to bring to the citizens of Tennessee–their business, their industry, and their government–the problem-solving capabilities uniquely embodied within their statewide university system.

Public service includes all services offered to those outside the University, including teaching in certain non-degree situations, technical assistance, and applied research which are conducted specifically at the request and for the benefit of non-University organizations in Tennessee.

IPS provides (1) a systemwide focal point for urban and public service, (2) a means to coordinate the various system-level public service activities, and (3) an organizational base for communication and program development that relates to both outside service clientele of the University and the campuses of the University system.

The operating units of the Institute and their dates of creation are: Center for Government Training (1967), Center for Industrial Services (1963), County Technical Assistance Service (1973), Municipal Technical Advisory Service (1949), and Center for Telecommunications and Video (1989).