Planning, Implementation and Operation of a Statewide Pavement Management System: Workplan Development and System Design

Prepared for

Iowa Department of Transportation
Ames, Iowa

Iowa Transportation Center

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Planning, Implementation and Operation of a Statewide Pavement Management System: Workplan Development and System Design

Prepared for
Statewide Pavement Management Steering Committee
Iowa Department of Transportation
Ames, Iowa

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ACKNOWLEDGMENTS

This document, "Planning, Implementation and Operation of a Statewide Pavement Management System: Workplan Development and System Design," reports on the progress made on the development of Iowa's statewide pavement management system (PMS) through October, 1994. It documents the workplan and system design of the statewide PMS. Future reports will document the progress made on the implementation of the system.

The project is being conducted for the Iowa Department of Transportation and being directed by a steering committee. Members of the committee include representatives of city, county, and regional governments as well as the Iowa Department of Transportation and the Federal Highway Administration. Members of the committee include:

- Committee Chair, Bernard C. Brown, Director, Office of Materials, Iowa Department of Transportation
- Roger L. Anderberg, Director, Office of Local System, Iowa Department of Transportaiton
- Denise L. Bulat, Transportation Director, Bi-State Regional Planning
- Robert L. Gumbert, County Engineer, Tama County
- Frank D. Howell, Construction/Pavement Engineer, Iowa Division, Federal Highway Administration
- Kevin B. Jones, Special Investigations Engineer, Office of Materials, Iowa Department of Transportation
- Randall M. Krauel, Director of Public Works, City of Carroll
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- John R. Selmer, Director, Office of Maintenance Operations, Iowa Department of Transportation
- George F. Sisson, Deputy Director, Engineering Division, Iowa Department of Transportation
- Gerald T. Solbeck, Director, Office of Program Management, Iowa Department of Transportation
- Marlee Walton, Special Projects Engineer, Maintenance Division, Iowa Department of Transportation

The Iowa Transportation Center (ITC) served as staff to the committee and developed this report. Tom Maze is the principal investigator of the project team. Omar Smadi is the project principal contributor and Patrick Pittenger is a research assistant for the project.

EXECUTIVE SUMMARY

This report documents the workplan development and system design of Iowa's statewide pavement management system (PMS). The system will cover all federal aid eligible highways in Iowa except the National Highway System (NHS). This includes approximately 24,000 center line miles of Iowa highways operated under the jurisdiction of cities, counties, and the Iowa Department of Transportation. A PMS to manage the NHS is being developed under a parallel effort.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 required that all federal aid eligible highways must be included in a PMS. In addition to PMS, ISTEA mandated states develop five other management systems and a statewide traffic monitoring system. Interim rules governing the development of the management systems require states submit to the Federal Highway Administration (FHWA) work plans for the development of systems by September 30, 1994 and the systems described in the workplans must be implemented on or before September 30, 1997.

The Statewide non-NHS Pavement Management System steering committee developed a workplan during the summer, 1994, for submission to FHWA. The workplan divides the Statewide PMS's development in three portions; design, implementation, and operation and maintenance. This report describes the workplan and tasks conducted to complete the system design.

The design emphasizes the use of the Statewide system as a network level planning tool where actual project level decisions are made by highway operating agencies. Some of the most difficult issues faced in the system design involve data management issues and data content. This is especially true of the development of a location referencing system to identify the location of the collection of highway test data, the location of highway features, and the location of pavement management sections.

The report summarize the workplan developed for the design and implementation of the statewide PMS and the system design tasks completed. The design tasks include:

- Development of a statement of purpose.
- Establishment of data needs.
- Identification of pavement management analysis and database tool issues.
- Establishment of information delivery systems for local and regional governments.
- Establishment of procedures for system governance, operation, and support.

The next step in the project is to implement the system. System implementation steps were started in October, 1994.

PLANNING, IMPLEMENTATION AND OPERATION OF A STATEWIDE PAVEMENT MANAGEMENT SYSTEM: WORKPLAN DEVELOPMENT AND SYSTEM DESIGN

A statewide pavement management system (PMS) is currently under development by the Iowa Department of Transportation (Iowa DOT). The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 requires all federal aid eligible roadways to be included in a pavement management system. The statewide system is intended to satisfy ISTEA's requirement and to facilitate more informed pavement management decisions by all Iowa highway operating agencies. The scope of the project is limited to Iowa's federal aid eligible highways which are not part of the National Highway System (NHS). Iowa's non-NHS federal aid eligible system is comprised of the principal arterials, minor arterials, major collectors, and minor collectors. The system contains approximately 24,000 centerline miles. A parallel project is developing the PMS for the NHS.

The Statewide non-NHS Pavement Management System steering committee is overseeing the project. The committee is chaired by Iowa DOT's Director of the Office of Materials and includes representatives of the Iowa DOT's Engineering Division, the Office of Program Management, the Office of Design, the Office of Local Systems, the Maintenance Division, Federal Highway Administration, and local and regional governmental representatives. The local and regional representatives include representatives of the Iowa Chapter of the American Public Works Association, the Iowa County Engineers Association and the Iowa Association of Regional Councils. The committee was scheduled to meet roughly once per month.

The project is being supported by staff from the Iowa Transportation Center (ITC). The project principal investigator is Tom Maze. Omar Smadi, a transportation specialist, is the principle staff member assigned to the project along with Patrick Pittenger, a graduate research assistant. The ITC began its activities in support of the Iowa DOT's development of a statewide PMS the spring of 1994. The ITC researchers worked closely with the steering committee in preparing the background information concerning issues and recommendations to be discussed and also in organizing the committee's monthly meetings.

This report summarizes the activities involving the development of a workplan and the development of the system's design. Activities described in this report are those conducted between April 1 and October 1, 1994. This report includes a description of the workplan and a description of system design decisions made by the committee.

WORK PLAN

The Federal Highway Administration (FHWA) required that the state submit a workplan for the statewide pavement management system. The following are brief descriptions of all work tasks included in the workplan. The dates for the commencement and conclusion of each task may be found in Table 1.

Design Task I: Develop a Statement of Purpose This task will include the development of a mission statement, system objectives, and measures of effectiveness.

Design Task II: Establish Data Needs This task involves determining which data elements to collect, which collection methodology should be utilized, how the pavement conditions should be inventoried, and structure of the data base.

Design Task III: Analyze Pavement Management and Database Tools A broad variety of pavement management analysis and database tools are available. However, each fits within one of a few fundamental categories of decision making tools. This task will determine which category of tools is most desirable.

Design Task IV: Establish Information Delivery for Regional and Local Governments This task deals with the development of a plan for data exchange with regional governments.

Design Task V: Establish System Governance, Operation and Support This task will determine institutional issues associated with the operation of the statewide pavement management system.

The following are implementation tasks for the non-NHS federal aid eligible statewide pavement management system. These implementation tasks will end when the system has been tested, evaluated, and is ready for routine use.

Implementation Task I: Establish the Database The database system will be establishment for later population by pavement management data.

Implementation Task II: Implement the Inventory Systems In this task, the physical inventory of pavements will be coordinated with the symbolic inventory system (inventory records). This will structure the spatial dimensions of pavement condition data collection and pavement management units.

Implementation Task III: Evaluate Data Collections Options It is likely the collection of pavement condition data will involve automated data collection equipment. This task will evaluate the financial, institutional, and technological options available for data collection and select the most desirable option.

Implementation Task IV: Collect Pavement Historical Data The historical data will be the first data elements collected. This task will collect historical data from state and local highway agencies and develop the historical data files.

Implementation Task V: Evaluate and Select Pavement Management Software In the design portion of phase II, the methodology of the pavement management model was selected. A determination will be made regarding whether performance predictions will be deterministic or probabilistic and whether resource allocation will be based on an optimization or a prioritization model. This task will evaluate the software options for each of the approaches and select software for use in the statewide pavement management process.

Implementation Task VI: Collect Base Line Data Using the equipment selected in Implementation Task III, sufficient baseline condition data will be collected.

Implementation Task VII: Calibrate Pavement Management Analysis System and Implement Database A model will be built to fit the requirements of the pavement management software selected. This will include the development of performance models, treatment strategies, development of treatment costs, performance triggers, etc. This is likely to require a significant level of effort and will involve input from county engineers, municipal engineers, public works directors, and Iowa DOT pavement managers. In addition to the development of the pavement management model, this will also include the development of a framework for life-cycle costing procedures for project level analysis of alternative designs.

Implementation Task VIII: Develop Data Exchange Mechanism One of the primary benefits of the system is to allow governmental jurisdictions access to data they may be unable to collect on their own. Through a statewide effort data can be collected that individual agencies would be unable to afford to collect on their own. In addition, it is also a system objective that local and regional agencies are able to up-load to the database and input pavement improvements made within their jurisdictions. This task will develop this data exchange mechanism.

Implementation Task IX: System Testing and Evaluation After the pavement management analysis model has been completely calibrated and implemented, the system will be tested on a sample of sections and then on a full scale, statewide analysis. Pavement managers from jurisdictions throughout Iowa will review the results of the system and critique the model.

Implementation Task X: Train Local and Regional Governmental Staff Members As the system enters the final stages of implementation, a series of training programs will be presented. The training programs will be offered throughout the state at locally accessible facilities. Most of the workshops will be hands-on training programs.

Implementation Task XI: Systems Evaluation The non-NHS pavement management system steering committee will review and evaluate the system with respect to its objectives. The evaluators will critique the system and recommend improvement to the system.

The work plan was developed for the benefit of both the Iowa DOT and the FHWA. An October 1, 1994 deadline for submission was set by the FHWA. The start of the system operation and maintenance was also set by the FHWA. Table 1 contains the timetable included in the work plan, outlining the phases, work tasks and the scheduled dates of task beginning and completion.

Table 1. Time Task Table from Work Plan Submitted to the FHWA

Time Task Table For Statewide Pavement Management System Implementation		
Task	**Begin Date**	**Completion Date**
Phase I, Development of Work Plan		July 1, 1994
Phase II, System Design and Implementation	April 1, 1994	Oct.1, 1997
Design Task I: Develop a Statement of Purpose		May 1, 1994
Design Task II: Establish Data Needs		Aug. 1, 1994
Design Task III: Analyze Pavement Management and Database Tools		Sept. 1, 1994
Design Task IV: Establish Information Delivery for Local and Regional Governments		Oct. 1, 1994

Time Task Table For Statewide Pavement Management System Implementation		
Task	**Begin Date**	**Completion Date**
Design Task V: Establish System Governance, Operation and Support		Oct. 1, 1994
Implementation Task I: Implement the Database		June, 1995
Implementation Task II: Implement the Inventory System		June, 1995
Implementation Task III: Evaluate Data Collection Options		June, 1995
Implementation Task IV: Collect Pavement Historical Data		December, 1995
Implementation Task V: Evaluate and Select Pavement Management Software		December, 1995
Implementation Task VI: Collect Baseline Data		December, 1996
Implementation Task VII: Calibrate Pavement Management Analysis System and Implement Database		December, 1996
Implementation Task VIII: Develop Data Exchange Mechanism		June, 1997
Implementation Task IX: System Testing and Evaluation		June, 1997
Implementation Task X: Train Local and Regional Governmental Staff Members		Sept., 1997
Implementation Task XI: System Evaluation		Sept., 1997
Phase III, System Operation and Maintenance	Oct. 1, 1997	

Also during the summer and early fall of 1994, the committee and the ITC staff began work on the system design. Design decisions were made through a committee process where ITC staff conducted background research and wrote a briefing paper which included recommended design decisions. During each monthly committee meeting the committee considered ITC staff recommendations and made decisions on system design issues being considered. The following sections and appendices include pertinent information presented at each monthly meeting and present conclusions and recommendations reached by the committee.

Design Task I: Develop a Statement of Purpose

Through the committee process a mission statement and project objectives were determined. The following is the mission statement of the statewide pavement management system.

> The statewide pavement management system mission is two-fold. The first is to provide information supporting the development of transportation improvement programs at the regional and state levels. The second is to provide information to highway operating agencies (local governments or the Iowa DOT) to facilitate the making of more informed project level pavement design, construction, and maintenance decisions.
>
> The pavement management system will be an unbiased and objective media for network level comparisons of highway pavement investment strategies using a mixture of principles from the fields of pavement maintenance, pavement design, and engineering economy. At the project level, the system will provide pavement information to assist pavement managers to make design, construction, and maintenance decisions which seek to maximize highway transportation user benefits and minimize the total life-cycle costs to all levels of government.
>
> A consistent and objective procedure will be used to collect data and perform analysis for all Iowa non-NHS federal aid eligible highways. The statewide system will provide guidance in making improvements to Iowa's non-NHS federal aid eligible highway network for the development of a statewide transportation improvement plan. The system's development will provide guidance for making system-wide resource allocations in an impartial and equitable decision making framework.
>
> To the extent possible, compatibility will be promoted between the statewide system, systems used by local and regional governments, and by the Iowa DOT. Project level design, construction, maintenance, and economic analysis will be supported by information provided through the statewide effort. Project level decisions will be the responsibility of local and state highway operating agencies. The statewide system will provide guidance and facilitate the use of objective pavement management models by highway operating agencies.

System development objectives include:

1. Develop a data collection and data management system which meets FHWA's pavement management rules. The elements collected for each highway section will depend on which measures are appropriate for each roadway surface type.

2. Provide information to perform network level pavement management analysis. The analysis will identify recommended network wide resource allocations which will become supporting information for the transportation improvement planning process at the regional and state levels.

3. Provide pavement management data to highway operating agencies to facilitate project level decisions and to regional governments to support development of regional transportation improvement plans.

4. Create a pavement management system inventory and data structure to be compatible with other transportation management systems to facilitate management system integration.

5. Recommend an organization to develop, implement, and conduct continuing operation of the pavement management system for the entire Iowa non-NHS federal aid eligible system.

A complete briefing paper was written on the statement of purpose for the statewide pavement management system. This paper is included in Appendix A.

Design Task II: Establish Data Needs

Data issues are important considerations in the development of pavement management systems because the system's performance is closely related to the quality of the data. The FHWA divides data issues into five categories: pavement system inventory, project history, condition survey, traffic data, and database management. These issues were formulated by the FHWA for the NHS, with the non-NHS to be tailored to meet the needs of the state.

The committee was presented with the following general topics for each of the above mentioned data issues:

Pavement System Inventory

- Sectioning Techniques - This involves determining the procedure used to determine the end of a pavement management section. This is a fundamental issue for the pavement management system since each section is treated, within the pavement system, as a uniform management unit. Criteria established for sectioning include minimum and maximum lengths, changes in pavement surface type, project history, changes in traffic volume or composition, changes in functional classification, and changes in jurisdictional boundaries.

- Location Referencing - Location of the beginnings and endings of pavement sections, other roadway features, and pavement condition measurements must be referenced by a reference locational system and several systems have been used in pavement management and several are in use in Iowa. A common reference technique is to locate features by their location relative to a mile-post. Because a pavement management system considers several different attributes in its analysis, all must be tied to a common location reference system. For example, it must be possible to locate a pavement management section with respect to the location of pavement condition measurements and with respect to pavement construction and maintenance activities. Given that several different referencing systems are currently being used, the pavement management system presents the problem of selecting a standard location reference system or a standard conversion between the varying systems.

- Input of Local Operating Agencies - It was noted that the Iowa DOT maintains an inventory of pavement construction on its own system and on the federal aid eligible system operated by local governmental agencies. Although these Iowa DOT maintained records provide a substantial base, local governmental agencies should have the opportunity to verify their accuracy and make any necessary corrections.

Project History

- Types of Data - Project history information involves past data so that pavement performance models may be calibrated with historical data, but also changes to pavement sections as pavement improvements are made through time. This includes both activity data (what improvement was made) and cost of the improvement. This issue relates to the collection of project data from local governmental agencies and what should be required and what should be optional.

- Acquisition of Data - It is essential to have access to current data on pavement project improvements and to accumulate this information through time to develop better performance models. How this information should be collected becomes the issue.

Condition Survey

- Pavement Roughness Data - The FHWA rules are very specific and require the use of a Present Serviceability Rating (PSR) or the International Roughness Index (IRI). Both require a measurement of pavement roughness. The IRI is highly correlated with the output values of most road roughness measuring devices. The IRI is also an objective index, as opposed to subjectivity implicit in the PSR and other indexes.

- Types of Distresses to be Collected - Clearly it would be useful to collect as many measures of distress as possible. Even if distress information is not useful at the statewide level, the information can be exchanged with local governmental agencies to support the making of project level decisions. On the other hand, the more data that is collected, the more expensive the data collection process will likely become. Therefore, it is necessary to identify the tradeoff between the amount of information collected and its cost. However, the statewide system is only required to conduct network level analysis. Pavement condition data requirements for network level analysis are generally much less thorough than for project level analysis. Therefore, minimum pavement condition collection data requirements must be established which meet or exceed these minimum requirements.

- Frequency of Data Collection - Clearly, it is also desirable to have pavement condition data collected frequently for the entire network. However, both increasing the frequency and the extent of data collection can be costly. Thus a compromise must be reached between the amount of data desired and the frequency of the data collection based on the cost of data collection. It was recommended that frequency decisions should consider roadway classification, traffic volume, and minimum data requirements necessary for network level analysis.

- Responsibility For Data Collection - Pavement condition data could either be collected locally by highway operating agencies (the Iowa DOT, cities, and counties) centrally by a single organization, or through a mixture of both.

- Automated Data Collection - Assuming some data will be collected centrally, the next issue to consider is the data collection technology. Automated techniques are becoming more widely utilized for pavement management data collection. The advantages of automated data collection are economies of data collection, objectivity of automation, and greater ease in managing data in an automated format.

Traffic Data

- Traffic Data - The collection of reliable traffic and traffic classification data is essential for the forecasting of future pavement conditions. The Iowa DOT routinely performs traffic counts on the rural portions of the federal aid eligible system. Some local agencies routinely collect traffic counts and all local agencies could conduct traffic counts. The issue to consider is, from which group or groups should traffic counts be derived.

Database Management and Information Exchange

- System and Database Management - Although it was assumed that a single database would have to be centrally managed, the committee needed to consider where the database or databases would reside.

- Information Exchange - Highway operating agencies and regional affiliations are likely to provide the pavement management database information on the pavements they manage. Also, highway operating agencies should provide the results of pavement management as well as any raw data collected by the system. The committee needs to consider how data are to be exchanged from and to highway operating agencies and regional affiliations.

At the July meeting of the steering committee the following recommendations were accepted:

1. *Adopt general guidance for defining section beginnings and ends. During implementation of the pavement management system, develop specific rules for identifying section ends.*

2. *Allocate responsibility for providing initial roadway feature information to the Iowa DOT, while giving the opportunity for highway operation agencies to review and correct the information..*

3. *Allocate responsibility for providing future project history information, and updating project histories as conditions change, to highway operating agencies.*

4. *Use IRI, rather than a serviceability index, as a measure of pavement performance.*

5. *During implementation of the pavement management system, identify the specific pavement distress measurements to be made in distress surveys.*

6. *During implementation of the pavement management system, define pavement distress survey frequencies.*

7. *Collect pavement condition data centrally (even though highway operating agencies will collect roadway feature and project history data).*

8. *Utilize automated distress data collection technology. During system implementation, study equipment options to determine recommendations for specific technology and ownership relationships.*

9. *Include traffic volume data, vehicle classification counts, and axle-load data in the database for the pavement management system. These data are to be obtained from*

existing Iowa Department of Transportation traffic counting resources. Cities will be asked to provide traffic data counts on a voluntary basis.

10. *Maintain central support over the database, data management, and the mechanisms for data exchange.*

Following the committee's August meeting, a Data Collection subcommittee was formed. The Data Collection subcommittee met twice to discuss the following topics: pavement types to be consider independently by the pavement management analysis, the test data requirements of each jurisdictions, data collection coverage, time frequency of data collection, distresses needed for network and project level analysis, sectioning, and sampling techniques.

For each jurisdiction, the important data elements to performing pavement management activities for both the network and project levels were considered. Finally, the subcommittee determined the vital data elements required for each pavement type. The subcommittee first prepared a list of data needs for project level analysis, and then reduced this list to those that are vital for network level analysis. Tables 2 and 3 include the results of this process.

The subcommittee discussed the required data elements to be collected to perform pavement management activities on the statewide system. The pavement network was divided into four pavement categories.

- Portland Cement Concrete (PCC)
- Composite Pavements (COMP)
- Asphalt Concrete (AC)
- Bituminous Treated (BT)

The statewide non-NHS federal aid eligible system was divided according to the following jurisdictions:

- County jurisdiction
- City jurisdiction
- State jurisdiction

Table 2. Vital Data Elements Needed for Network Level Analysis by Pavement Type and Jurisdiction

	PCC	COMP	AC	BT
COUNTY SYSTEM	Ride	Ride	Ride	Ride
	Joint Distress & T-Cracking	Joint Distress & T-Cracking	T-Cracking	Pot Holes
			Block/Alligator	
CITY SYSTEM	Ride	Ride	Ride	Ride
	Joint Distress & T-Cracking	Joint Distress & T-Cracking	T/L-Cracking	Pot Holes
	Patching	Pot Holes	Block/Alligator	
STATE SYSTEM	Ride	Ride	Ride	Ride
	Joint Distress & T-Cracking	Joint Distress & T-Cracking	T-Cracking	Rutting
		Rutting	Rutting	

Table 3. Data Elements needed by Pavement Type and Jurisdiction for Project Level Analysis

	PCC	COMP	AC	BT
COUNTY SYSTEM	Ride	Ride	Ride	Ride
	Joint Distress	T-Cracking	T-Cracking	Pot Holes
	T-Cracking	Rutting	Block/Alligator	Patching
	Faulting	Bleeding	Rutting	Block/Alligator
	ASR/D-crack		Bleeding	T-Cracking
				Rutting
				Bleeding
CITY SYSTEM	Ride	T/L-Cracking	T/L-Cracking	Pot Holes
	Joint Distress	Ride	Ride	Block/Alligator
	T/L-Cracking	Pot Holes	Block/Alligator	Ride
	Faulting	Patching	Pot Holes	Patching
	Patching	Rutting	Patching	Rutting
	ASR/D-crack		Rutting	Bleeding
			Bleeding	
STATE SYSTEM	Ride	Ride	Ride	Ride
	Joint Distress	T-Cracking	T-Cracking	Pot Holes
	T-Cracking	Rutting	Block/Alligator	Patching
	Structure	Structure	Structure	Block/Alligator
	Patching	Patching	Patching	T-Cracking
	Faulting	Bleeding	Rutting	Rutting
	ASR/D-crack		Bleeding	Bleeding

Coverage of Pavement Testing

The non-NHS federal aid network includes both rural and urban areas. The system is made up of approximately 63,000 rural lane kilometers and 9,000 urban lane kilometers.

In considering how to structure the testing of pavements, the subcommittee decided it would be more effective to divide the pavement network into uniform length pavement test sections. Test sections should not be confused with pavement management sections. Test sections are only created for pavement testing purposes (e.g., roughness measurement, friction measurement, measurement of cracking, etc.) while pavement management sections are the fundamental unit for management of pavements. The test sections are short enough in length to ensure that one or more are located within almost all pavement management section. Pavement management sections are often non-uniform in length (e.g., length of pavement management sections may vary from one section to the next) and pavement management section end points may vary through time as new pavement reconstruction and construction takes place. The variability of pavement management section ends and lengths makes it difficult to identify the specific section of pavement a test vehicle is traveling along a roadway. By using uniform and independent test sections, locating a test vehicle along a pavement will be simplified. Locations of test sections and pavement management sections can be matched using the dynamic segmentation capabilities of the database (dynamic segmentation is defined later in the text).

Within each test section, only a portion of the pavements along the entire section length will be tested. For example, in a test section of two kilometers in length, a random sample of rut depth within the test section will be stored for pavement management purposes The sample is assumed to be representative of the entire test section.

<u>Rural sections:</u> The subcommittee's recommended test section parameters in rural areas are the following.

- Rural pavement test sections should be two kilometers in length. The data collection subcommittee recommended a two kilometer section length as a compromise between a shorter section length requiring more tests and costing more, and providing enough tests to result in ample samples for pavement management. Because of the cost implications of the sampling scheme, a recommended sampling scheme and corresponding data collection cost will be provided to the management systems policy committee for approval. There will be occasions where the random sample is located within two pavement management sections. In this case the sample would be discarded. As a result, if pavement sections were decreased to only one kilometer, fewer test samples would be discarded.

- A ten percent random sample within each test section was recommended by the Data Collection subcommittee. The subcommittee recommended a random location within the test section rather than a specific location to avoid any potential for location bias.

- Testing in both directions on a two-lane facility was recommended by the Data Collection subcommittee. When this recommendation was presented to the full committee, many felt that it may not be necessary to perform tests in both directions because opposing lanes should be exposed to similar traffic volumes. On the other hand, in some cases where a roadway leads to a truck loading or unloading facility (e.g., a grain elevator or a land fill), the loads the truck experiences in opposite directions may be extremely different. Therefore, the committee decided to wait for an accurate cost estimate before recommending to the management system policy committee whether pavements should be tested in both directions (the higher cost option) or in one direction.

- The subcommittee also recommended that for highways with four lanes or more, one lane in each direction should be tested (the outside lane in one direction and the inside lane in the other direction). Again, the final recommendation to the management systems policy committee will be dependent on the estimated cost implications.

<u>Urban sections:</u> The subcommittee's recommended test section parameters in urban areas are the following.

- The subcommittee recommended that urban pavement test sections be 0.5 kilometer in length. In urban areas, pavement management sections are likely to be much shorter than they are in rural areas. Therefore, there is a need for shorter test sections in urban areas, but shorter test sections increases the number of tests required which increases the total cost of testing. Test section lengths of 0.5 kilometers was believed to be a reasonable compromise between the total costs of tests and the need to have short test sections in urban areas.

- A twenty percent random sample within each section should be tested. The subcommittee recommended a random location within the test section rather than a specific location to avoid any potential for location bias.

- The subcommittee recommended that pavement sections should be tested in both directions on a two-lane facility. The justification for testing in both directions, instead of testing in only one direction, was that opposing lanes may experience different traffic volumes and axle loadings. Similar to the recommendation to test in both directions on the rural system, when this was presented to the entire committee, some felt sampling in both directions was unnecessary. Therefore, the committee decided to wait for an accurate cost estimate before recommending to the management system policy committee whether pavements should be tested in both directions (the higher cost option) or in one direction.

- The subcommittee also recommended that for highways with four lanes or more, one lane in each direction should be tested (outside lane in one direction and the inside lane in the other direction). Again, the final recommendation to the management systems policy committee will be dependent on the estimate of cost implications.

Frequency of Testing

The subcommittee recommended covering one-half of the non-NHS federal aid system annually, but recognized testing as much as one-half the entire system every year may be cost prohibitive. However, the subcommittee felt that if the cost of testing half the system during each year was too great, a satisfactory alternative would be to place testing on a three year rotation, testing one-third of the non-NHS federal aid system every year.

The subcommittee also recommended testing be conducted over an entire Regional Planning Affiliation during each year. More specifically, the data collection regions would be divided along Regional Planning Affiliations (RPA) lines. This would mean all municipal, county, and state roads in one-half or one-third of the regions would be tested during each year.

Design Task III: Pavement Management Analysis and Database Tools

The design of the pavement management analysis tool and the database tool included three areas: location referencing systems, automated data collection tools, and pavement management analysis issues.

Location Referencing Systems

Location referencing systems are methods used to identify unique location points on a roadway or the ends of roadway segments. Several methods have been developed to reference locations and many are used by local and state highway operating agencies in Iowa. The Iowa DOT uses several different location reference systems to identify different types of data associated with physical locations along roadways. For example, the Iowa DOT uses one system to reference the location of accidents and another system to locate pavement test locations. Historically, different data types were collected for independent purposes and a common referencing system was not needed. However, management systems deviate from the traditional approaches of managing roadways by using a systems approach and by considering all relevant information simultaneously.

A systems approach to management requires that all pavement data associated with a specific roadway location be referenced to a uniquely identified location so that all data may be considered simultaneously. This does not mean that all data must be collected using the same location referencing system. It does mean that a conversion must exist which relates the location of all relevant data to one unique location. In other words, it should be possible to reference or convert existing location references of all roadway data elements to a single reference systems.

Most local agencies having pavement management systems use literal descriptions to locate points in their system. The location referencing systems currently used by the Iowa include the following[1]:

Linear Referencing Systems This is one dimensional reference system where points are located a linear distance from a specific reference. The Iowa DOT uses two linear referencing systems. They are:

- Milepost system - This is a linear measurement, in increments of one-mile, from the point where the route crosses the state's boundary or at the beginning of the route. Mileposts are placed at one-mile increments and are sequentially numbered. Because distances between mileposts along the highway are modified by highway realignment and routes are very seldomly re-posted to meet the new modified route length, mileposts typically become reference points at arbitrary locations rather than true mileposts, located serially at mile increments.

- Milepoint system - This is a system where points along a route are identified by their distance a long the roadway from the county boundary or from the beginning of the route. Because the linear distance from the county boundary is not a unique location identifier, the milepoint location is coupled with roadway's county, highway systems, route, and segment sequence (a system of sequentially numbered segments on the route).

Segmental Systems In this system, routes are broken into segments and referenced sequentially. For example, pavement management sections many be considered segments and the location of each segment is referenced by the preceding segment and the length of the segment.

Link/node Systems Nodes are located at points of significance within a link/node system. Nodes are typically an intersection, railroad crossing, or other important roadway or jurisdictional feature. Roadways between nodes are links and locations on the roadway are identified by their distance and direction from a node. The accident location and analysis system (ALAS) used for located all accident locations in Iowa is a link/node system.

Jurisdictional and Land Survey System Although not a true point referencing system, secondary roads in Iowa are located in the Iowa DOT's base record system by county, township, range, section and route number.

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1 This discussion of reference systems in use in Iowa was extracted from: Knight, P., "Evaluation of Referencing Systems for the Iowa Department of Transportation," Creative Component in partial fulfillment of requirement for a Masters of Science in Civil Engineering, Iowa State University, 1994.

Spatial Referencing Systems These systems involve locating points in two or three dimensions. They range from simple Cartesian (X - Y grids) systems to geographic coordinate systems like the state plane coordinate system and locations identified by their latitude, longitude, and altitude.

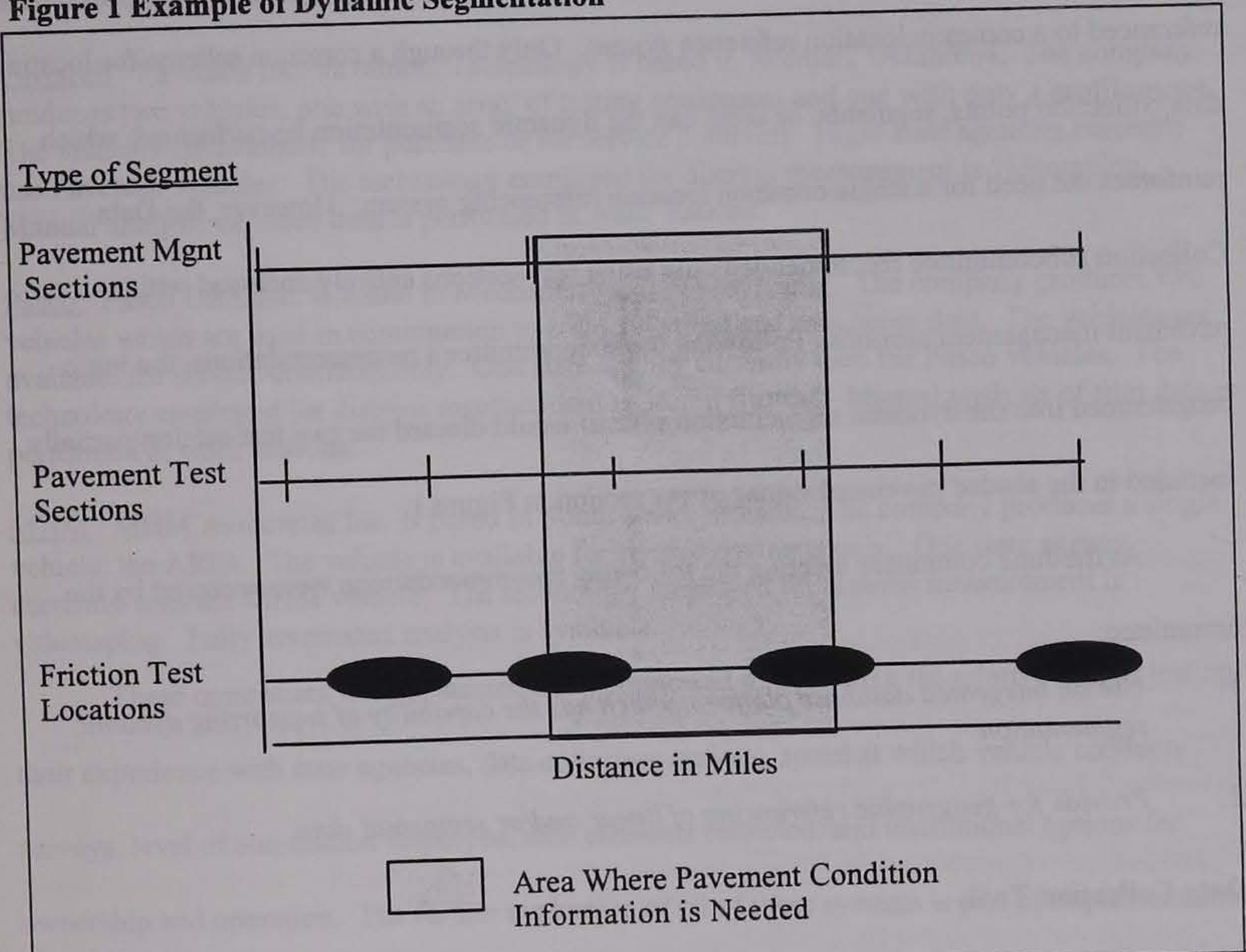
It was recommended to the committee that geographical coordinates, based on latitude and longitude, should be used as an single method for referencing all data elements relevant to the pavement management system. This does not mean that all data collected must be referenced by geographical coordinates. It does mean that all other systems must be capable of being converted to unique geographical coordinates. Further, this recommendation does not require that a geographic system be put in place immediately. Rather, a plan should be developed to migrate to a geographic system.

Dynamic Segmentation

It was recommended that all database and data decisions be based upon the use of dynamic segmentation. In other words, the committee will only consider using database software solutions which offers dynamic segmentation. To illustrate dynamic segmentation, consider Figure 1. In Figure 1, the same length of roadway is shown from three different perspectives. In the upper most perspective, the roadway is divided into pavement management sections. In the middle perspective, the roadway is divided into pavement test sections and the bottom perspective shows the location of pavement friction measurements. No data are collected over an entire pavement management section. Therefore, data from the other sampling schemes must be aggregated (mapped) into pavement management sections.

In the illustration shown in Figure 1, the pavement management section contains parts or all of three pavement test sections (test sections are shown in the middle perspective). Dynamic segmentation will map the test data onto the pavement management section following user

Figure 1 Example of Dynamic Segmentation



defined logical rules. For example, suppose a measurement of the extent of transverse cracking is need for the pavement management section. Also assume the extent of transverse cracking is found to vary in each of the three test sections. To develop a composite measurement for the entire pavement management section, the dynamic segmentation logical rules may ask for a weighted average of each of the three test section measurements. The weighted average may weigh each test section measurement by the relative length of the test section's overlap with the pavement management section.

A requirement of dynamic segmentation is that location of all data collected must be referenced to a common location reference system. Only through a common scheme for locating data collection points, segments, or areas can the dynamic segmentation be performed, which reinforces the need for a single common location referencing system. However, the Data Collection subcommittee recommended only using test sections entirely enclosed within pavement management sections. Following the subcommittee's recommendations, the logic programmed into the dynamic segmentation system would discard the two test section partially included in the shaded pavement management section in Figure 1.

At the June committee meeting the following recommendations were accepted by the committee:

1. *Use an integrated database platform which has the capability of supporting dynamic segmentation.*

2. *Provide for geographic referencing of linear and/or segmental data.*

Data Collection Tools

The committee established as a goal the use of an automated system for pavement testing data collection. To provide initial data on the use and costs of automated systems for data collection, preliminary evaluation was initiated on the five most popular models of automated pavement testing systems. The five evaluated were:

Roadware The Roadware Corporation is based in Paris, Ontario and has regional offices throughout the United States. The company produces three versions of their ARAN vehicle. The vehicles are available for purchase or for service contracts. Nineteen state agencies currently use Roadware vehicles. The technology employed for distress measurement is videotaping, with automated and manual analysis available.

IMS Infrastructure Management Systems is based in Arlington Heights, Illinois and has regional offices in the United States and Canada. The company produces a single vehicle, PAVUE. The vehicles are available for service contracts only. One state agency currently uses the IMS vehicle. The technology employed for distress measurement is a combination of lasers and videotaping. Fully automated and manual distress evaluation are both available.

Pavetech Pavetech Inc. Pavement Technology is based in Norman, Oklahoma. The company produces two vehicles, one with an array of testing equipment and one with only a profilometer. The vehicles are available for purchase or for service contracts. Eight state agencies currently use Pavetech vehicles. The technology employed for distress measurement is videotaping. Manual analysis of video data is performed at work stations.

Pasco Pasco USA Inc. is based in Mechanicsburg, Pennsylvania. The company produces two vehicles which are used in combination to collect distress and roughness data. The vehicles are available for service contracts only. One state agency currently uses the Pasco vehicles. The technology employed for distress measurement is 35mm filming. Manual analysis of film data is performed at work stations.

MHM MHM Associates Inc. is based in South Bend, Indiana. The company produces a single vehicle, the ARIA. The vehicle is available for service contracts only. One state agency currently uses the MHM vehicle. The technology employed for distress measurement is videotaping. Fully automated analysis is available.

These companies were contacted and interviewed to determine the relative cost of testing, their experience with state agencies, data collection options, speed at which vehicle conducts surveys, level of automation employed, data elements collected, and institutional options for ownership and operation. The further evaluation of all of these systems is part of implementation phase of the project.

The Iowa DOT is in the formative stages of a research project with the Manley Corporation to develop equipment capable of conducting distress evaluation using image analysis. The concept is that video images of the roadway will be collected with a digital camera and intelligent software will be used to automatically interpret the images. Although the image interpretation concept holds great promise, it is still in the development stage. As a result, the video image system will not be considered as a possible data collection solution.

The data collection subcommittee requested that the ITC researchers attain cost estimates for data collection from vendors of automated data collection systems. The five vendors were asked to provide preliminary estimates of the cost of testing pavement based on the subcommittee's sampling scheme. Almost all of the vendors provided an estimated range of costs. The majority of vendors' estimates were in the range from 500,000 to 700,000 dollars per year, assuming data collection covered 50 percent of the network annually. The lowest estimate was 350,000 dollars per year, while the high estimate was 1,300,000 dollars per year. The low estimate is based on a significant level of automation and a high speed of travel by the data collection equipment. The high costs alternative involves a semi-automated system where data are collected automatically but data are interpreted manually. The vendor of the semi-automated system knows the human interpretation of data places their system at a cost disadvantage but also believes the interpretation provided improves the value of information derived from the system. The actual price would be affected by the Iowa DOT Management Systems Policy committee's decisions concerning section length and testing in both directions.

Pavement Management Analysis Issues

This issue pertained to the considerations for selecting a pavement management system analysis tool. There are three major considerations in the selection of an appropriate analysis tool including 1) operational level or working level of the decision support system, 2) decision analysis process, and 3) performance prediction.

<u>Operational levels</u> Pavement management is a process that has two basic working levels: 1) network level and 2) project level. Network level pavement management has as its primary purpose the development of a prioritized program and schedule of work, within overall budget and performance constraints. The network level is primarily responsible for the development of long range planning programs that shape the health or condition of the entire pavement network

being managed. It involves a "top down" approach where project candidates are developed as a result of the network level analysis.

Network level pavement management analysis tools can utilize either optimization or prioritization techniques. In general, network level pavement management models have three major components: 1) an objective (e.g., minimize cost or maximize benefits), 2) constraints, and 3) performance prediction.

Project level pavement management essentially involves specific pavement sections or project considerations and decisions. It represents the actual physical implementation of network decisions and recommendations. The application of project decisions is carried out through an iterative process between the higher level network analysis and project level analysis. Thus, the project level decisions are derived from the network level schedule.

Project level analysis is vital the feedback and updates to the network level estimates. Project level analysis requires more detailed data to make specific project level design decisions.

Both of the two operational levels have some major activities or functions to perform. The following is a summary of these activities.

Network level:

Network level analysis requires the following activities to support the analysis:

1. Identifying pavement management sections and their properties.
2. Acquiring pavement condition and history data.
3. Determining performance criteria for use in gauging the condition and performance of the pavements.
4. Forecasting future pavement conditions.
5. Calculating existing and future budget requirements.
6. Identifying program alternatives and a schedule of work.

Project level:

Project level analysis requires the following activities to support the analysis:

1. Identifying pavement management sections and their properties.
2. Acquiring detailed pavement condition and history data.
3. Performing technical and economic analyses within project alternatives.

4. Selecting the most cost effective alternative.
5. Comparing results with network level recommendations.
6. Implementing the results.

Looking at the major activities for each level, some similarities and differences between network and project level analysis can be seen and both operational levels work with the pavement network in terms of homogeneous pavement sections.

A major difference between the two operational levels comes from the data needed to carry out the pavement management analysis. Project level analysis requires more detailed pavement condition data for the making of project specific decisions. A second major difference is the results of the analysis performed at each level. Network level results provide general guidelines for the entire pavement network based on condition or treatment categories. On the other hand, project level results identify specific maintenance or rehabilitation alternatives for pavement sections, then, on the basis of life-cycle cost or economic analysis techniques, the most cost effective alternative project is selected for implementation.

<u>Decision Analysis Process</u> The purpose of the decision analysis process of the pavement management system is to support pavement management decision making. In most cases, the pavement management analysis system recommends allocations of resources to activities or projects (projects in the case of project level analysis) and recommends when resources are to be allocated.

Decision analysis processes can be divided into three major methodologies: 1) prioritization, 2) heuristics (near optimal, not a true optimization), and 3) optimization. Projects can be prioritized by many methods, ranging from a simple subjective ranking to the more complex methods using priority indices. Subjective ranking defeats many of the advantages of pavement management systems because of the subjective nature of the ranking process. Many highway agencies use parameter-based ranking, which is based on a priority index. This approach is simple and easy to use, but it may provide results far from the optimal solution.

Heuristics are usually iterative procedures that are believed to offer near optimal solutions but do not necessarily reach an optimal solution. They often use computational shortcuts to reach desirable solutions, resulting in shorter computer analysis periods and allowing analysis to reach solutions for very large pavement management problems on microcomputers. Heuristics used in pavement management decision analysis include incremental benefit cost analysis, and marginal cost effectiveness. Incremental benefit cost analysis is a very popular approach and was selected by the Iowa DOT for project level analysis for the Department's own pavement management decision support system.

Optimization methods are applied using mathematical programming techniques and can be applied to either single year or multi-year pavement management analyses. Optimization methods select pavement management strategies which satisfy a specific objective function and remain within a set of system constraints. Formulations used in pavement management systems include variations of linear programming, integer programming, and dynamic programming. Objective functions can maximize benefits (user or agency) or minimize cost (user, agency, or a combination of both). Constraints to the pavement management system can include budget limits, performance minimums, and resources availability.

Performance Prediction To determine future pavement needs, it is necessary to have the ability to predict a pavement's condition in the future. Performance prediction models can be divided into two general categories: 1) deterministic and 2) probabilistic. A pavement prediction methodology should be selected based on the availability of data and the analysis level of pavement management activities (network level and/or project level).

Deterministic models are usually regression models that relate pavement condition to pavement age or traffic loadings. Performance curves, whether linear or nonlinear, are one of the more common deterministic models to predict pavement condition. Deterministic models provide valuable tools to conduct project level pavement management analysis.

An example of a deterministic performance curve is shown in Figure 2. In this case, the performance curve is simply a nonlinear regression fit of a curve through historical pavement condition data.

The disadvantage of using deterministic pavement condition forecasting models is that they forecast the exact condition of every pavement section for the future. Clearly, future pavement conditions will vary from the predicted conditions, thus providing the possibility for selecting the incorrect management strategy. Because deterministic models ignore variability in future pavement conditions, they are most appropriate when projecting performance over short time frames (less than five years). In general, deterministic approaches are most appropriate for project level analysis.

Probabilistic performance models allow for subjectivity in performance prediction, where the experience of pavement management personnel is captured using formally structured methods. Survivor curves and transitional probabilities matrices (Markov or semi-Markov chain models) are excellent examples of probabilistic pavement performance predictions. For example, a transitional probability matrix defines the probability that a pavement in a certain initial

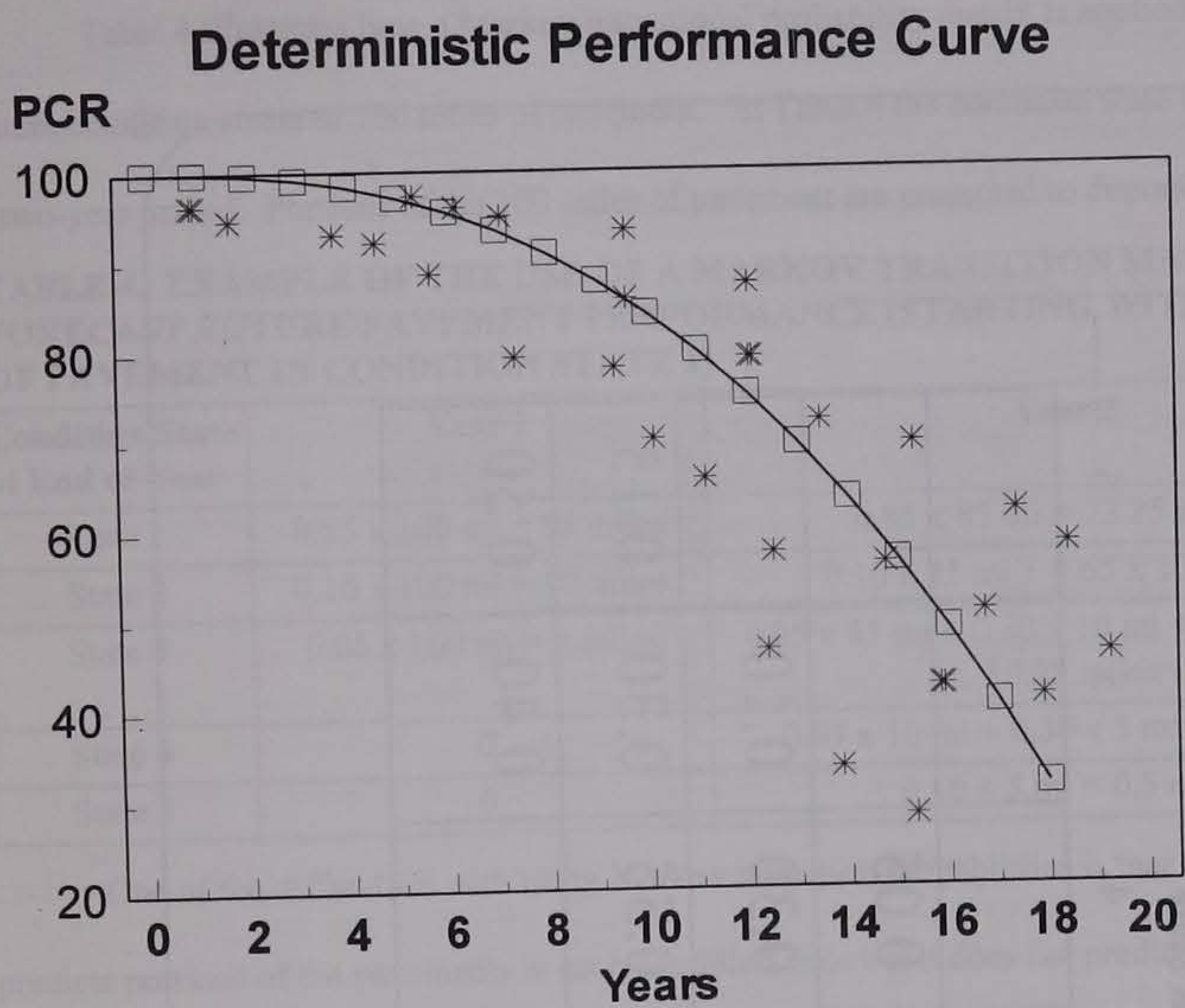


Figure 2 Deterministic Pavement Performance Curve

condition will transcend to a lower condition within one year. In the terminology of Markov chain models, the condition in any single year is defined as its state.

An example Markov transitional probability matrix is shown in Figure 3. On the vertical axis is the condition state of a pavement section at the beginning of a year and on the horizontal axis is the condition state of the pavement at the end of the year. Inside the matrix the probabilities of the pavement section moving from one condition state to another during one year are shown. For example, the probability of a pavement remaining in condition state 1 (the highest pavement condition) over the course of one year is 85 percent. The probability of a pavement moving from condition state 1 to condition state 2 in one year is 10 percent.

Markov Transitional Probabilities

To PCR State

From PCR State	1	2	3	4	5	6 -------
1	0.85	0.10	0.05			
2		0.65	0.30	0.05		
3			0.60	0.30	0.10	
4				0.55	0.30	0.15
5					0.40	0.50

Figure 3 Markov Transition Matrix

Table 4 illustrates how a Markov transitional probability matrix is applied to predict the future condition states of 100 miles of pavement. In Table 4 the condition state is predicted over a two-year period. Portions of the 100 miles of pavement are projected to degrade over time.

TABLE 4. EXAMPLE OF THE USE OF A MARKOV TRANSITION MATRIX TO FORECAST FUTURE PAVEMENT PERFORMANCE (STARTING WITH 100 MILES OF PAVEMENT IN CONDITION STATE 1)

Condition State at End of Year	Year 1	Year 2
State 1	0.85 x 100 mi = 85 miles	0.85 x 85 mi = 72.25 miles
State 2	0.10 x 100 mi = 10 miles	0.10 x 85 mi + 0.65 x 10 mi = 15
State 3	0.05 x 100 mi = 5 miles	0.05 x 85 mi + 0.30 x 10 mi + 0.60 x 5 mi = 10.25 miles
State 4	0	0.05 x 10 mi + 0.30 x 5 mi = 2.0 miles
State 5	0	0.10 x 5 mi = 0.5 miles

One of the difficulties with using Markov transition probabilities is that the analysis predicts portions of the pavements in each condition state but it does not predict which specific pavement section is at which state. The analysis only forecasts condition of portions of the entire pavement network and not the condition of each individual section. Despite this drawback, the use of Markov transition probability matrices is very popular for conducting network level pavement management.

The following recommendations were made by ITC staff and accepted by the committee:

1. *Preliminary selection of a Markov transition matrix approach to forecasting future pavement condition*
2. *Preliminary selection of linear programming to support decision analysis.*

These two analysis approaches are the most popular tools for network level pavement management. In addition, the Iowa DOT has recently purchased the software to support the department's network level pavement management. This decision to select a Markov chain based model should be reconsidered when the system advances to implementation.

Design Task IV: Establish Information Delivery for Local and Regional Governments

During this task, ITC researchers made numerous site visits to discuss the perspectives of city, county, Metropolitan Planning Organization (MPO), and RPA agencies. Presentations were also made at the statewide annual meetings of the Iowa Chapter of the American Public Works Association and the Iowa County Engineers Association. Numerous topics were discussed, focusing on project progress, local agencies' methods of pavement management status, and information delivery. Agencies visited included twelve cities, ten counties, two MPOs, and three RPAs.

The following issues generally received a positive response when presented to local and regional organizations:

- Many of the local governmental representatives felt it would be satisfactory to allow them to review pavement project data available from the Iowa DOT's base record system before inputting it into the statewide pavement management system's history files. The approach of providing local agencies with the opportunity to review and validate the original pavement history data and annual changes to the project history files was generally thought to be a very reasonable approach and one which would not burden local agencies with extensive administrative work.
- Several agencies were interested in extending data collection to include testing pavement on roadways that are not part of the federal aid eligible network. They also believed that the choice of an automated system for evaluating pavements helped to remove any bias or subjectivity in pavement evaluation.
- Several of the agencies attending the meeting were supportive of the MPO or RPA acting as a clearing house for regional pavement management activities. They felt that the MPO or RPA is in the best position to represent the interests of the entire region.
- Local and regional agencies were very interested in training and assistance to help them to better understand pavement management, allowing them to better interpret the results of pavement management systems, and how to apply pavement management principals to their own plans and programs.

The following issues were brought-up as concerns at many of the meetings:

- Several expressed a concern over the cost of automated pavement testing.
- Local governmental agencies that already had a pavement management system were concerned about the ability to integrate their existing local system with the statewide system.
- Some organizations were concerned they might lose out on funding as a result of pavement management. Believing that their organization already has superior pavement maintenance practices, some were concerned that their highways would receive less funding because they were already in good shape. Thus agencies already practicing good pavement management would be punished to elevate those that had neglected their pavements.
- Several agencies questioned the ability of a statewide system to consider the condition of the gravel surfaced portion of the federal aid eligible highway network. The surface condition of gravel roads changes every time the road is graded. Thus several questioned the validity of a statewide system which would measure the condition of the roadway once every other year.
- Many local agencies and particularly cities with populations less than 10,000, have little experience with pavement management and, if they are to make any use of the information derived from the system, highly accessible assistance will be required. Some even questioned the usefulness of pavement management at the local level. Almost all were concerned about the need for additional training for local governmental staff members and the availability of technical support.
- Some local governmental staff members questioned the validity of the Iowa DOT traffic data.

In consideration of the local and regional governmental concerns regarding information exchange, the committee adopted the following recommendations:

1. *Although the Iowa DOT will support the pavement management activities of the regional governments and provide them with the information necessary to conduct regional pavement management programs, the point of contact for regional affiliations is most appropriately with the regional transportation centers. During the implementation stage of the program, the steering committee will work to identify processes which utilize the centers as intermediaries with regional governments.*

2. *The meetings with local and regional governments confirmed the need to involve local agencies in the verifying and correction of inventory and project history data. Initially, project historical data will be provided to local governments and they will be required to validate the information in the Iowa DOT's base records. On an annual basis, local governments will be expected to update pavement project files as new projects are completed.*

3. *During the implementation portion of the project, the committee should consider the level of technical support and training provided to local governmental agencies.*

Design Task V: Establish System Governance, Operation, and Support

It was concluded that the system should be centrally managed and supported. It was recommended that the non-NHS Statewide Pavement Management steering committee continue to operate and governed during the implementation phase. Given that the implementation phase may last up to three years (October 1, 1994, to September 30, 1997), it was recommended the steering committee consider rules for rotation of membership and consider the expansion of the steering committee's membership to allow for participation by additional local and regional governmental agencies.

Future Tasks

The future tasks of this project were listed in the work plan for the entire project. The more immediate plans have been described in more detail in the implementation proposal prepared by ITC staff. This proposal covers Implementation Tasks I through V, and runs from October, 1994 through December, 1995. The tasks deal with implementation of the database, implementation of the inventory system, evaluation of data collection options, collection of pavement historical data, and evaluation and selection of pavement management software.

The following are brief descriptions of the five tasks:

Implementation Task I: Implementation of the Database This task will include an analysis of alternative database platforms and architectures. The analysis will include investigation of the relationship between the database to the base records and to other databases and the potential for integration. The mechanics of transitioning to a geographically based location referencing system must be partially resolved before this task can be completed. Recommendations will be made concerning database integration, database software, and system architecture. This task is scheduled to begin October 1, 1994 and to be completed by February 1, 1995.

Implementation Task II: Implementation of the Inventory System This task involves the division of Iowa's federal aid eligible system into pavement management sections. Local agencies will have the opportunity to harmonize section locations in the statewide system. Counties and cities with populations over 5,000 will be asked to indicate on maps and in literal descriptions the locations of pavement management sections. ITC researchers will code the information received into a Geographical Information System (GIS), with the literal descriptions attached to each location. This task is scheduled to begin December 1, 1994 and to be completed by June 1, 1995.

<u>Implementation Task III: Evaluation of Data Collection Options</u> The committee recommended the further investigation of automated distress measurement techniques. Institutional issues are to be investigated, as well as technological issues. Testing is currently being conducted by numerous states and by the FHWA. Investigation will build on these tests already being performed. A subcommittee will make recommendations to the entire committee concerning procurement of equipment or services. ITC researchers will work with Iowa DOT procurement staff to support development of a satisfactory services or equipment specification. This task is scheduled to begin November 1, 1994 and to be completed by April 1, 1995.

<u>Implementation Task IV: Collection of Pavement Historical Data</u> A decision was not reached concerning the necessary project history data elements. Possible data may include cost information, past performance data, roadway construction specifications, and cost and performance of past maintenance treatments. The data will be utilized in the calibration of pavement management models. Most historical data will be derived from the base records. Each local agency will be asked to review and correct the base records for the respective jurisdictions. ITC researchers will evaluate the corrections and make any necessary follow-up phone calls. The output of this task will be a corrected historical database of pavement sections. This task is scheduled to begin June 1, 1994 and to be completed by January 1, 1996.

<u>Implementation Task V: Evaluation and Selection of Pavement Management Software</u> The Iowa DOT recently conducted a review of pavement management software, but there are always new products being introduced to the market. The ITC researchers will review the available software and contact current users. The committee will be asked to select a limited number of candidates for further review. The vendors of the software packages will be invited to present and demonstrate their software to the committee. The committee will be asked to select one or two for bench testing. Bench testing will be conducted by ITC researchers, with committee members any local agency representatives having the opportunity to work with the systems before selection. This task is scheduled to begin July 1, 1994 and to be completed by January 1, 1996.

The remaining six implementation tasks in phase II will be addressed by an additional proposal to be prepared in late 1995. Phase III of the project, system operation and maintenance, will also be addressed by an additional proposal prepared by the ITC.

APPENDIX A

STATEMENT OF PURPOSE

BRIEFING PAPER

INTRODUCTION

The purpose of this chapter of the implementation plan is to identify the mission, objectives, measures of effectiveness, and evaluation process for the implementation of a statewide pavement system for Iowa federal aid eligible highways, streets, and roads **not** on the National Highway System (NHS). This chapter, and the rest of this document, describes only the implementation activities.

Mission

The statewide pavement management system mission is two fold. The first is to provide information supporting the development of transportation improvement programs at the regional and state levels. The second is to provide information to highway operating agencies (local governments or the Iowa Department of Transportation) to facilitate the making of more informed project level pavement design, construction, and maintenance decisions.

The pavement management system will provide an unbiased and objective media for network level comparisons of highway pavement investment strategies using a mixture of principles from the fields of pavement maintenance, pavement design, and engineering economy. At the project level, the system will provide pavement information to assist pavement managers to make design, construction, and maintenance decisions which seek to maximize highway transportation user benefits and minimize the total life cycle costs to all levels of government.

The statewide pavement management system will collect data and perform analysis using a consistent and objective procedure for all Iowa federal aid eligible highways. The statewide system will provide guidance in making improvements to Iowa's federal aid eligible highway network for the development of a statewide transportation improvement plan. The system's development will devise a method for making system wide resource allocations using an impartial and equitable decision making framework.

To the extent possible, compatibility will be promoted between the statewide system, systems used by local and regional governments, and the Iowa Department of Transportation. Project level design, construction, maintenance, and economic analysis will be supported by information provided through statewide effort, however, project level decisions will be the responsibility of the highway's operating jurisdiction. The statewide system will support and facilitate the use of objective pavement management models of the highway operating agency to provide cost effective and objective project-level decision making.

Pavement Management System Development Objectives

This section covers objectives for the development of the pavement management system. During the system implementation phase, operational objectives will be developed. Operational objectives will relate to the performance of an operational statewide pavement management system.

System development objectives include:

1. Develop a data collection and data management system that meets the Federal Highway Administration pavement management rules. The elements collected for each highway section will depend on what are appropriate measures for each roadway surface type. In general, the data collection and data management will include:

- A physical inventory of pavement features to include at a minimum the number of lanes, length, width, surface type, functional classification, and shoulder information.
- A history of project dates and types of construction, reconstruction, rehabilitation, and preventive maintenance. The system will accept historical information for the entire life of a pavement but will only require historical data starting from the time the pavement management system has been initiated.
- Collection of pavement condition data.

- Collection of traffic data to include at least volumes and vehicle classification.
- Management, storage, and retrieval of pavement management data within a relational database.

2. Perform network level pavement management analysis, identifying recommended network wide resource allocations, to provide input into the transportation improvement planning process at the regional and state levels. The analysis will consider the following:
    - A pavement management network analysis model that will, in its resource allocation algorithm, consider pavement condition.
    - A pavement management network analysis model that will include performance predictions that forecast the condition for each uniquely performing pavement surface type over the pavement's remaining life.
    - An economic analysis model that allows the statewide consideration of all federal aid eligible highways and recommends funding allocations at the network level.

3. Provide pavement management data to highway operating agencies to facilitate the making of more informed project level decisions and to regional governments to support development of regional transportation improvement plans.
    - A pavement management data exchange mechanism for local highway agencies, regional governments, and the Iowa Department of Transportation. The pavement management data provided through the exchange will support analysis of project level decisions made by local jurisdictions, and the Iowa Department of Transportation. Project level analysis will be the responsibility of the highway's operating jurisdiction. All operating jurisdictions will be provided data and technical training to allow project level analysis to consider single and multi-year life cycle analysis.
    - A mechanism to allow local and state highway agencies to electronically update changes to their pavement history data as new projects are completed.
    - A statewide data collection system that will provide a feedback loop for the evaluation of pavement conditions over time with respect to pavement design, construction, rehabilitation and maintenance treatment strategies, preventive maintenance, and other aspects related to the pavement's performance.

4. The pavement management system inventory and data structure will be compatible with other transportation management systems to facilitate management system integration.

This will include consideration of the following:

- Use of an integrated database platform or development of the compatibility to link the output of the pavement management system with a complete integrated transportation information system.
- Development of linkages between the pavement management system and other transportation management systems to allow consideration of common elements.
- Development of a uniform life-cycle cost analysis tools that perform an economic evaluation of improvements in all portions of the transportation infrastructure.

5. Structuring an organization to develop, implement, and conduct continuing operation of the pavement system management for the entire Iowa federal aid eligible system.

   Development of the organization will consider:

   - The qualifications of the individuals to be involved at various stages in the pavement management system's development.
   - The organization established to implement the system will determine a data collection framework. This will include establishing a uniform location reference system for pavement segment limits and monuments, a system for the collection of pavement history, a structure for the collection of pavement condition data, and a system for the collection of traffic information.
   - The organization will routinely collect pavement condition data.
   - The organization will work with pavement design and pavement maintenance professionals to calibrate the selected pavement management analysis tools. This will include a program to assist in the allocation of resources at the network level and tools to facilitate project level analysis.
   - The organization will conduct upgrading and modifications to the system as needed.
   - The organization will report on the current status of system, make presentations at informational meetings and conferences, periodically train highway operating agency pavement managers in the use of pavement conduction data and use of pavement management and project analysis tools, and provide technical consultation to highway operating agency staff personnel on pavement management issues.

Measures of Effectiveness

The following are some measures to determine how effectively the pavement management system development accomplishes its mission and objectives. Later, measures of effectiveness will be developed to determine how well the pavement management system will perform.

- Number of local jurisdictions capable of receiving the statewide system's pavement condition data in electronic format and utilizing the data in an automated project level pavement management system.
- Number of regional governments capable of receiving the statewide system's pavement condition data in electronic format and utilizing the data in an automated network and project level pavement management system.
- Number of local jurisdictions capable of electronically entering changes to their pavement data into the statewide pavement history database.
- Number of regional governments capable of electronically entering changes to their pavement data into the statewide pavement history database.
- Correlation of the budget and program recommendations of the network level pavement management system to the present network level recommendations.
- Ability to link pavement management data with data from other management systems within a common relational data base.
- Cost of operating the statewide pavement management on a per mile basis.

Evaluation Process

At the end of the implementation, a committee consisting of Iowa Department of Transportation and local and regional governmental staff will review the implementation of the pavement management system to insure the system accurately represents the actual pavements and provides information that is timely and useful.