ILLINOIS PAVEMENT FEEDBACK DATA AND MANAGEMENT SYSTEM

FINAL REPORT

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A Report of the Findings of:
Development and Field Testing of an
Illinois Pavement Feedback System

Project IHR-517
ILLINOIS COOPERATIVE HIGHWAY RESEARCH PROGRAM

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The Interstate highway system is "the most critical lifeline of the economy in the nation as well as Illinois." This vital transportation facility carries more than fifty percent of all goods shipped by highway in Illinois. Most of the system was built in the 1960's and 1970's and due to its age and heavy truck traffic, is currently experiencing considerable deterioration and requiring large rehabilitation funding. The Illinois Pavement Feedback Data and Management System (IPFS) was developed to assist administrators, planners and engineers of IDOT in managing this strategic transportation system. This report provides an overview of the capabilities of IPFS. Two major components of IPFS include:

1. A comprehensive Illinois Interstate highway pavement database of over 500 sections.

2. Procedures for retrieval and analysis of information through direct user queries, menu-driven automated database reports and analysis programs for pavement evaluation and rehabilitation and determining multi-year pavement funding needs. For example, several useful analysis results were obtained using the database including traffic loading trends and the performance of JRCP, CRCP and AC overlays over the past 30 years.

Future rehabilitation needs for the Interstate system are substantial. About one half of the network has now been rehabilitated and by the year 2000 nearly all of the sections in the network will be rehabilitated at least once. A continuous stream of maintenance and rehabilitation needs will exist into the future for all of these sections. The rehabilitation timing, type, design, materials and construction will all have an impact on the overall cost required to maintain this large highway network in an acceptable condition. Results obtained from the IPFS study provide several valuable tools for use by IDOT personnel in managing the Interstate highway network into the 1990's and beyond.
ACKNOWLEDGMENTS

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DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.
LIST OF IHR-517 REPORTS


517-4 "Analysis of the Traffic Loadings on Interstate Highways in Illinois," 1989 (FHWA-IL-UI-222). Describes the compilation of annual traffic volumes and classifications and the estimation of equivalent single-axle loads (ESALs) for each pavement section and shows the dramatic growth of ESALs over the past 30 years.


517-6 "Prototype Network Pavement Management System for the Illinois Interstate Highway System," 1990 (FHWA-IL-UI-230). Describes the ILLiNET software program which utilizes the IPFS database to evaluate multi-year rehabilitation funding needs for the Interstate highway system.

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ILLINOIS PAVEMENT FEEDBACK DATA AND MANAGEMENT SYSTEM—FINAL REPORT

INTRODUCTION

This final report provides a summary of the Illinois Pavement Feedback Data and Management System (IPFS) that has been developed jointly by the Illinois Department of Transportation and the University of Illinois. This system includes two major components.

1. Data collection procedures and a comprehensive database of key Illinois Interstate highway pavement inventory and monitoring information.

2. Procedures for retrieval of information through menu-driven automated database reports and analysis programs for project- and network-level pavement evaluation and rehabilitation, and also through direct user queries.
   
   (a) Data retrieval queries and menu driven reports to access the main IPFS database.
   
   (b) EXPEAR software for evaluation and rehabilitation of JRCP and CRCP.
   
   (c) ILLINET software for determining Interstate highway network multi-year rehabilitation and funding needs.

During the development of IPFS, several useful results were obtained using pavement data from the database. These were documented in several reports as demonstration results.

1. Traffic loading evaluation over the past 30 years.
2. Performance of JRCP and CRCP.

Illinois Interstate Highway System

The Illinois Interstate System includes over 500 different pavement sections, totaling over 1700 centerline miles and having a pavement replacement cost of over 7 billion dollars. The majority of these sections were built during the 1960’s and early 70’s and have experienced severe climatic conditions and much higher traffic loadings than those for which they were designed. About half of the network has already been rehabilitated and the rest either is currently in need of rehabilitation or will be within the next 10 years. It is estimated that by the year 2000 nearly all of the sections in the network will have been rehabilitated at least once and about half will already have been or will be in need of another rehabilitation.
A continuous stream of maintenance and rehabilitation needs will exist into the future for all of these sections. The rehabilitation timing, type, design, materials and construction will all have a great effect on the overall cost required to maintain this large highway network in an acceptable condition. Results obtained from the IPFS study provide several valuable tools for use by IDOT personnel in managing the Interstate highway network through the 1990's and beyond.

**Historical Development of IPFS**

In 1982 the Illinois Department of Transportation (IDOT) formed a high-level Standing Committee on Pavement Management composed of representatives from all pavement-related areas within the Department to oversee the IDOT pavement management process. The Committee recognized that a major deficiency in the Illinois pavement management process was the lack of and accessibility of many types of pavement data. As a result, IDOT undertook a cooperative research study with the University of Illinois Department of Civil Engineering to investigate the feasibility of an Illinois Pavement Feedback System (IPFS). The results of this study indicated a great need for improved pavement information for engineers, planners and management, as well as procedures and software to aid them in performing various pavement management activities, including the following. [1,2]

1. Evaluation of pavement performance, design procedures and various departmental pavement policies.

2. Conduct of special studies and research projects that require data from the pavement network.

3. Prediction of future condition of in-service pavements (e.g., CRS, cracking, rutting, punchouts, roughness).

4. Rehabilitation strategy selection for individual projects.

5. Multi-year rehabilitation programming and funding needs analysis for the Interstate highway pavement network.

As a result of the investigative study, a major research effort was initiated in 1985 to develop an Illinois Pavement Feedback System (IPFS) as a joint effort between the University of Illinois and IDOT. The new project was titled "Development and Field Testing of an Illinois Pavement Feedback System" (IHR-517). A broad-based Steering Committee was established to help guide the research project.

The development of IPFS has continued through FY 1990 and has reached a significant level of completion whereby various implementation activities can begin. Practically all of the development efforts were focused upon the Interstate highway system. Several practical and useful results have already been obtained through use of the database and associated software programs. A list of reports that were prepared under IHR-517 is provided at the beginning of this report.
CAPABILITIES AND STATUS OF IPFS

The IPFS has many capabilities to assist IDOT engineers, planners, and management in carrying out their pavement management activities, as illustrated in Figure 1.

Many Capabilities Available

   - Provides easy and rapid access to vital pavement management data and analysis programs.
   - Provides pavement feedback performance, design and traffic data on all individual construction sections on the Interstate highway system for many different planning, design, rehabilitation, maintenance, materials and construction purposes.
   - Provides readily available information for special studies such as an evaluation of various designs and standards (such as a comparison of 8-in CRCP versus 10-in JRCF, or the life extension of 4.5-in versus 3-in AC overlays of JRCF with "D" cracking, or the performance of the new doweled full-depth repairs).

2. Prototype Interstate highway network-level rehabilitation software program (ILLINET) that can be used to do the following:
   - Predict the loss of CRS for every section, and the number of years for CRS to fall below a set minimum level. Thus, it is possible to predict the remaining life of each section and place it into the standard rehabilitation priority time frames (e.g., 1-2 years, 3-5 years, 6-10 years and 10+ years).
   - Determine the unconstrained multi-year rehabilitation funding needs for up to 10 future years to maintain the network above a specified CRS condition. This information may be used to support future funding requests to top management and others. This may be done for individual districts as well as for the State's entire Interstate highway system.
   - Determine the pavement condition (CRS, distress) that will exist for each section in the database as a consequence of any input funding levels for each of 10 years and selected rehabilitation strategies.
Figure 1. Components of IPFS.
Select rehabilitation strategies for the network by several different policies and methods. Different policies can be simulated and the consequences observed over a 10-year period (e.g., only 3.25-in AC overlays, only reconstruction, a combination of CPR and 3.25-in AC overlays, combination of CPR, 3.25-in AC overlays, 4.5-inch AC overlays and reconstruction).

Program rehabilitation projects over 10 years so as to maximize the CRS level of the network, or even maximize vehicle miles traveled (VMT) on good roads with CRS greater 6.5, all within a given funding budget.

Produce graphical maps and hard copy displays of each district's pavement conditions, multi-year rehabilitation work, key construction history data, pavement types and traffic, as illustrated in Figure 2.

3. Answers to many difficult and varied pavement management questions such as the following (using the IPFS database and ILLINET software):

- "How do CRCP and JRPC performance compare? How has "D" cracking affected each of these pavement types? How do thicker CRCP slabs and increased steel content affect performance?" Figure 3 shows some preliminary results for CRCP.

- "What have the traffic loadings on the Interstate highway system been over the past 30 years? Have they been much higher than expected? How has this affected pavement life?" Increased traffic loadings are shown in Figure 4.

- "How have AC overlays performed when placed over JRPC and CRCP? Do thicker AC overlays improve service life? How does "D" cracking in the PCC slab affect the life of the overlay?" How does a thin AC overlay and a "D" cracked slab affect overlay life?

- "How much funding is needed each year over the next 10 years to maintain the entire Interstate highway system above a CRS of 6.5 for a given rehabilitation policy? For a different rehabilitation policy?"

- "Given the level of current funding for rehabilitation, what will be the expected mileage of backlog (CRS less than 5) Interstate highways over the next 10 years?" "Where will they be located?"

- "If the current rehabilitation budget were cut by 20 percent below current levels, what would be the expected mileage of backlog highways over the next 10 years?"

- "What percentage of total vehicle miles traveled (VMT) would be expected to occur under the above conditions?"
Figure 2. Sample network map.
Figure 3. Performance comparison of 8-in CRCP and 10-in JRCP.
Figure 4. Mean 18-kip ESAL applications per year for all Interstate highways.
- "What would be the effect on pavement deterioration and rehabilitation funding needs if truck weights and axles were changed in a certain way?"

- "Is there a large ‘wave’ of rehabilitation needs coming in the next few years due to past rehabilitation policies and limited funding availability?"


- Provides guidelines for data collection, evaluation and selection of feasible rehabilitation strategies.

- Estimates rehabilitation quantities and costs for each rehabilitation technique.

- Estimates the service life of different rehabilitation alternatives.

5. Capability (software) to analyze many different pavement rehabilitation design and policy issues, and the basic information to conduct special studies to solve a particular problem (e.g., problems with rutting, reflection cracking, patching effectiveness, overlay thickness, "D" cracking, exceptionally high traffic highways, subdrainage effectiveness, life-cycle costs).

6. Prediction equations for future pavement deterioration (approximate equations are available for predicting CRS, rutting, transverse cracking, joint deterioration, joint faulting, CRCP punchouts, etc.).

Status of IPFS Development and Field Testing

The development of IPFS began with a feasibility study, for which all bureaus and offices were interviewed about their pavement data needs and the kinds of questions that they were interested in having answered. The results showed that a tremendous amount of pavement management data existed that would be very useful to IDOT personnel, particularly management, if it were accessible and available. Many diverse data analysis needs existed in the different bureaus and offices. Therefore, the development of the IPFS began, focusing on the Interstate highway system.

The database was developed using the NOMAD2 mainframe database management system and all Interstate contracts, both original and rehabilitation were included. Many types of design, construction, traffic and performance data were added to the database. The initial data collection effort required a large amount of time and effort.
Pavement condition surveys were made of the entire Interstate system (except the Chicago area) in 1985, 1987 and 1989. In addition, previous distress data collected in 1977, 1979 and 1982, as well as CRS data from 1981 to 1988, were included in the database.

Several important analysis programs and automated reports have been developed that utilize the information in the IPFS database, including ILLINET (network-level rehabilitation programming software), EXPEAR (project-level evaluation and rehabilitation software), and various automated reports that directly access the NOMAD2 database to obtain desired information about any sections.

DESCRIPTION OF DATA COLLECTION AND THE DATABASE

Data Collection

All IPFS data is maintained in the NOMAD2 mainframe computer database. The database now contains over 97 percent of all Interstate section contract and rehabilitation information. Additional verification and obtaining of missing data is still needed and will be continued under the IHR-529 project. There are a number of discrepancies that need to be resolved including the beginning and ending section mileposts of some sections and the lack of distress data from the Chicago expressway system.

NOMAD2 Database

The database was developed using the NOMAD2 mainframe database management system and all Interstate contracts, both original and rehabilitation were included. Many types of design, construction, traffic and performance data were added to the database. The database currently contains information on over 500 individual sections as well as extensive traffic loading data and condition data.

Five different major database files exist: contracts, distress, traffic, CRS, and section summary. The NOMAD2 database includes several menu driven automated results output reports, in addition to many different user defined reports. The automated reports include the following: summary contract section, contract information, distress, traffic, CRS, and various ad hoc reports.

Other Data

The IPFS database was developed to fill information deficiencies in existing IDOT information systems for pavement management activities. Efforts were made to utilize existing data bases whenever possible. The development of future IPFS outputs including network analysis, project analysis, and research studies will utilize other information in addition to the NOMAD2 database. These include integration with roadway inventory, bridge inventory, materials inspection, accident, contract, and maintenance information systems.
Geographic Display

Geographic display capabilities will be developed in conjunction with IDOT’s roadway referencing project which is creating a link/node base for the entire state, county, township, and Federal-aid municipal roadway network. This project is still in the development phase; however, pavement management information has been integrated into initial link/node maps to show capabilities.

Geographic displays were also prototyped during project IHR-517 using the Illinois Department of Energy and Natural Resources Interstate highway base map.

PREDICTION OF PAVEMENT PERFORMANCE

Need for Performance Prediction

Future programming and budgeting require the capability to predict future pavement conditions. Without future prediction capabilities, multi-year programming cannot be done. During the course of the development of IPFS several different regression prediction equations were developed for CRS and distress. These equations were used in the ILLINET and EXPEAR programs to forecast future performance of in-service pavements. In addition to these regression equations, survival curve technology was used to analyze the service life of JRCP, CRCP and AC overlays of these pavements.

Historical Traffic Loadings

A pavement is designed to carry a certain number of standard equivalent 18-kip equivalent single-axle loads (ESALs) over a design period such as 20 years. If this traffic level is exceeded in a fewer number of years, the pavement may not last as long. Many engineers have long believed that the traffic level in Illinois and many other states has increased far more rapidly than expected. Therefore, to analyze the actual situation, volumes and weights of single and multiple unit trucks were determined and converted to cumulative 18-kip ESALs for every Interstate construction section over the period 1956 to 1986. [4]

Results show that the Interstate highway pavements have been subjected to far greater traffic loadings than those for which they were designed. Annual 18-kip ESALs (one direction, outer traffic lane), which averaged about 300,000 in the late 1950’s and early 1960’s, have grown to 1,200,000 in 1986. The growth rate of cumulative ESALs for the average pavement section has been over 8 percent compounded annually over the past 20 years and shows no signs of slowing down.

The traffic data have been input into the IPFS database for use by agency personnel.
Performance of CRCP and JRCP

A survival analysis was conducted for continuously reinforced concrete pavement (CRCP) and jointed reinforced concrete pavement (JRCP). Pavement data that was stored in the IPFS database was used to analyze the performance of the CRCP and JRCP. [3] Figure 3 shows the comparison.

The mean Interstate highway pavement age as of 1987 was 21 years, which is approximately equal to the design life of 20 years. The average accumulated traffic loadings were 13 million ESALs, nearly triple the design ESALs for the 8-in CRCP and 10-in JRCP.

Thirty-five percent of the pavements had been overlaid as of 1987. Durability "D" cracking of PCC aggregates severely affects CRCP performance, shortening life by as much as five years. Overall, 8-inch CRCP performed equally as well as 10-inch JRCP. CRCP thickness had a major effect on performance. For example, the following results were obtained from the survival analysis. (Note that some of these values will change with time as additional sections are rehabilitated).

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Mean Age</th>
<th>Mean ESALs</th>
</tr>
</thead>
<tbody>
<tr>
<td>7&quot; CRCP</td>
<td>17 years</td>
<td>8 million</td>
</tr>
<tr>
<td>8&quot; CRCP</td>
<td>20 years</td>
<td>15 million</td>
</tr>
<tr>
<td>9&quot; CRCP</td>
<td>Not available</td>
<td>19 million (est.)</td>
</tr>
<tr>
<td>10&quot; CRCP</td>
<td>Not available</td>
<td>27 million</td>
</tr>
<tr>
<td>10&quot; JRCP</td>
<td>22</td>
<td>13 million</td>
</tr>
</tbody>
</table>

(Note: Mean is defined as age or ESAL at which 50 percent of the pavements of a particular type have been rehabilitated.)

Performance of AC Overlays

A study was conducted on the survival of asphalt concrete (AC) overlays on the Illinois Interstate highway system. Data were obtained from the Illinois Pavement Feedback Database (IPFS) for 410 AC overlay construction sections placed on CRCP and JRCP between 1964 and 1989. These overlays range in thickness from 1.5 to 6.0 inches of AC. Both in-service life and 18-kip equivalent single-axle loads carried until the overlay was rehabilitated were analyzed through the use of survival curves. [5]

The mean age and 18-kip ESALs at the time of overlay rehabilitation were estimated for each category of overlay thickness (thin and thick), pavement type (JRCP and CRCP, although not quite enough CRCP data are now available for evaluation), and PCC durability (with and without "D" cracking). Results showed that each of these factors along with traffic level had a significant effect on the life of the overlays.
Figure 5 shows the effect of "D" cracking on performance of thin overlays of JRCP. Overall means for age and ESALs are given for AC overlays of JRCP below. (Note: some of these values will change as additional sections require a second rehabilitation).

<table>
<thead>
<tr>
<th>Mean Thickness</th>
<th>Non &quot;D&quot;-Cracked</th>
<th>&quot;D&quot;-Cracked</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Overlay</td>
<td>JRCP</td>
<td>JRCP</td>
</tr>
<tr>
<td>3.1&quot;</td>
<td>12 years</td>
<td>7 years</td>
</tr>
<tr>
<td></td>
<td>18 million ESALs</td>
<td>6 million ESALs</td>
</tr>
<tr>
<td>4.6&quot;</td>
<td>16 years</td>
<td>14 years</td>
</tr>
<tr>
<td></td>
<td>45 million ESALs</td>
<td>15 million ESALs</td>
</tr>
</tbody>
</table>

This information will be very useful in improving the design of AC overlays in the future.

Predictive Equations for Distress and CRS

Several equations for distress and CRS were developed using data obtained from the IPFS database. Other equations were obtained from previous research. [7] The ILLINET and EXPEAR programs use predictive equations for the following pavement condition items to forecast future pavement conditions for determining remaining service life. [6,8]

CRCP:  Failures (punchouts, existing repairs, ruptured steel)
       CRS (failures)

JRCP:  Joint deterioration or spalling
       Crack deterioration or spalling
       Joint faulting
       Serviceability rating
       CRS

AC Overlay Rutting of JRCP: Reflection cracking

AC Overlay Rutting of CRCP: Reflection cracking

These equations include design, traffic, materials and climatic factors as explanatory variables. Figure 6 shows some interesting results obtained from the predictive equation for CRCP.
Figure 5. Age survival curves for thin AC overlays of "D"-cracked and non-"D"-cracked JRPC.
Figure 6. Sensitivity of CRCP failures per mile to area of steel.
PROJECT EVALUATION AND REHABILITATION SELECTION

EXPEAR was originally developed for the Federal Highway Administration [8] and was further developed for the IDOT under this study. EXPEAR is an advisory system to assist the practicing engineer in evaluating a specific pavement section and selecting rehabilitation alternatives. An EXPEAR program currently exists for each of three pavement types: JPCP, JRCP, and CRCP. The current version of the system is EXPEAR 1.4, which includes the capabilities to delay rehabilitation for up to 5 years and to perform life-cycle cost analysis of rehabilitation alternatives.

Inputs

Project-level evaluation using EXPEAR begins with the collection of some basic design, construction, traffic, and climate data for the project in question, and a visual condition survey. In the office, the design and condition data are entered into EXPEAR by the engineer using a full-screen editor. The program extrapolates the overall condition of the project from the distress data for one or more sample units.

Engineering Logic

EXPEAR evaluates a project in several key problem areas related to specific aspects of performance. For jointed pavements, the problem areas are: structural adequacy, roughness, drainage, joint deterioration, foundation movement, skid resistance, joint sealant condition, joint construction, concrete durability, load transfer, loss of support, and shoulders. The evaluation is performed using decision trees which compare the pavement's condition to predefined critical levels for key design and distress variables. EXPEAR produces a summary of the deficiencies found, and by interacting with the engineer, formulates a rehabilitation strategy which will correct all of the deficiencies. The major rehabilitation options are: reconstruction of one or both lanes, resurfacing (with one of several overlay types), and restoration. Appropriate repair techniques for the shoulders which are compatible with the mainline pavement rehabilitation strategy are also selected.

Performance Prediction and Cost Analysis

A large number of predictive models for concrete pavement performance with and without rehabilitation are incorporated into EXPEAR. Some of the models were developed from national databases of new construction and rehabilitation projects, while others were developed using data from Illinois pavements. The models allow the engineer to predict the performance of the rehabilitation strategy developed. This information is then used, along with rehabilitation unit costs (either default values built into the program or values provided by the engineer) to compute the cost of the strategy over the predicted life.
Outputs

EXPEAR produces a summary of the project's data file, the evaluation results, recommendations for physical testing, predictions of the pavement's future condition without rehabilitation, and rehabilitation techniques, performance predictions, and cost calculations for as many rehabilitation strategies as the engineer wishes to investigate.

NETWORK-LEVEL REHABILITATION PROGRAMMING

A network pavement rehabilitation management program called ILLINET has been developed to aid IDOT districts and central offices in pavement management decision making for the Illinois Interstate highway network. [6] A schematic illustration of ILLINET's use is shown in Figure 7. This program helps users analyze data regarding pavement design, condition, traffic, climate, and other factors to provide answers to critical questions often asked about the network at the planning and administration levels before budget allocations are made. These questions are mainly regarding the selection of sections to receive rehabilitation, rehabilitation type and timing. Another question is the likely effect of different rehabilitation and funding policies on the pavement network.

Rehabilitation Alternative Selection

Rehabilitation types considered in ILLINET are:

1. Concrete pavement restoration (CPR).
2. AC Overlay (3.25-in thick).
3. AC Overlay (5.0-in thick).
4. Reconstruction.

The unit costs used for each rehabilitation type can be varied by the district. The cost of an AC overlay is affected by the quantity of preoverlay repair needed, which is included in the analysis.

Rehabilitation selection routines select one candidate rehabilitation for all deficient pavement sections. The rehabilitation type for each section is selected based on one of the following approaches:

1. Single rehabilitation alternative specified by the user.
2. Decision tree specified by the user.
3. Life-cycle cost of all rehabilitation types.
Network Inputs
Identification
Inventory
Monitoring
Traffic
Distress
Condition

Project-Level
Life Cycle Cost
Decision Tree
Single Rehab

Network-Level
Ranking
Benefit Cost Ratio
Incremental B/C
Optimization

Program Outputs
Network Summary
Project Summary
Project Detailed

<table>
<thead>
<tr>
<th>Section</th>
<th>Year</th>
<th>Rehabilitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>3* ACOL</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>C.P.R.</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>5* ACOL</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>RECONST</td>
</tr>
</tbody>
</table>

Figure 7. Illustration of ILLINET.
Benefit of Rehabilitation

There are four choices for defining the "benefit" of a particular rehabilitation strategy:

1. Area under the pavement condition curve.
2. Predicted life of rehabilitation.
3. Vehicle Miles Traveled (VMT) on adequate pavements.
4. User's benefit (reduction in user's cost).

Rehabilitation Selection Algorithms

ILLINET includes different methods of selecting rehabilitation type and timing for each pavement section in a network. A "needs" algorithm is used to assess pavement rehabilitation needs assuming an unlimited budget. In this algorithm, as soon as the condition of any pavement section drops below a minimum CRS it is identified to be deficient and some kind of rehabilitation is applied to the pavement to correct the deficiency. The output of the "needs" algorithm is the funding needed for the network and the performance of the pavements in the network.

When the yearly budget is limited, "ranking" and "benefit/cost" algorithms are used to select sections for rehabilitation. In "ranking," all deficient pavement sections are ranked based on their condition every year in the analysis period. Pavements with the lowest conditions are selected for rehabilitation until the yearly budget is exhausted. Rehabilitation of the remaining deficient sections is delayed for one year. The same routine is repeated for every year of the analysis period. Figure 8 shows a sample network summary for one district using the ranking algorithm. Figure 9 is the corresponding sample rehabilitation program (type and timing) for all of the pavement sections in the district's network.

The "benefit/cost" or "B/C" algorithm is similar to "ranking" except that sections are ranked based on their benefit-to-cost ratio (benefit of rehabilitation divided by the cost of rehabilitation) and sections with the highest B/C ratios are selected first. With the "B/C" algorithm it is possible to consider all possible rehabilitation alternatives for every section at the network level. Since every section will have more than one rehabilitation alternative in this case, a routine called "incremental benefit-cost ratio" is used to select pavement sections and rehabilitations at the network level.

IMPLEMENTATION

IPFS has many applications for use in the daily work of IDOT managers, engineers and planners. Work is needed to implement these applications into the daily activities of the IDOT. The following are but a few of the many possible pavement management applications for IDOT bureaus, offices and districts.
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</tr>
</thead>
<tbody>
<tr>
<td>AVERAGE CI</td>
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Figure 9. Sample project summary report.
Districts: Rapid access to individual construction section pavement data, such as construction history, design, traffic, rehabilitation, distress, rate of failure, future conditions, etc.

Central Bureaus: Rapid access to individual pavement section data, ability to evaluate the performance of Interstate pavement sections and rehabilitation techniques, data for conduct of special studies, evaluation of traffic loadings increases, rates of deterioration of various pavement sections, etc.

Office of Programming and Planning: Rapid access to individual pavement section data (e.g., current CRS and distress, roughness, rates of deterioration), ability to predict future CRS and other types of distress for sections, ability to determine funding needs for each district to maintain any level of CRS, more accurate determination of when sections will reach a critical CRS value, funding levels needed to maintain a minimum CRS level for all sections, etc.

Top IDOT Management: Rapid answers to many urgent pavement management questions, ability to determine at a glance (at the Interstate highway graphics map) information about the design and current condition of any section and its projected condition in the future, etc.

Implementation will be undertaken through a series of efforts. Overall direction will be provided by IDOT's Standing Committee on Pavement Management. A Pavement Feedback Implementation Advisory Committee has been formed with Central Office and District representatives who are directly involved in Interstate pavement management activities. The IPFS Steering Committee and Pavement Feedback User Team were disbanded upon completion of the IPFS database.

The implementation process will include the development of prototype output reports to address pavement management needs. These include network analysis programs (ILLINET), network summary reports, project-specific analysis, and providing data analysis for pavement research activities. Ad hoc requests will be handled by the Bureau of Materials and Physical Research in conjunction with the University of Illinois when appropriate. Although initial prototype outputs were developed as part of IHR-517, work remains to integrate IPFS information into daily IDOT activities.

Implementation efforts will be directed toward providing outputs of immediate use to IDOT pavement management practitioners addressing the specific needs of district and central office personnel. Specifically, these will address the annual and multi-year programming process, research studies, and project-specific rehabilitation evaluation.
CONCLUSIONS

A major effort has been underway over the past five years to develop the Illinois Pavement Feedback System. This work has already resulted in some important results for engineers, planners and managers of the IDOT as described under the previous sections of this report. Further development and implementation will continue this important process and get the IPFS into daily use within the districts, bureaus and offices of the IDOT.

The benefits provided to IDOT by the work completed under this contract include the following:

1. Improved pavement management decisions, design procedures and policies that are based on factual performance data.

2. Savings of labor and time to obtain needed pavement information for any section on the Interstate highway system.

3. Ability to address many urgent pavement management questions concerning future funding needs, rehabilitation needs and performance and pavement conditions.

4. Conduct of special studies and research projects that require data from the pavement network.

5. Prediction of future condition of in-service pavements (e.g., CRS, cracking, rutting, punchouts, roughness).

6. Rehabilitation strategy selection for individual projects.

7. Rehabilitation multi-year programming and funding needs analysis for the Interstate highway pavement network.
REFERENCES


