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IOWA DEPARTMENT OF TRANSPORTATION

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To Office
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Attention Bernie Ortgies, Pat Cain, Bill McCall

Date June 5, 1984

Ref. No. 722

From Jim Cable JKC

Office Advance Planning

Subject Long-Term Pavement Monitoring

Attached is a draft copy of the report evaluating the FHWA Long-Term Pavement Monitoring Program. We are required to make such a report prior to June 29, 1984. It is a companion to another report on Iowa's Pavement Management work over the last two years. That report was reviewed by representatives from the Offices of Materials, Road Design, and Transportation Inventory.

The specific references to inventory or monitoring forms are used to evaluate the method of reporting data annually. Copies of the forms can be viewed at this office if you have any questions.

Please inform Mike Clayton of this office (x1612) of any additions, deletions, or corrections to the report prior to June 13, 1984. Mike will be completing the transmittal to FHWA in my absence. The current time schedule allows for a review by the Highway and Planning and Research Division Directors prior to FHWA submittal.

JKC/cjb
Attach.
cc: Don Ward
    Mike Clayton

Draft

Long Term Pavement Monitoring

Evaluation of the FHWA Sponsored Program

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In Cooperation with
Federal Highway Administration
U.S. Department of Transportation

June 1, 1984

Introduction

In applying for the Long Term Pavement Monitoring study in 1982, the Department identified several short and long range goals. The goals could only be achieved through pavement performance monitoring and the development of a pavement management system. The primary goal was the development of a management tool to evaluate existing primary road system short and long range rehabilitation and improvement needs. Improved methods of selecting cost effective project concepts were required. Pavement monitoring was needed to evaluate various construction, maintenance and funding strategies.

Long term goals included the evaluation of the performance of various highway pavement designs, materials, construction methods, and maintenance procedures. Improved identification of safety improvement projects and a measure of their effectiveness could be achieved through a pavement management system.

To achieve the Department's long range goals, several initial items of work had to be accomplished. Included in that work were:

1. Development of a common reference system for all data elements.
2. Development of a pavement loading history for each primary road section.
3. Development of a visual display of data elements for use by decision makers.
4. Analysis of existing pavement performance in terms of each data element.

The Long Term Pavement Monitoring program provided the seed money and direction to move Iowa into development of a pavement management system. It also provided funds for testing new ideas in measuring remaining life in pavements that otherwise may have been delayed.

Case Study Sites

Iowa selected 21 sites for pavement monitoring. They were selected based on the following variables:

1. Pavement type and thickness.
2. Pavement overlay type and thickness.
3. Pavement age.
4. Total traffic volume.
5. Truck volume.
6. Geographical coverage of the state.
7. Traffic service levels.

The test sites were designated to provide a cross-section of values and variables rather than concentrating on only roads with high truck and car volumes. The Department also chose to select both interstate and non-interstate sites. Twelve two lane non-interstate sites are included in addition to two sites on a four lane non-interstate route. The Department determined pavement management and performance monitoring must address the problems on both a small interstate system 780 miles and an 9,220 mile primary system to be of value.

The original sites ranged from one to five miles in length and considered both directions of travel. This provided approximately 125 centerline miles of road to monitor. After review with program staff from FHWA in 1984, the site lengths are being reduced to one mile and a single direction of survey is being established for each route segment. Divided highway sections are comprised of two lanes in one direction. The revised sections will be used for distress survey purposes in 1984. All other monitoring activities will use the reduced sections beginning in 1985. The revised location descriptions for each site are shown in Attachment D. The surface type code identifies:

Asphaltic cement concrete - 6202

Portland cement concrete - 7001, 7011, 7222, 7333, 7730

Composite design - 6706, 6708

A map showing the location of the test sites, traffic counts and weight stations is also attached. The FHWA case study weight stations were used for the cost allocation studies and are retained for state use in studies such as LTM.

Date Elements Collected

Iowa chose to collect items of data for long term monitoring that have been previously collected by staff or other government agencies. The test sections included portland cement concrete, asphaltic concrete and composite design sections. Our testing procedures have remained constant over a long period of time. This has provided Iowa with certain long term monitoring data on each of the sections prior to the FHWA study. Our problem was that of bringing all the data types together with a common reference system. The interrelationship of each data item collected can then be measured in terms of pavement performance.

The LTM manual was supplied to Iowa in 1982 after we had begun gathering monitoring and inventory data. We also planned to minimize the costs of collection by using existing data sources and information formats. This philosophy also provided FHWA and the project consultant with alternate formats to consider for future expanded LTM activities.

The data supplied for the project can best be described by discussing the requirements of each data sheet in the manual for inventory and monitoring activities.

Inventory Data

Sheet 1 - Section identification.

The sections picked for this study do not coincide with HPMS sample sections at this time. Allowances have been made in Iowa's record system to add those numbers for each record section in the test section. This work will be done when and if both FHWA and the state agree on such a need.

Many of Iowa's test sections were located on two lane roadways. Both directions of travel were monitored in 1982, 1983 and are being monitored in 1984. After consultation with FHWA the section lengths have been reduced to one mile in length and a single direction of survey has been selected for each test section. Location data in terms of milepost and milepoint have been added.

Sheet 2 - Geometric and General Information

All data required to complete this sheet was readily available.

Sheet 3 - Thickness of Pavement Layers

The data for this sheet was obtained from project plans. A verification of the pavement and subgrade layer thickness for a depth of two feet below the pavement were verified in 1983 by core samples. Approximately two cores per mile were used to verify thickness of layers, pavement compressive strength, soil moisture content, soil density and soil classification. This appears to be a primary way of correlating the soil layer characteristics designed to those built and present at a given point in time.

Care should be taken in analyzing subgrade data. Iowa uses a soil selection process in an attempt to place the best foundation material available in the upper 2 feet of subgrade. Moisture and density controls are applied to this area. Locally available materials are most often used and may vary over the length of a test section.

Sheet 4 - Construction Timing

Data on the year of opening is usually available in each state. In Iowa we are limited in some data items by a record retention system. Some of the general historical data is destroyed approximately seven years after the construction project costs are paid.

The month of opening is often misleading or missing. It should be treated with caution.

Sheet 5 - Rigid Pavement Slab

Structural Design

Sheet 6 - Rigid Pavement Joint Data

Sheet 7 - Rigid Pavement Reinforcing Steel Data

Information for Sheets 5, 6 and 7 was obtained from project plans where available. The information is useful, but is limited for projects built several years ago. Variations between the design and placement of each item cannot be measured without extensive field investigation.

Sheet 8 - Rigid Pavement Concrete Data

Design mix data was available for many of the items requested. Modulus of elasticity was not available for any of the projects. Slumps, air content and cement additives were included where data was available. Average values were inserted due to multiple tests being conducted for the test area during construction.

Strength of concrete at 28 days was estimated from 7- and 14-day beam break tests. These tests were used to control traffic use opening dates. The 28-day strengths were not available in most cases.

Sheets 9 and 10 - Rigid Pavement Concrete Data

Data available on curing of the slab and aggregates used in the slab was limited. Available historical data from project records was included where available.

Sheets 11-19 - Flexible Pavement Surface, Binder and Base Courses

The aggregate data was generally available and was reported. Asphaltic cement grade and source data were also available with the job mix intended asphalt content. The physical characteristics of ductility, viscosity, penetration and softening point were limited by the testing procedures in place at the time of construction. They will vary from state to state due to the materials available and the performance characteristics desired by the contracting authority.

Density, marshall stability and flow and air voids of the mix are measured by the Department. Hveem stability, resilient and dynamic modulus are not measured. These tests are used by other states and should be retained in the format. Users of the forms should be instructed to fill in all available data. Many states may change some tests over time as the technology changes. The same reasons for lack of data apply to the deformation, tensile and fatigue properties of the various asphaltic concrete layers.

Sheet 20 - Subgrade Data

Iowa does not test for CBR, resistance, resilient modulus, swell potential and frost susceptibility. The density, moisture content, plasticity limit, and liquid limit for the 1983 point in time were included from the core tests. The original planned values of these items were obtained from project field records where those records had not been destroyed. Research is continuing into freeze characteristics of Iowa aggregates.

Sheet 21 - Shoulder Data

The shoulder construction data and drainage data were gathered from the project plans where available.

Sheets 22-24 - Environmental Data

The data was obtained from weather records of Iowa State University and the National Weather Service. Temperature and precipitation data was supplied for 1982 and 1983 along with similar data for each year of pavement life. Freeze-thaw cycle information and solar radiation data were not readily available or included. Deicing salt application quantities were estimated for 1982 and 1983 based on statewide use averages. Future improvements in maintenance record keeping should provide more accurate usage rates.

Sheet 25 - Maintenance Data

Maintenance data was extracted by hand from maintenance management files. The format for this form could be revised. Many states will have the data in the form of manhours or costs, equipment hours or costs and materials type, quantity and cost.

Iowa's maintenance costs are now being collected for road surface and shoulder with the milepost reference system. Computer programming efforts are being directed, in 1984, to providing both systemwide and project specific historical maintenance costs for pavements and shoulders. The data has been entered into storage since July 1, 1981 by way of the employee timesheet.

Sheet 26 - Traffic Data

Data for two directional travel was available on all routes and directional values were available on some divided highways. The data was stored in paper reports. The 50% split in direction of travel and 50% split in lane use was assumed for the inventory data. Data is available for many of the sections since the date of original pavement construction.

Sheet 27 - Vehicle Classification

This data was available from the same source as the vehicle count materials. Data obtained prior to 1959 utilized a different definition of vehicle types and must be considered differently.

Consideration should be given to retaining vehicle count and classification data for the test locations on forms similar to those used by FHWA in the special cost allocating case studies. This form used with the standard report form give a full picture of the measured traffic.

Sheet 28 - Typical Axle Loads

Sheet 29 - Traffic Data

The historical data for Sheets 28 and 29 could only be provided from the "W-4" tables of the biannual truck weight study reports prepared for FHWA. The data requested needed for pavement design and performance measurements.

The Department is currently evaluating the results of program which estimates the damage in 18 Kip EAL that a pavement has experienced. The program uses traffic volumes, and truck weight and classification data to estimate the use for periods between each successive traffic study. It is being used to accumulate the pavement life usage by direction of travel, and the amounts used since the section was paved and last resurfaced. Project program testing should be completed in December 1984.

Monitoring Data

Sheets 1 and 5 - Roughness, Skid and PSI

The format supplied for this item assumed that all items would be gathered on the same day each year. Roughness and friction data are gathered in separate operations at different times. The Iowa method of determining PSI requires a separate crack and patch survey to adjust the IJK roadmeter values. Data input to the pavement management system has been computerized in 1983. This means the data will have to be transferred by hand to the LTM forms or submitted in the format established by the Office of Materials. That format also contains rut depth data for each test section regardless of surface type.

The Department provided for two tests of roughness and friction during one of the test years. The Department plans to test annually for both items in the future. The results of annual tests since 1968 indicate that seasonal variations cannot be differentiated from mechanical variations where several tests are made annually.

Sheets 2 and 3 - Distress Survey

Distress data is being provided in two ways to this program. Cracks are measured in terms of number as part of the crack and patch survey. This work is accomplished by trained field crews during the winter months on a scheduled basis.

At the request of FHWA and the LTM program, special distress surveys are being conducted on each LTM site. The work is being done by six District Transportation Planner/Engineers. They are utilizing the FHWA "Highway Pavement Distress Identification Manual for Highway Condition and Quality of Construction Survey" and the monitoring forms to identify current distress. They will continue to do this work annually on the test sites.

The Department feels strongly about retaining the crack and patch survey. This provides continuity between successive past years of data collection and analysis of pavement performance. It also acts as a direct link to the work and results of the AASHO road test in pavement design and performance. The dual distress survey work is being provided as a way to research pavement performance and monitoring techniques.

It should also be noted that the amount and type of distress required and measured by each state will vary. The data reported depends on the individual states' problems and pavement materials.

Sheets 4 and 6 - Structural

This data has been collected and computerized in a manner similar to roughness and friction testing. Tests are conducted in the late spring and early summer to measure the worst condition. Spring and fall tests were conducted as part of the program in 1982-83. Initial analysis of the data indicates that spring is still the ideal testing time.

Data from the tests can be placed on the LTM forms or computer output depending on available funds and person-power.

Sheet 7 - Rigid Pavement Transverse Joint Faulting

This data is collected with the roughness and crack and patch data. It can best be supplied with the summary data on those subjects. The data form is best suited where an individual faulting survey is to be conducted.

Sheet 8 - Maintenance Data

The same comments apply as were noted for inventory of previous maintenance costs earlier in this report.

Sheet 9 and 10 - Environmental Data

Sheets 9-10 will be completed in the manner discussed in the inventory section.

Future maintenance cost recording and retrieval plans will improve the quality of data gathered on the test sections.

Current temperature records utilize the fahrenheit scale rather than celsius. The conversion can easily be made but a change in the LTM form should be considered.

Sheet 11 - Traffic Data

Sheet 12 - Vehicle Classification

Sheet 13 - Typical Axle Loads

Sheet 14 - Traffic Data

The forms will be used in the same manner as they were discussed for inventory purposes.

Special truck weight and vehicle classification case studies were conducted for the Federal Highway Cost Allocation Study. They verified the factors established by Iowa to adjust individual traffic counts for time of day and year. Vehicle classification factors were also verified for state highways.

The Department plans to continue monitoring traffic on an annual basis for each test section. A four year cycle is currently used on most state highways in Iowa. Interstate routes are counted more frequently.

Truck weight data will continue to be collected biannually. Data for LTM sites is extracted from comparable sites on the primary road system.

Future improvements include the use of weight in motion sites (4) and installation of telemetrics at over 100 sites to improve the speed and accuracy of traffic count and weight data.

Sheet 15 - Distress Survey

The future distress surveys will be conducted two ways as discussed in the inventory section.

Additional items of information were gathered for the test sections in 1982 and 1983. The items included accident histories and core samples from the pavement and subgrade.

The accident data came from the Accident Location and Analysis System (ALAS) files. Those files are set up on a link-node reference base and contain detailed accident records for a period that begin in 1979. This data source provides another tool for pavement management to identify pavement safety related projects. Relationships between the pavement design and conditions and the accident types and rates can be explored with this data.

The pavement coring operation conducted in the fall of 1983 provided many side benefits to the Department staff. The work consisted of determining both deflections by the roadrater and core data on pavement and subgrade at the same locations and time.

The results of this work have aided the Department staff in the design of overlays and the correlation of roadrater values obtained at different times of the year. The deflections were used to determine the remaining structural number of each pavement. Using the existing structural number and a new design structural number, overlay thicknesses could be determined.

The project is also adding to our knowledge of interpretation of roadrater values in the measurement of subgrade support values. The cores indicated near optimum moisture contents in a dry period of the year at many sites. This has the staff reviewing the soil types used under a pavement and the drainage systems provided. Work is continuing on this project.

We would recommend the addition of accident data to the monitoring effort. Core data may be required once on each site to verify existing conditions. Additional coring should only be done when a special study is specified or major change in pavement condition is noted. The remaining items of data each serve a state or federal need and should be retained. One data collection period per year on each item is sufficient where the state has a sufficient data base to verify accuracy of measurement or convert to annual values.

Costs

the costs reported to FHWA in January 1984 for inventory and monitoring activities were those recorded for the project. They do represent costs associated with a large existing data base and a staff trained in conducting such activities. The work plan was designed to make maximum use of the federal funds and state funds. In some cases the total state funds expended may not have been reported correctly by individuals.

Assume that the LTM program was expanded to all states and funding was established for administering such an activity. The following costs represent an estimate of the time and effort required to start and maintain such a system for 20-40 test sections on a per two-lane mile basis. The costs per section or test are as follows:

1. Inventory
   a. Study Section General Identification and Construction Data (Sheets 1-21)

Labor	$52.00
Time	4 Hours

2. Past Environmental Data (Sheets 22-24)

Labor	$25.00
Equipment	$20.00
Test Section Total	$45.00 (for 5 Years Data)
Time	2 Hours

3. Past Maintenance Data (Sheet 25)

Labor	$13.00
Equipment	$20.00
Test Section Total	$33.00 (for 5 Years Data)
Time	1 Hour

4. Past Traffic Data (Sheets 26-29)

Labor	$26.00
Equipment	$20.00
Test Section Total	$46.00
Time	2 Hours

5. Skid Monitoring (Sheet 1)

a. Labor and Equipment Direct Cost and Overhead	$20.00
b. Trailer and Tow Vehicle Depreciation	$ 5.00
Test Section Total	$25.00

6. Roughness and PSI (Sheet 1)

a. Labor and Equipment Direct Cost and Overhead	$116.00
b. Van and Test Equipment Depreciation	$ 5.00
Test Section Total	$121.00

7. Flexible and Rigid Distress (Sheets 2, 3, 5 and 7)

a. Labor and Equipment Cost per Test Section	$109.00

8. Flexible and Rigid Deflection (Sheets 4 and 6)

a. Labor and Equipment Direct Cost and Overhead	$47.00
b. Equipment Depreciation	$ 2.50
Test Section Total	$49.50

9. Maintenance Data (Sheet 8)

a. Labor	$ 7.00
b. Equipment	$10.00
Test Section Total	$17.00
Time	0.5 Hours

10. Current Environmental (Sheets 9 and 10)

a.	Labor	$ 3.00
b.	Equipment	$10.00
	Test Section Total	$13.00
	Time	0.5 Hours

11. Traffic Data (Sheets 11-14)

a.	Labor and Overhead	$76.50
b.	Equipment	$36.00
	Test Section Total	$112.50

12. Laboratory and Field Coring (Sheets 13, 14, 17 and 18)

a.	Modified Proctor Tests Labor and Equipment Direct Cost and Overhead per Pavement Core Tested	$45.00
b.	Equipment Depreciation	$ 4.00
	Test Section Total	$49.00

13. Other Laboratory Tests (Sheets 13, 14, 17 and 18)

a.	Modified Proctor Tests Labor and Equipment Direct Cost and Overhead Cost per Test	$13.00
b.	Plasticity Index Labor and Equipment Direct Cost and Overhead Cost per Test	$14.00
c.	Mechanical Analysis Labor and Equipment Direct Cost and Overhead Cost per Test	$ 6.00

Data Summary and Analysis

A summary of each data item for one or all test sections seems inappropriate at this time. Two years of data and 21 unique sections do not provide adequate data for meaningful summaries.

The Department is planning to analyze the LTM data items on the complete primary road system beginning in late 1984. This work will provide results based on large road mileage samples and multiple years of testing on each section.

Three items of information have resulted from the development of a pavement management system and the long term monitoring effort. They include a correlation test of various roughness measuring equipment, an improved rehabilitation programming technique and the increased use of deflection data in the design of pavement overlays.

Initial field work was completed in developing correlations between roughness measurements taken by the photo log van, the IJK road meter and Michigan's profilometer. The road meter was correlated to Michigan's equipment in 1983 (Appendix A). Due to mechanical problems, the photo log van did not participate in the activity. Correlation of the photo log van, road meter, and the CHLOE have been accomplished (Appendix B). Additional field checks of the photo log van results to the other Iowa equipment are anticipated in 1984.

A major goal of improved rehabilitation programming techniques has been developed in the form of a matrix. The attached presentation material (Appendix C) on the development and use of the matrix describes the required inputs and outputs. The process is numerical and uses objective ratings for the determination of the most urgent rehabilitation project candidates. It has been in use two years and the mathematics were computerized in late 1983. Results are used by the Office of Program Management to identify the immediate one-year rehabilitation program and a portion of the following two years of projects. The analysis is made annually and results are reviewed with office and field staff to assure accuracy.

The Department staff has not been able to complete work on verifying the pavement life curves developed prior to this study. Work is continuing on this item in 1984 with the aid of computers. The entire primary road system will be included in the analysis. Various pavement types and design sections will be reviewed to assess performance and predict remaining life.

The special deflection data acquired in the fall of 1983 was used as part of an effort to assess remaining structural capacity. The tests when conducted with the soil and pavement coring began to show the relationship of each layer to the deflection values. Over 200 such tests were conducted on the LTM sites. The results of the tests provided accurate deflections to develop structural numbers for the existing pavements and their condition. This type of testing is being used as a primary input to the design of overlays. Testing on other pavements is continuing to improve the overlay design process.

Recommendations for Future LTM Program

Recommendations for any LTM program should include considerations for data collection amounts and methods, data processing and analysis, training, and distribution of results.

Data collection must include the items of roughness and distress. These are the items that the driver can relate to and will support in rehabilitation funding. As previously noted roughness measures should be correlated between states to provide a common data base. A set of roughness threshold values can be used at the national level to establish service goals and funding levels. The FHWA should emphasize the need for each state to set the same or different threshold values to measure individual goals and needs.

Roughness measurements should be taken on a one to three year cycle. Multiple runs in one year only serve to develop adjustment factors related to allowable testing periods. The mechanical errors associated with existing equipment override any gains in measuring roughness more frequently to predict remaining life.

Distress measurements should also be taken on a one to four year cycle due to the manpower costs involved. The use of lasers, video cameras and photographic techniques may reduce the cost and speed up data collection. Annual reviews can be made on 10-20 test sections, but not a 10,000 mile system. The frequency established and proven on the test sections should transfer to a state system of roads. In Iowa's case it has proven to work on the 10,000 mile system.

States should be provided training to identify different distress types and severities. They should be trained to measure only the distress types that will trigger a rehabilitation action in their state. This type of action reduces cost of data collection and usually improves accuracy.

Participants in a recent pavement testing conference recommended an LTM program for all states. They suggested establishment of 40 test sites per state, a 20 year study period and dedicated funding for monitoring. This approach will provide a minimum data base for the development of design equations. We suggest that the test locations include both divided and non-divided two lane highways. Due to mileage and age of pavements many states have more interest in the rehabilitation of two-lane roads.

Data provided by states on LTM sites should be stored and analyzed by federal agencies or others such as pavement consultants or universities. State analysis is limited by experience, manpower and data base size. The combination of state and others' analysis can provide better solutions through technology transfer of other states' experiences. The data bank at the federal level should be accessible to all states and analysis results should be made available to each state.

Dedicated funding for LTM in each state aids in overcoming the manpower, equipment and funding needs associated with such research. It encourages staff to research the performance of pavements. In Iowa the development of a pavement management system and the LTM program funding drew the various offices together in a common goal. The results included the pavement management data base, structural adequacy research and new methods of assessing rehabilitation needs.

The benefits of LTM gained by Iowa can be applied in some degree to all states. Historical and monitoring data from 40 sites in each state is a very large start on providing new design equation data. It plays the role of maintaining a mature highway system that the AASHO road test did to build the system. It also provides the FHWA and states with a quick and uniform way of assessing the current and future condition of the highway system. Impacts of highway design, vehicle size and weight and funding legislation could be predicted accurately. Pavement management systems, long term monitoring at the state level, and a pavement data base at the national level are necessary to properly administer the current mature highway system needs.

Appendix A

Long-Term Pavement Monitoring Special Project

Correlation of Iowa IJK Road Meter and Michigan GM Profilometer

August 23-24, 1982

Currently, several items of equipment are used by various states to gather pavement roughness data. They range from the Mays meter to the BPR meter to the more sophisticated GM profilometer. In Iowa, a special piece of equipment named the IJK road meter is utilized for this purpose.

The Federal Highway Administration gathers roughness data from each of the 50 states through the Highway Performance Monitoring System for use in assessing the condition of the road systems throughout the nation. The statistics contain information gathered in a variety of ways from mechanical measurements to those gathered with mechanical measurements and adjustments by a panel of raters. To make this data meaningful for utilization across the nation, a uniform baseline must be established to correlate with data from each of the various states.

One of the objectives of Iowa's Long-Term Pavement Monitoring Study was to illustrate the potential for correlation of readings from each of the various states' equipment. Iowa currently utilizes the services of the IJK road meter, a CHLOE, and the short- and long-distance roughness measurements gathered by a second generation photo log van. Separate

Ride Quality Index	Panel Rating
0-30	Good
30-70	Average
70-100	Poor

At the time of the testing in 1982, the majority of Michigan's one-quarter mile test sections were in an average condition range. The test sections included both portland cement concrete sections and asphaltic concrete sections. Data was obtained with the GM profilometer at the same time it was being obtained with the IJK road meter.

The results of the testing were compiled on two separate graphs which are attached. The first graph information was plotted correlating the ride quality index numbers to the summation of the roughness counts divided by the length of the test section for the IJK road meter. A best fit curve was established through the points to indicate their relationship. The best fit curve approach was utilized since the extreme cases of good and bad pavement were not available in the test sections. These results showed a very good correlation between the two pieces of equipment. The correlation coefficient of the raw test data was determined to be 0.93. A second graph was also plotted indicating the correlation between the PSI measurements determined from the IJK road meter readings versus the GM profilometer ride quality index figures. This graph illustrates the correlation in a much better way than the first graph.

centers where the equipment could be correlated to each of the states' individual roughness measuring devices. The use of individual test sections in each state and a touring piece of equipment allows each state to recalibrate their equipment on a weekly or monthly basis during the measurement season. Regional centers can create a problem in travel authority and costs for various states to maintain a calibration.

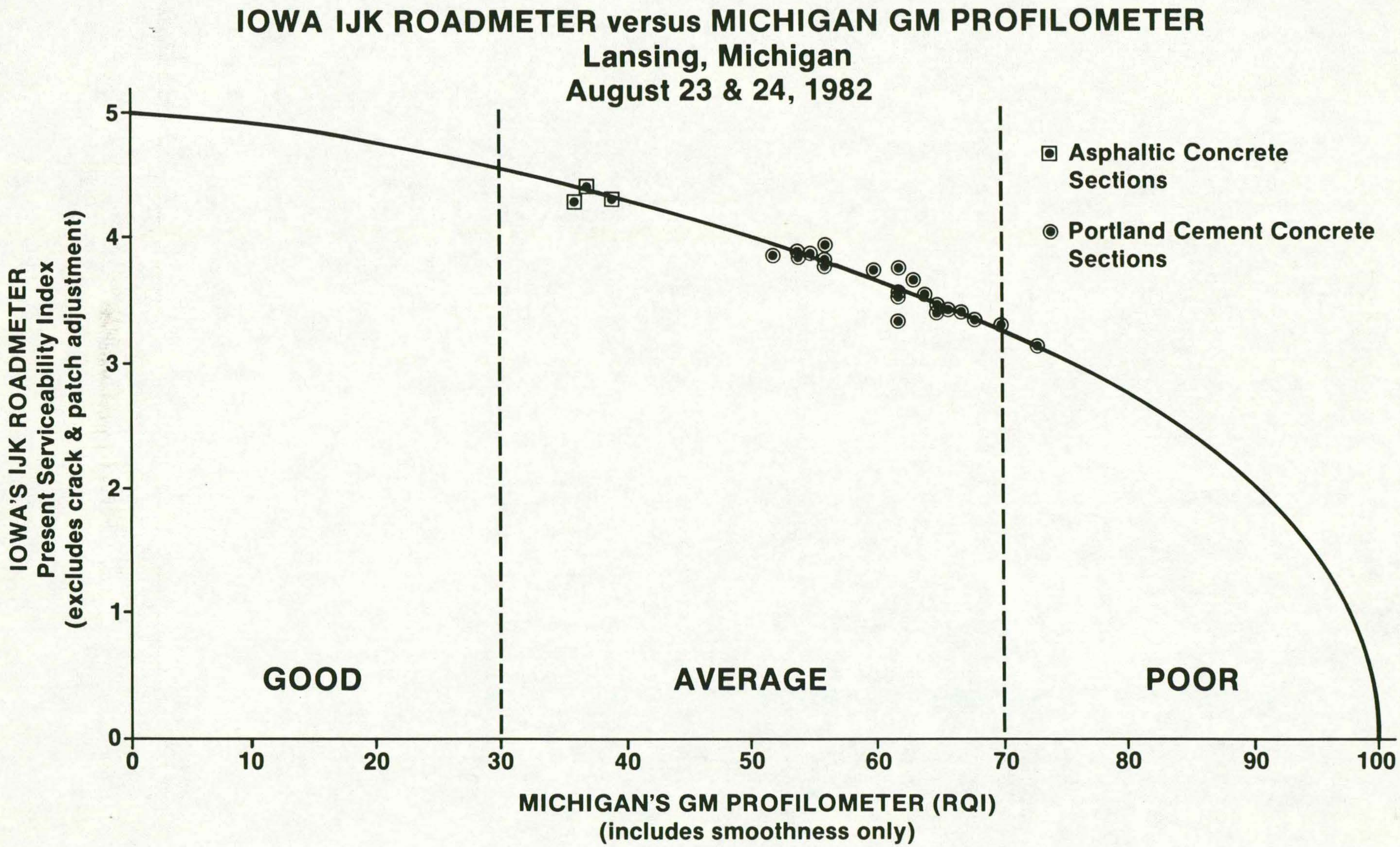
3. The Federal Highway Administration could participate in continuing to review the development of roughness measuring equipment to reduce its initial cost and recommend to states the type of equipment to be purchased and utilized for correlation to a central FHWA testing device or series of devices. This alternative could include the development of a standard test section device that could be developed to measure roughness in a uniform manner for calibration of individual items of equipment. Test site devices developed thus far have exhibited some problem in maintenance and providing uniformity in measurements regardless of the type of equipment being utilized.

The correlation study was a success and has provided the Iowa Department of Transportation with additional support for the data gathered by the IJK road meter, the photo log van, and the CHLOE roughness measuring devices. We recommend the Federal Highway Administration consider the alternative ways to gain uniformity in roughness measurements.

Michigan DOT
Riding Quality Index Test Sections
(1982)

Section	Speed, mph	Route	Width, ft	Surface
1	50	SB I 496	24	Dual conc.
2	50	SB I 496	24	Dual conc.
3	35	Jolly Rd	22	Bit.
4	35	Jolly Rd	22	Bit.
5	35	Jolly Rd	22	Bit.
6	35	Jolly Rd	22	Bit.
7	35	Okemos Rd	22	Conc.
8	35	Okemos Rd	22	Conc.
9	35	Okemos Rd	22	Conc.
10	35	Holt Rd	22	Conc.
11	35	Holt Rd	22	Conc.
12	50	SB US 127	24	Dual conc.
13	50	SB US 127	24	Dual conc.
14	50	SB US 127	24	Dual conc.
15	35	Cedar St	22	Dual conc.
16	35	Cedar St	22	Dual conc.
17	35	Cedar St	22	Dual conc.
18	35	Cedar St	22	Dual conc.
19	60	WB I 96	24	Dual conc.
20	60	WB I 96	24	Dual conc.
21	60	WB I 96	24	Dual conc.
22	60	WB I 96	24	Dual conc.
23	60	WB I 96	24	Dual conc.
24	60	WB I 96	24	Dual conc.
25	60	WB I 96	24	Dual conc.
26	50	EB M 78	24	Dual conc.
27	50	EB M 78	24	Dual conc.
28	50	EB M 78	24	Dual conc.
29	50	EB M 78	24	Dual conc.
30	50	EB M 78	24	Dual conc.
31	50	EB I 496	24	Dual conc.
32	50	EB I 496	24	Dual conc.

* Ranges from 1.0 (worst) to 10.0 (best). All sections 0.25 miles in length.


IOWA IJK ROADMETER versus MICHIGAN GM PROFILOMETER
Lansing, Michigan
August 23 & 24, 1982
Asphaltic Concrete Sections
Portland Cement Concrete Sections
IOWA'S IJK ROADMETER
Present Serviceability Index
(excludes crack & patch adjustment)
GOOD
AVERAGE
POOR
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
MICHIGAN'S GM PROFILOMETER (RQI)
(includes smoothness only)

PSI SHORT ROUGHNESS CORRELATION

APRIL 1983

Iowa Department of Transportation

Iowa Department of Transportation

PSI Short Roughness Correlation

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By The Office of Transportation Research
Planning and Research Division
(515)239-1140

In Cooperation With
Federal Highway Administration
U.S. Department of Transportation

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PREFACE

This is a preliminary study to determine the ability of the photologging van to calculate pavement serviceability indexes (PSI).

This report contains a comparison of the short roughness data from the Iowa DOT photologging van and the longitudinal profile data from the IJK roadmeter. A comparison of surface ratings, made by the District Transportation Planners, to the short roughness measurements was also made.

Comparing the data from the photologging van and the IJK meter, it is apparent that both devices can be used to develop PSIs. In comparing short roughness to surface ratings, the data is less consistent, in part due to the factors used in deriving surfacing ratings and the subjective nature of the rating.

Research is currently underway to gather additional data as recommended in this report.

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This report will compare roughness data gathered from the IJK ride indicator, data gathered from photologging van and the surface adequacy rating. Also contained in Appendix A is a comparison of the IJK to Michigan's GM Profilometer.

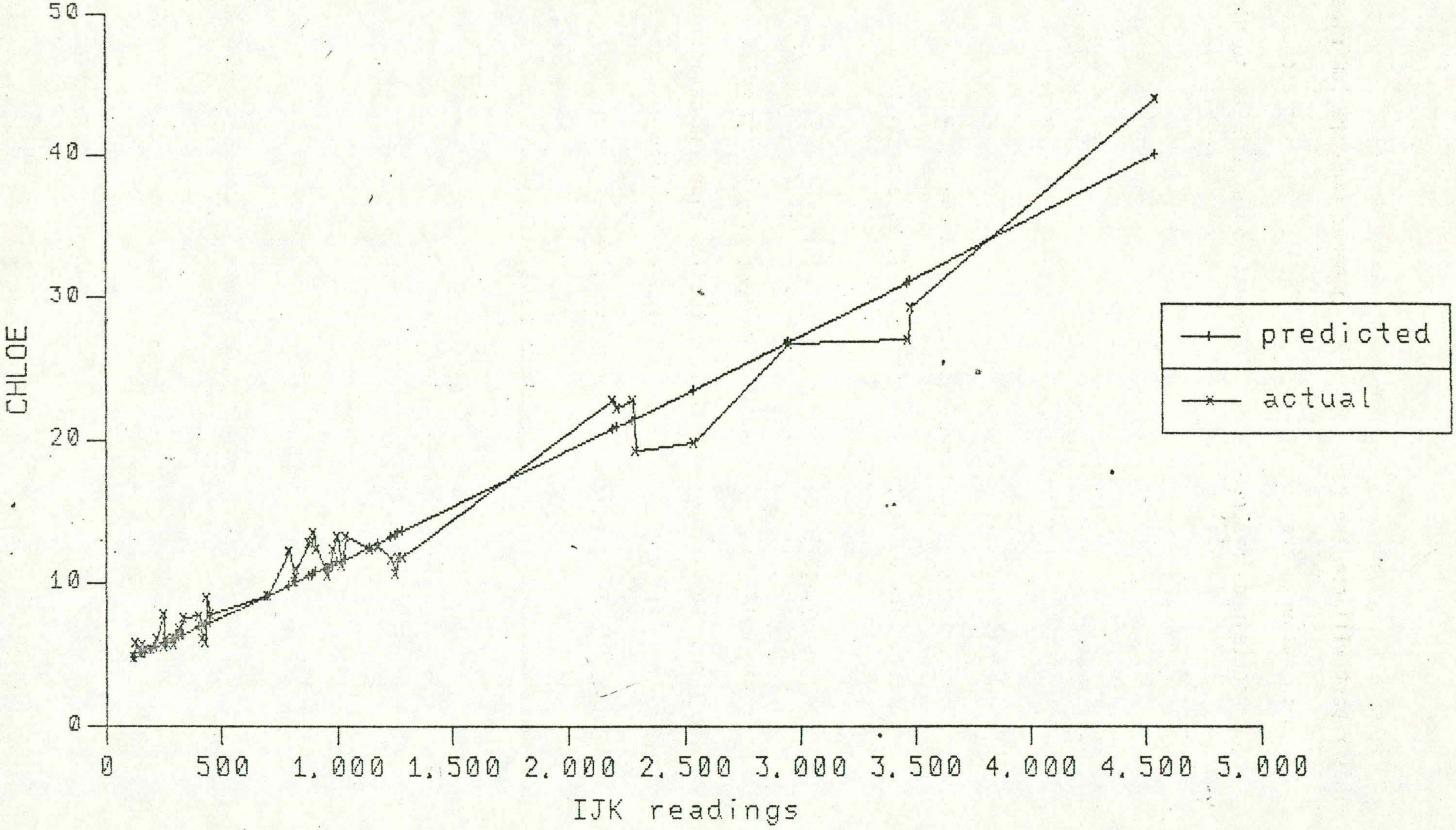
IJK vs CHLOE

Currently Iowa uses the IJK (Iowa-Johannsen-Kirk) ride indicator to evaluate the longitudinal profile (roughness) of a section of pavement. Test data on control sections is gathered each year from the IJK ride indicator and CHLOE profilomter. The CHLOE profilometer is used as a basis for PSI (Pavement Serviceability Index) since the CHLOE profilometer does not depend upon the suspension of the vehicle, which changes from year to year. A regression equation ($Y = CX^2 + BX + A$) is derived with the CHLOE profilometer values being Y and the X values coming from the IJK ride indicator. The correlation coefficient (R) from the data gathered for 1982 was .9737. The closer R is to 1 the better the fit of the evaluated equation. The following (graph 1) shows the actual and the projected values of the 1982 control sections.

Photo Logging Van

Readings were taken on 50 1/2 mile control sections about two weeks after the CHLOE-IJK calibration was made. The data was gathered at 25 MPH, 40 MPH, and 50 MPH. Straight line least-square linear regression models were developed in order to predict the roughness of a section of road at 50 MPH from the 25 and 40 MPH data. Because data was available for each 1/100th of a mile and there were sometimes less than or more than 50 observations, the average deflection in inches per reading was used as a measure of roughness.

GRAPH 1
IJK VS. CHLOE READINGS
50 CONTROL SECTIONS



The following (graph 2) shows the average deflection for each control section. This data is sorted in ascending order by the average deflection at 25 MPH then 40 MPH and then 50 MPH. The following table shows the models and their correlation coefficients (R).

Predicted Value	Equation	R
50 MPH Roughness	1.563 * Speed 25 + 13.669	.90
50 MPH Roughness	1.139 * Speed 40 + 6.748	.98

The predicted values are in inches per reading at 50 MPH and the independent variables (speed 25 and speed 40 MPH) are in inches per reading at the respective speeds.

A second model was fitted using the equation:

$$\text{Speed } 50 = A(\text{Speed } i)^2 + B(\text{Speed } i) + C$$

Speed i = Speed 25 and Speed 40

R was .96 for 25 MPH and .98 for 40 MPH.

All models were fitted using SAS's GLM procedure and output from these procedures can be found in the Appendix B.

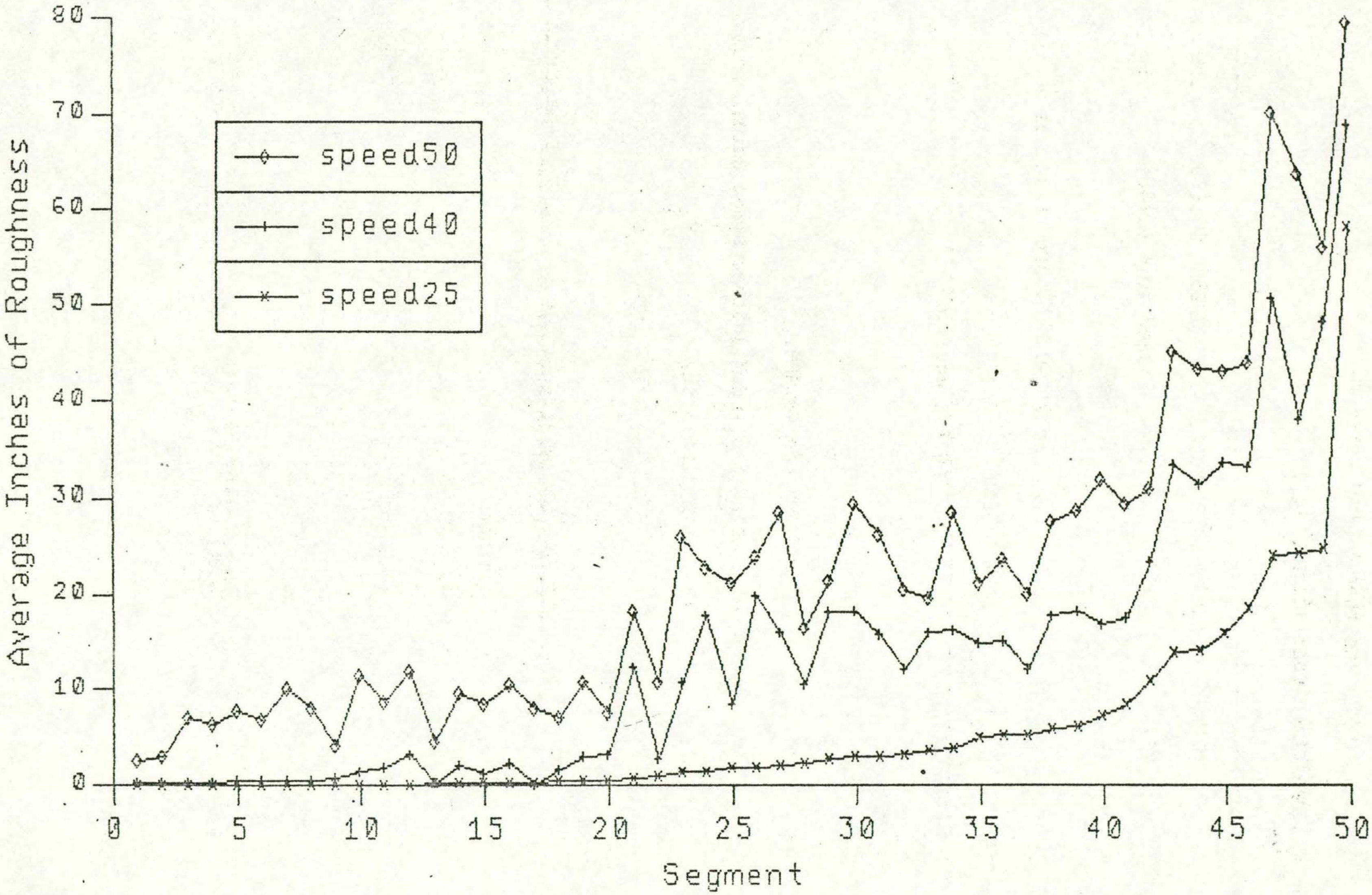
Surface Rating

The surface rating is a subjective evaluation preformed by the District Transportation planners. Appendix C contains a description of how this evaluation is made.

The following rating system is used:

6-7	Excellent
4-5	Good
2-3	Fair
0-1	Poor

GRAPH 2
PHOTOLOGGING SHORT ROUGHNESS DATA



Only 46 of the 50 control sections were evaluated, since 4 sections had been resurfaced after the photologging van and IJK readings were taken. These rating were expected to be the least reliable in measuring pavement roughness for the following reasons:

1. The ratings are made based on criteria which may not have an immediate impact on roughness (cracking, sparring, etc.).
2. Ratings are in discrete units (i.e., only integers 0-7 are possible.)
3. They are subjective.

A comparison of the average inches of displacement at 50 MPH was made. The following table displays this data.

	Surface Rating	Number Segments	Range in Inches	Average Inches
Best	7	4	4.76 - 10.02	7.84
	6	13	2.55 - 11.98	7.74
	5	6	7.67 - 21.27	15.68
	4	4	20.65 - 28.84	24.55
	3	17	7.80 - 79.80	34.62
	2	2	56.14 - 64.08	60.11
	1	0	---	---
Worst	0	0	---	---
	Missing	4	---	---

Comparison of PSI from IJK and Photologging Van

Based upon the correlation coefficients for the IJK meter and the photologging van it would appear that both do an equally good job when compared to the CHLOE. The correlation coefficients obtained from computer runs by Charles Potter (Matrials Inspection) were .9737 for the IJK with the CHLOE and .9694 for the photologging van.* The following (graph 3) displays the PSIs derived from both measuring devices.

Examining this graph it can be seen that the differences between the two readings appear to be random (i.e., fall both above and below the line). However, at the higher range of PSI values the photologging van is consistently below the IJK. When the regression model for the IJK-CHLOE was fitted, 3 zero values were added. This was done to simulate a perfect (PSI = 5) section of pavement. These three values, in part, explain the discrepancy noted above.

Conclusions

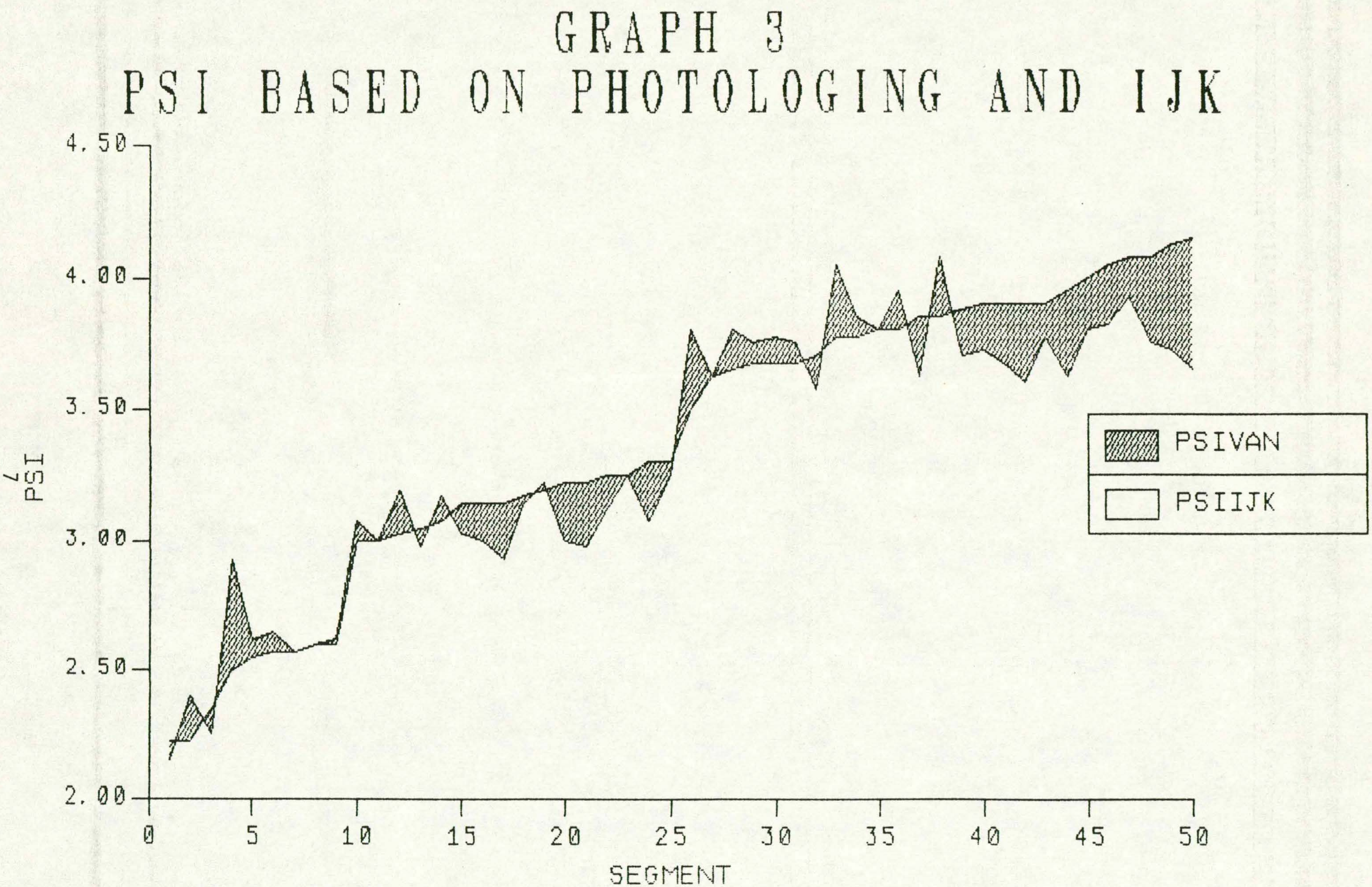
Based on the data gathered from the 50 control sections and the comparison of the IJK and photologging van to the CHLOE, PSIs can be derived from either of the devices. The surface ratings did not show a very strong relationship to the photologging van. This is probably due to the subjective nature of these ratings and the fact that some of the areas evaluated may not immediately contribute to pavement roughness.

It would also appear that PSIs can be derived from the photologging van for sections of pavement that the IJK cannot be used (i.e., sections on which it is not possible to take readings at 50 MPH).

The following data would be useful in evaluating the photologging van's ability to derive PSIs.

1. Data on the same section of pavement under wet and dry surface conditions.
2. Data on the same section of pavement at different temperatures.
3. Multiple readings from the same section of pavement.

* See Appendix D for photologging computer listing.



GRAPH 3
PSI BASED ON PHOTOLOGING AND IJK
4.50
4.00
3.50
3.00
2.50
2.00
PSI
0
5
10
15
20
25
30
35
40
45
50
SEGMENT
PSIVAN
PSIIJK

This data would be used to evaluate the experimental error (i.e., how consistant the readings are).

In order to use the photologging van to derive PSIs, it will be necessary to coordinate activities with Materials Inspection. Each year control runs will be needed to establish the equations used to derive PSIs and periodic runs over the control sections will be needed to insure accuracy.

Iowa Department of Transportation
800 Lincoln Way, Ames, IA 50010 515-239-1190

September 15, 1982 Ref. No. 722

Mr. R. L. Felter
Michigan Department of Transportation
Research Laboratory
P.O. Box 30049
Lansing, MI 48909

Dear Mr. Felter:

We appreciate the assistance of you and your staff in the correlation of road roughness equipment performed on August 25, 1982. The information gathered will assist the Department in preparing recommendations to FHWA on long-term pavement monitoring.

Enclosed are copies of materials requested by your staff on the Iowa equipment and methods for measuring roughness and skid. They include:

1. P.C. Concrete Texturing (March 1975)
2. Iowa Motorcycle Ride Meter, Final Report (January 1980)
3. The IJK Ride Indicator (March 1976)
4. Method for determining smoothness using the 25-foot California profilometer (April 1981)

It is my understanding that you will be sending a copy of the Chloe simulation print for data obtained by the profilometer on the test sections, when computer time is available this fall. It would be helpful to have data on the test sections including pavement age, layer thickness and material composition and current traffic volumes on sections 1, 5, 17, 18, 24, 25, 26, 29 and 30 due to their exclusion from testing. Information regarding the mounting and operation of your noncontract sensor would aid us in evaluation of potential application to our equipment.

Please contact me if there are questions (515-239-1190).

Sincerely,

Jim Cable
Office of Advance Planning
Planning and Research Division

JKC:maa
cc: Charles Huisman, Director
Office of Materials, Iowa DOT

Don Ward, Director
Office of Advance Planning, Iowa DOT

IOWA DEPARTMENT OF TRANSPORTATION

Materials - Administration   Date September 22, 1982

ention C. L. Huisman   Ref. No. 435.202

m C. J. Potter CJP

ice Materials Special Investigations

bject Michigan GM Profilometer Correlation

This memo is to serve as the final report for the Iowa IJK Roadmeter correlation with Michigan's GM Profilometer at Lansing Michigan August 23 and 24, 1982. I analyzed this data for my own purposes, but turned all information over to Jim Cable of Advance Planning for further analysis and reporting since this study was initiated and arranged by the Planning and Research Division.

The attached graph is the only information I kept and briefly summarizes the results of this study. Michigan correlates their GM Profilometer to a human rating panel to determine the Riding Quality Index (RQI) of a tested roadway segment. The RQI is based on rideability only with no influence due to visual pavement distress. Michigan's rating scale is as follows:

Riding Quality Index (RQI)	Panel Rating
0-30	Good
30-70	Average
70-100	Poor

Most of Michigan's 1/4 mile test sections were in the average range so I manually used the best-fit curve that went through the test points and the extreme values of both Iowa's and Michigan's rideability rating scales. The correlation coefficient of the raw test data was about 0.93.

I concluded from this study that: (1) Iowa's IJK Roadmeter correlates very well to the GM Profilometer and (2) It is possible to correlate response type road roughness measuring equipment of different States on a common set of test sections to talk in terms of the same rideability rating index.

I feel comfortable with this graph that I can predict what Michigan's GM Profilometer would read on a roadway segment in Iowa based on the IJK Roadmeter Longitudinal Profile Value (LPV) which is the Present Serviceability Index without the Crack & Patch Deduction.

In my telephone conversation with Bob Felter of the Michigan DOT yesterday he indicated that their investigative expert who works with this type of equipment felt that our IJK Roadmeter "did a good job for as simple as it is". Bob also informed me that K. J. Law is working on a more inexpensive non-contact GM Profilometer that would be mounted in an automobile with an on-board computer for about $30,000. This amount could be reduced to about $15,000 if we used a cassette recorder and our central computer system to reduce the data in lieu of the on-board computer.

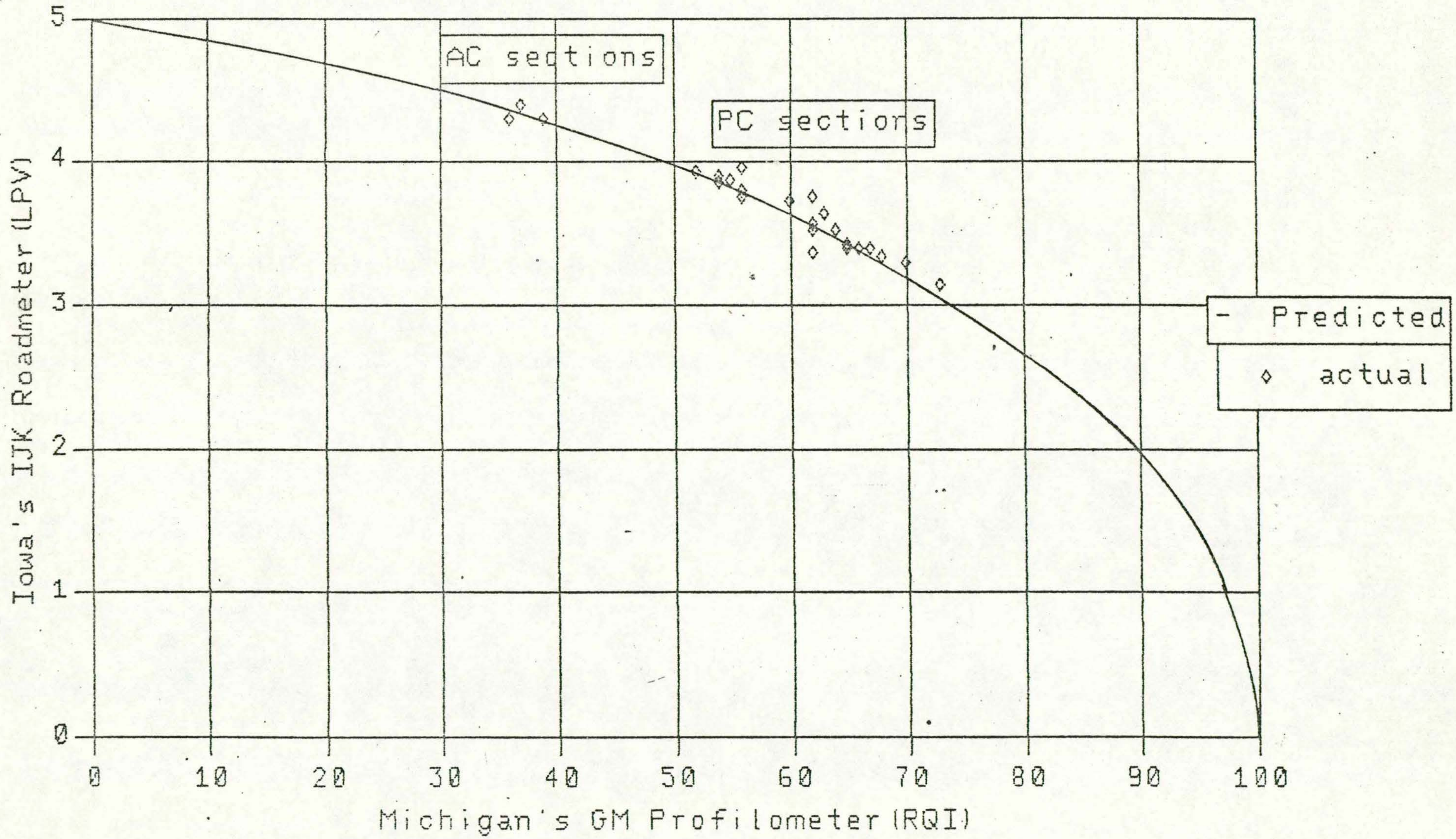
Steve Kadolph
3/24/83

RIDING QUALITY INDEX (RQI)

Section	RQI	IJK Sum/L
PC 2	67	1495
AC 3	36	297
AC 4	39	285
AC 6	37	225
PC 7	62	1509
PC 8	62	1152
PC 9	62	1241
PC 10	65	1433
PC 11	70	1688
PC 12	56	791
PC 13	54	674
PC 14	54	719
PC 15	68	1574
PC 16	64	1214
PC 19	63	993
PC 20	52	643
PC 21	55	688
PC 22	62	858
PC 23	56	605
PC 27	73	2090
PC 28	65	1480
PC 31	60	901
PC 32	56	863
PC 33	66	1467

RQI
0 - 30 Good
31 - 70 Average
71 - 100 Poor

Iowa IJK Roadmeter vs. Michigan GM Profilometer
Lansing Michigan 8/23 & 8/24 1982



GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: AVE_INC3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	12442.81596842	12442.81596842	200.78	0.0001	0.807059	34.8184
ERROR	48	2974.66271358	61.97213987		STD DEV		AVE_INC3 MEAN
CORRECTED TOTAL	49	15417.47868200			7.87223855		22.60940000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
AVE_INC1	1	12442.81596842	200.78	0.0001	1	12442.81596842	200.78	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	13.66918802	10.68	0.0001	1.27965840
AVE_INC1	1.56324742	14.17	0.0001	0.11032314

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: AVE_INC3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	14760.53566937	14760.53566937	1078.49	0.0001	0.957390	16.3627
ERROR	48	656.94301263	13.68631276		STD DEV		AVE_INC3 MEAN
CORRECTED TOTAL	49	15417.47868200			3.69950169		22.60940000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
AVE_INC2	1	14760.53566937	1078.49	0.0001	1	14760.53566937	1078.49	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	6.74761141	9.48	0.0001	0.71204792
AVE_INC2	1.13941445	32.84	0.0001	0.03469556

ENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: AVE_INC3

OURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
ODEL	2	14783.18099159	7391.59049580	547.70	0.0001	0.958859	16.2483
RROR	47	634.29769041	13.49569554		STD DEV		AVE_INC3 MEAN
CORRECTED TOTAL	49	15417.47868200			3.67364880		22.60940000

OURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
AVE_INC2*AVE_INC2	1	12020.62381845	890.70	0.0001	1	22.64532222	1.68	0.2015
AVE_INC2	1	2762.55717315	204.70	0.0001	1	2762.55717315	204.70	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	6.16413320	7.35	0.0001	0.83835751
AVE_INC2*AVE_INC2	-0.00202836	-1.30	0.2015	0.00156586
AVE_INC2	1.24269643	14.31	0.0001	0.08685744

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: AVE_INC3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	2	14071.42063813	7035.71031906	245.66	0.0001	0.912693	23.6698
ERROR	47	1346.05804387	28.63953285		STD DEV		AVE_INC3 MEAN
CORRECTED TOTAL	49	15417.47868200			5.35159162		22.60940000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
AVE_INC1*AVE_INC1	1	7054.22458051	246.31	0.0001	1	1628.60466971	56.87	0.0001
AVE_INC1	1	7017.19605762	245.02	0.0001	1	7017.19605762	245.02	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	10.41742745	10.73	0.0001	0.97093004
AVE_INC1*AVE_INC1	-0.02730259	-7.54	0.0001	0.00362059
AVE_INC1	2.77413752	15.65	0.0001	0.17722670

APPENDIX C

Surface Rating

WEARING SURFACE - Primary Roads Subsection
(7-point maximum as shown below)

The wearing surface is analyzed by considering all physical defects such as faulting at joints and cracks, transverse cracks, longitudinal cracks, corner breaks, multiple cracking, nonuniform slab displacement, spalling and disintegration of the concrete, irregular profile and cross section, alligator cracking, raveling, bleeding, cracking and rutting. For gravel surfaces, the following defects are considered: adequate type of binding, quality of loose aggregate crown, secondary ditches, oversized aggregate erosion from steep grades, corrugated surface, warped cross section and settlement. The numerical rating is coded as follows:

Code	Meaning
6-7	Excellent
4-5	Good
2-3	Fair
0-1	Poor

```
END OF JOB
READY
rdm

IF YOU WANT ROAD METER RUN ENTER M
OR IF YOU WANT ROUGHNESS RUN OR PIPE TABLE ENTER R
OR IF YOU JUST WANT TO DO A TEST ENTER T : m

 ENTER RMNO, 10 CHAR. MAXIMUM  : chloeav50

 ENTER DATE, 20 CHAR. MAXIMUM  : 11-5-82

 ENTER NUMBER OF OBSERVATIONS  : 50
ENTER ROAD METER SUM/L VALUES (X VALUES)
ENTER 99999 TO END X VALUES
:

780 807 7980 1823 1649 1968 2127 2950 2369 2014 2400 2065 2757 2884 2116 3102 7044 6408 5614 1071 767 1047 972 1074
:
714 1198 867 650 690 1149 2935 2857 2602 3188 2855 2629 2150 2294 1002 859 476 800 4362 4416 4337 4524 255 300 724 426
:
99999
  50 OBSERVATIONS SPECIFIED  50 X VALUES ENTERED
ANY X VALUES IN ERROR? (Y OR N)  : n
ENTER CHLOE SLOPE VARIANCE VALUES (Y VALUES)
ENTER 99999 TO END Y VALUES
:
6.20 5.83 44.16 10.74 10.96 10.63 9.09 13.54 12.39 12.83 12.82 12.31 13.32 11.33 11.12 19.83 29.38 26.82 27.02 5.82
:
7.87 6.21 6.20 7.85 6.45 7.78 5.96 5.52 5.44 5.65 12.53 12.43 10.14 13.22 11.90 11.84 11.75 12.50 4.97 5.88 5.79
:
5.18 19.29 22.74 22.75 22.28 6.20 7.65 9.08 6.94
:
99999
  50 OBSERVATIONS SPECIFIED  50 Y VALUES ENTERED
ANY Y VALUE IN ERROR? (Y OR N)  : n


ROAD METER:              CHLOEAV50                DATE                 11-5-82

    SUM OF X=    113047  SUM OF Y=       606.13  SUM OF X SQUARED=      409767271  SUM OF X CUBED =     1998516288745
SUM OF X TO THE 4TH POWERS=    11646605093892307   SUM OF XY PRODUCTS=     2016487.52  SUM OF X2Y=      9671110680.52
INTERMEDIATE VALUE TEMP = C*X**2+B*X+A-2 AT XMIN IS LESS THAN OR EQUAL TO ZERO.
IMPOSSIBLE TO COMPUTE VALUES OF Y_AC OR Y_PC FOR XMIN. BOTH VALUES SET EQUAL TO ZERO.
VALUE OF TEMP =       -3.26665782

A =      4.554889020159789  B =      0.002428855466764  C =       0.000000253340695
VALUE OF ABSCISA WHERE MINIMUM OCCURS =   . -4793.654393
    AC ORDINATE WHERE MINIMUM OCCURS =          0.000000
    PC ORDINATE WHERE MINIMUM OCCURS =          0.000000
```

CORRELATION COEFF.= 0.9694 STD ERROR OF ESTIMATE OF Y ON X =

SUM/L	SV
0	4.55
400	5.57
800	6.66
1200	7.83
1600	9.09
2000	10.43
2400	11.84
2800	13.34
3200	14.92
3600	16.58
4000	18.32

SUM/L	AC	PC
100	4.176	4.605
300	4.038	4.475
500	3.916	4.360
700	3.805	4.255
900	3.704	4.160
1100	3.611	4.073
2000	3.262	3.744
4000	2.714	3.227
6000	2.320	2.856
10000	1.750	2.319

VALUE OF MAX AC Y-INTERCEPT = 4.251
VALUE OF MAX PC Y-INTERCEPT = 4.676

POSITION PAPER AT TOP OF NEW SHEET
DEPRESS SPACE THEN RETURN WHEN READY :

PSIR	AC	PC	PSIR	AC	PC
0.000	36563	58539	3.000	2856	5158
0.025	35949	57537	3.025	2767	5021
0.050	35344	56552	3.050	2679	4886
0.075	34749	55582	3.075	2593	4754
0.100	34163	54628	3.100	2509	4624
0.125	33585	53688	3.125	2426	4496
0.150	33016	52764	3.150	2345	4371
0.175	32456	51855	3.175	2266	4248
0.200	31904	50960	3.200	2188	4127
0.225	31360	50079	3.225	2111	4009
0.250	30825	49212	3.250	2036	3893
0.275	30298	48360	3.275	1962	3779
0.300	29778	47520	3.300	1890	3667
0.325	29267	46694	3.325	1819	3557
0.350	28763	45882	3.350	1749	3449
0.375	28267	45082	3.375	1681	3343
0.400	27778	44295	3.400	1614	3239
0.425	27297	43520	3.425	1548	3138
0.450	26823	42758	3.450	1484	3038
0.475	26357	42008	3.475	1421	2940
0.500	25897	41270	3.500	1359	2844
0.525	25444	40544	3.525	1299	2750
0.550	24998	39829	3.550	1240	2657
0.575	24559	39126	3.575	1181	2567
0.600	24127	38434	3.600	1125	2478
0.625	23701	37753	3.625	1069	2391
0.650	23282	37083	3.650	1014	2305
0.675	22869	36424	3.675	961	2222
0.700	22462	35775	3.700	908	2140
0.725	22062	35136	3.725	857	2060
0.750	21667	34508	3.750	807	1981
0.775	21279	33890	3.775	758	1904
0.800	20896	33282	3.800	709	1828
0.825	20520	32683	3.825	662	1754
0.850	20149	32094	3.850	616	1682
0.875	19783	31514	3.875	571	1611
0.900	19424	30944	3.900	527	1541
0.925	19070	30383	3.925	484	1473
0.950	18721	29831	3.950	441	1407
0.975	18377	29288	3.975	400	1342
1.000	18039	28753	4.000	360	1278
1.025	17706	28227	4.025	320	1215
1.050	17378	27709	4.050	282	1154
1.075	17055	27200	4.075	244	1094
1.100	16738	26699	4.100	207	1036
1.125	16425	26206	4.125	171	979
1.150	16116	25721	4.150	136	923
1.175	15813	25244	4.175	101	868
1.200	15514	24774	4.200	67	815
1.225	15220	24312	4.225	35	762
1.250	14930	23857	4.250	2	711
1.275	14645	23410	4.275	....	661
1.300	14364	22970	4.300	....	612
1.325	14088	22537	4.325	....	564
1.350	13816	22111	4.350	....	518
1.375	13548	21692	4.375	....	472
1.400	13284	21280	4.400	....	428
1.425	13025	20874	4.425	....	384
1.450	12769	20475	4.450	....	342
1.475	12518	20082	4.475	....	300
1.500	12270	19696	4.500	....	260

1.525	12026	19316	4.525	....	220
1.550	11786	18942	4.550	....	102
1.575	11550	18574	4.575	....	144
1.600	11317	18212	4.600	....	107
1.625	11088	17856	4.625	....	71
1.650	10863	17506	4.650	....	36
1.675	10641	17161	4.675	....	2
1.700	10423	16823	4.700	....	....
1.725	10208	16489	4.725	....	....
1.750	9997	16161	4.750	....	....
1.775	9789	15839	4.775	....	....
1.800	9584	15521	4.800	....	....
1.825	9382	15209	4.825	....	....
1.850	9184	14902	4.850	....	....
1.875	8989	14600	4.875	....	....
1.900	8797	14303	4.900	....	....
1.925	8608	14011	4.925	....	....
1.950	8422	13724	4.950	....	....
1.975	8239	13441	4.975	....	....
2.000	8059	13163	5.000	....	....
2.025	7882	12890	5.025	....	....
2.050	7708	12621	5.050	....	....
2.075	7536	12357	5.075	....	....
2.100	7367	12097	5.100	....	....
2.125	7202	11841	5.125	....	....
2.150	7038	11589	5.150	....	....
2.175	6878	11342	5.175	....	....
2.200	6720	11099	5.200	....	....
2.225	6564	10860	5.225	....	....
2.250	6412	10625	5.250	....	....
2.275	6261	10393	5.275	....	....
2.300	6114	10166	5.300	....	....
2.325	5968	9943	5.325	....	....
2.350	5825	9723	5.350	....	....
2.375	5685	9507	5.375	....	....
2.400	5547	9294	5.400	....	....
2.425	5411	9085	5.425	....	....
2.450	5277	8880	5.450	....	....
2.475	5146	8678	5.475	....	....
2.500	5017	8480	5.500	....	....
2.525	4890	8285	5.525	....	....
2.550	4765	8093	5.550	....	....
2.575	4642	7905	5.575	....	....
2.600	4522	7719	5.600	....	....
2.625	4403	7537	5.625	....	....
2.650	4287	7359	5.650	....	....
2.675	4172	7183	5.675	....	....
2.700	4060	7010	5.700	....	....
2.725	3949	6840	5.725	....	....
2.750	3841	6673	5.750	....	....
2.775	3734	6509	5.775	....	....
2.800	3629	6348	5.800	....	....
2.825	3527	6190	5.825	....	....
2.850	3425	6035	5.850	....	....
2.875	3326	5882	5.875	....	....
2.900	3229	5732	5.900	....	....
2.925	3133	5584	5.925	....	....
2.950	3039	5440	5.950	....	....
2.975	2946	5297	5.975	....	....
			6.000	....	....

WOULD YOU LIKE TO HAVE THE SECOND SOLUTION FOR YOUR DATA? Y OR N: n

Rehabilitation Candidate Listing by Matrix

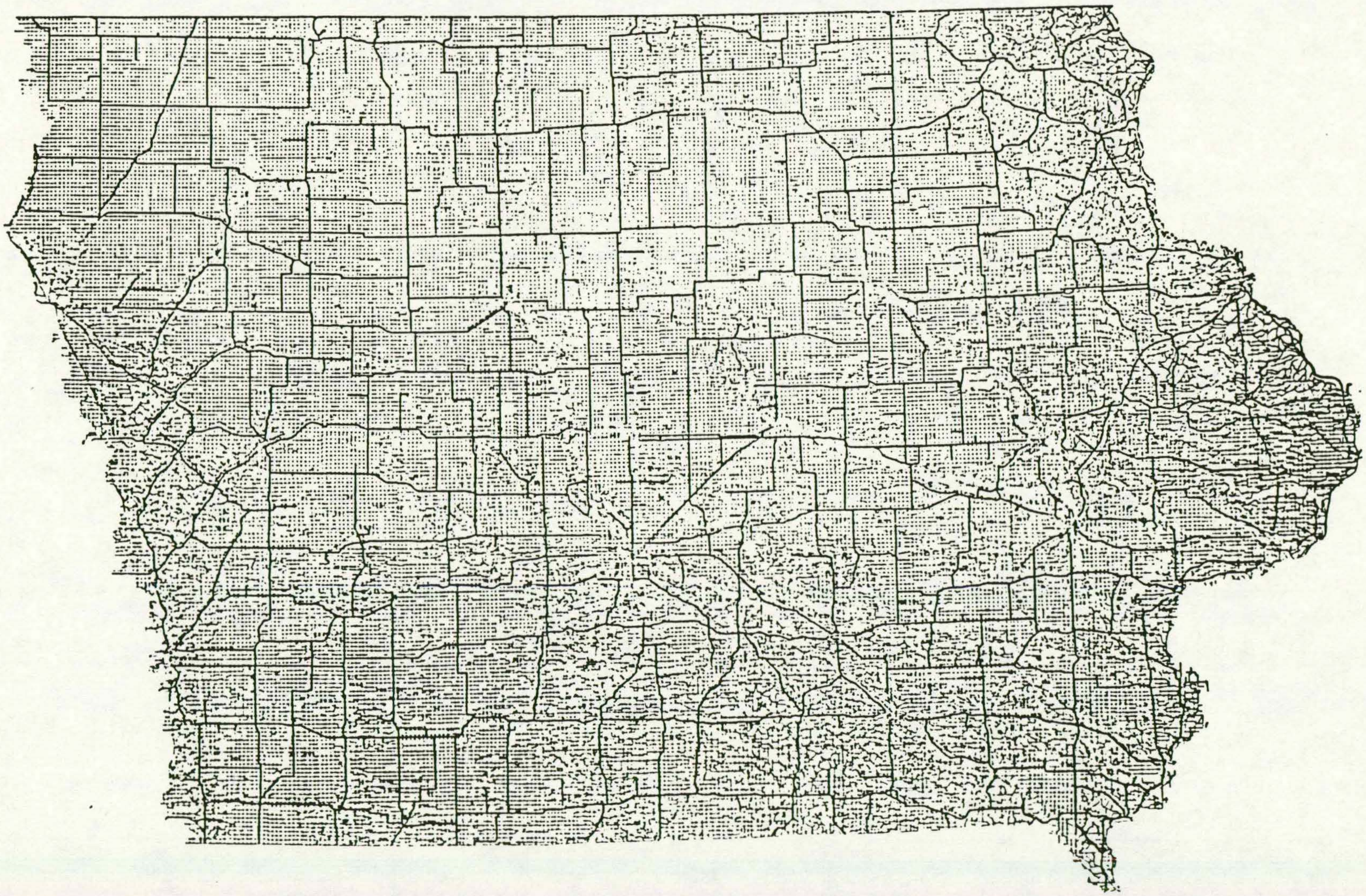
Slide One The Highway System in the State of Iowa is essentially a grid network with a total mileage in excess of 112,000. Of that total, approximately 9% or 10,105 miles falls under the jurisdiction of the Iowa Department of Transportation. Approximately 45% of the primary (IDOT jurisdiction) system is portland cement concrete surfacing with the balance being asphalt cement surfacing of various types including AC over PC, AC over stabilized base, AC over brick, or full depth asphalt cement concrete. It is readily apparent that an investment of this magnitude requires a workable pavement evaluation process based on engineering principles and judgement to determine programming priorities and needs to maximize limited funds to maintain our roadways at levels of service acceptable to the citizens in the State of Iowa.

Slide Two In 1982, the Highway Division of the Iowa Department of Transportation updated the system preservation program to better utilize our reduced staff and maximize our programming capabilities. A strict timetable was implemented which outlined the critical events and time period for decision making. A key element of the decision making process is the input from pavement management, specifically a listing of potential rehabilitation candidates based on a realistic pavement evaluation process.

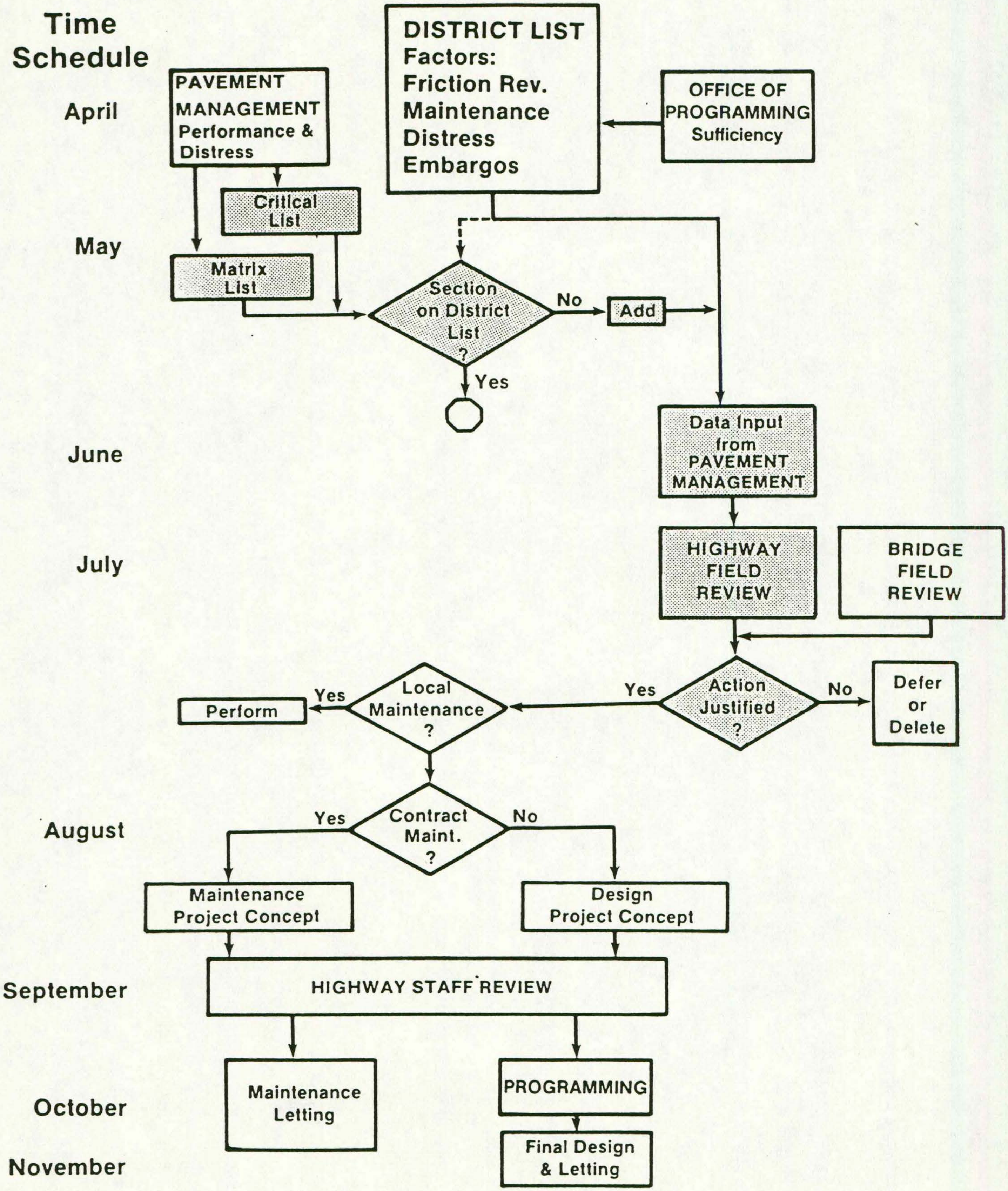
-- BRIEFLY GO THROUGH FLOWCHART --

Roadway Network for the State of Iowa

County Mileage	89,687
City Mileage	12,260
Primary Mileage	10,105
Parks & Institutions	310
Total	112,362



Proposed
System Preservation Flowchart



The Highway Division developed a pavement evaluation process in 1981 to assist management in selecting potential rehabilitation candidates for programming purposes on the basis of needs. The method (process) utilizes a matrix which is composed of key attributes of the pavement which our engineers deem significant in evaluating the overall adequacy of the pavement to serve its intended use -- i.e., a safe and comfortable riding surface for the traveling public.

Slide Three The Iowa pavement management matrix is composed of eight attributes which are arranged in an array which assigns a factor value to a measured or computed numeral. The factors are added and then divided by the number of attributes to calculate an index number which is based on a seven point scale. The index number gives us a quantifiable figure which is unique for that particular roadway segment and used to base comparisons to other roadway sections in our highway network. A list is then generated from which the candidates for rehabilitation can be selected based on programming criteria -- i.e., availability of funds, type of work, level of service, etc. The roadway segments are tabulated according to a milepost system based on original construction limits and ascending order of index numbers.

The eight attributes are: traffic, PCC D-crack occurrence factor, structural adequacy, pavement width, rut depth, crack and patch, longitudinal profile value (IJK Ride), and PSI decrease/year, 6-year basis. Traffic will be replaced with 18K ESAL in May '84 and pavement width will be replaced with maintenance costs in December '84. I will briefly describe each attribute and the frequency with which the information is gathered.

PAVEMENT MANAGEMENT MATRIX

	Factor Value						
	1	2	3	4	5	6	7
Traffic Factor	>8,000	<8,000	<6,000	<5,000	<4,000	<3,000	<2,000
P.C.C. D-Crack Occurrence Factor	>2	2	1				0
Structural Adeq.	1	2	3	4	5	6	7
Pavement Width	18	20			22		24
Rut Depth	>.50	.40	.30	.20	.10	<.10	.00
Crack and Patch	>.80	.60	.40	.25	.15	.05	<.05
Longitudinal Profile Value (I.J.K. Ride)	<3.00	3.20	3.40	3.55	3.65	3.75	>3.75
P.S.I. Decrease/Year 6 year basis	>.35	.35	.30	.25	.20	.15	<0.10

Add factors and compute to a 7 point scale.

Traffic is the term used to describe the traffic volume on a section of highway and is expressed by AADT (annual average daily traffic), which is the total traffic for the year divided by 365. The Office of Transportation Inventory is responsible for obtaining traffic data.

PCC D-Crack Occurrence Factor refers to a characteristic crack pattern that develops in certain portland cement concrete pavements. The Office of Materials is responsible for obtaining the D-crack occurrence factor and it is determined as part of the Crack and Patch Survey, performed on a biennial basis.

Structural Adequacy is a term used to describe how a pavement section responds to a dynamic force. A series of sensors measure the pavement deflection caused by the dynamic force and the resultant rating gives the engineer an indication of the pavement's ability to withstand repeated heavy traffic loads. The Office of Materials is responsible for obtaining the structural adequacy rating and uses a Road Rater. The data is gathered on an "as needed" basis and when the longitudinal profile value falls below 3.0.

Pavement Width is the measured distance from the edge of slab to edge of slab. The Office of Transportation Inventory is responsible for obtaining the pavement width.

Rut Depth is defined as the mean depth of rutting, in inches, in the wheel path of the pavement section. The Office of Materials is responsible for obtaining the rut depth and it is a part of the Crack and Patch Survey.

Crack and Patch is a term used to describe the surface deterioration that has occurred in a pavement section. A physical survey is performed to inventory the extent of cracking and patching of the roadway. The Office of Materials is responsible for obtaining the crack and patch value. The Crack and Patch Survey is conducted biennially by crews in each respective district. The interstate system is surveyed by a team composed of central lab materials technicians.

Longitudinal Profile Value (IJK Ride), Iowa-Johannsen-Kirk is a measure of the pavement's smoothness at a speed of 50 MPH. The Office of Materials is responsible for obtaining the longitudinal profile value. One third of the state is tested each year.

The PSI Decrease/Year - 6-Year Basis is a mathematical computation which averages the PSI value differences over the last six years. The PSI (present serviceability index) value is the longitudinal profile value minus the crack and patch value.

Slide Four The matrix is a network level tool which allows us to compare the performance of a particular roadway to the state as a whole or within each individual district according to its service level or functional classification. The service level categories are: A - interstate and freeway; B - expressway and major arterial; C - arterial; and D - arterial connector. The major programming emphasis is on the A and B level roadways.

Analysis of Pavement Matrix Values By District Weighted Average[1]

Level	Statewide	District No. 1	2	3	4	5	6
A	5.46	4.67	6.23	5.29	5.58	5.84	5.15
B	5.50	5.49	5.29	5.54	5.69	5.44	5.54
C	5.58	5.74	5.75	5.09	5.82	5.46	5.60
D	5.39	5.77	5.44	5.19	5.32	5.34	5.29

Statewide -- All rated sections: 5.46

[1]Does not include mileage not yet rated.

After the evaluation of the total system, a management decision is made to determine what matrix index number is to be used as the minimum level of satisfactory performance for each service level. We are using the following limits for 1985, which were also used for 1984 programming: B-5.6, C-5.2, D-5.0. The A level roadways are funded from other sources and are not a function of this particular program.

Slide Five It is recognized that a roadway segment could have an overall matrix index number which would be above the program cutoff limit but may exhibit extreme distress in only one area which may need immediate attention; therefore, a critical value list is generated based on the following criteria. Ride meter value of not less than 3.2, rut depth not greater than 0.25", crack and patch deduction not greater than 0.5, annual change in PSI not greater than 0.2 and D-crack occurrence factor not greater than 2. If the value of one or more data items fails the acceptable level criterion, the highway segment will be listed as a potential candidate for remedial action.

Once the network listing has been reviewed and approved, it progresses to the project level where design concepts are formulated. A project review team composed of a representative from Road Design, Maintenance and Materials, together with a representative from the respective district perform a field review of each project candidate to determine the most effective method to rehabilitate a particular roadway. We are programming approximately 425 miles of rehabilitation work per year.

CRITICAL VALUES

Data Item	Acceptable Level
IJK Ride Value	Not less than 3.2
Asphaltic Concrete Rut Depth	Not greater than 0.25″
Crack & Patch Deduction	Not greater than 0.5
Annual Change in PSI	Not greater than 0.2
D-Crack Occurrence Factor	Not greater than 2

If the value of one or more data items fails the acceptable level criterion, then the highway segment will be listed as a potential candidate for remedial action and will be field reviewed.

GENERAL NOTES

Crack and Patch

Detailed survey of 1/2 mile sections per 5 miles of surface.

AASHTO Deduction for PSI

Flexible Pavement

$$PSI = LPV - .01\sqrt{C + P} - 1.38\ \overline{RD}^2$$

LPV = longitudinal profile value

$\overline{RD}^2$ = mean rut depth squared

C = sq. ft. of alligator or fatigue cracking per 1000 square feet of surface.

P = sq. ft. of skin or full depth patches per 1000 square feet of surface.

Also record longitudinal cracks 1/4" wide and 100 feet long, transverse cracks 1/4" wide, and faulting - information only, not part of deduction.

Rigid Pavement

$$PSI = LPV - .09\sqrt{C + P}$$

LPV = longitudinal profile value

C = lineal ft. of cracking per 1000 square feet of surface which are open at least 1/4".

P = sq. ft. of skin or full depth patches per 1000 square feet of surface.

Also record faulting which is for information only, not part of the deduction.

18K ESAL

The weighting factors have not been determined at this time. We will try to relate anticipated distress to the 18K ESAL crossing the pavement structure.

Maintenance Costs

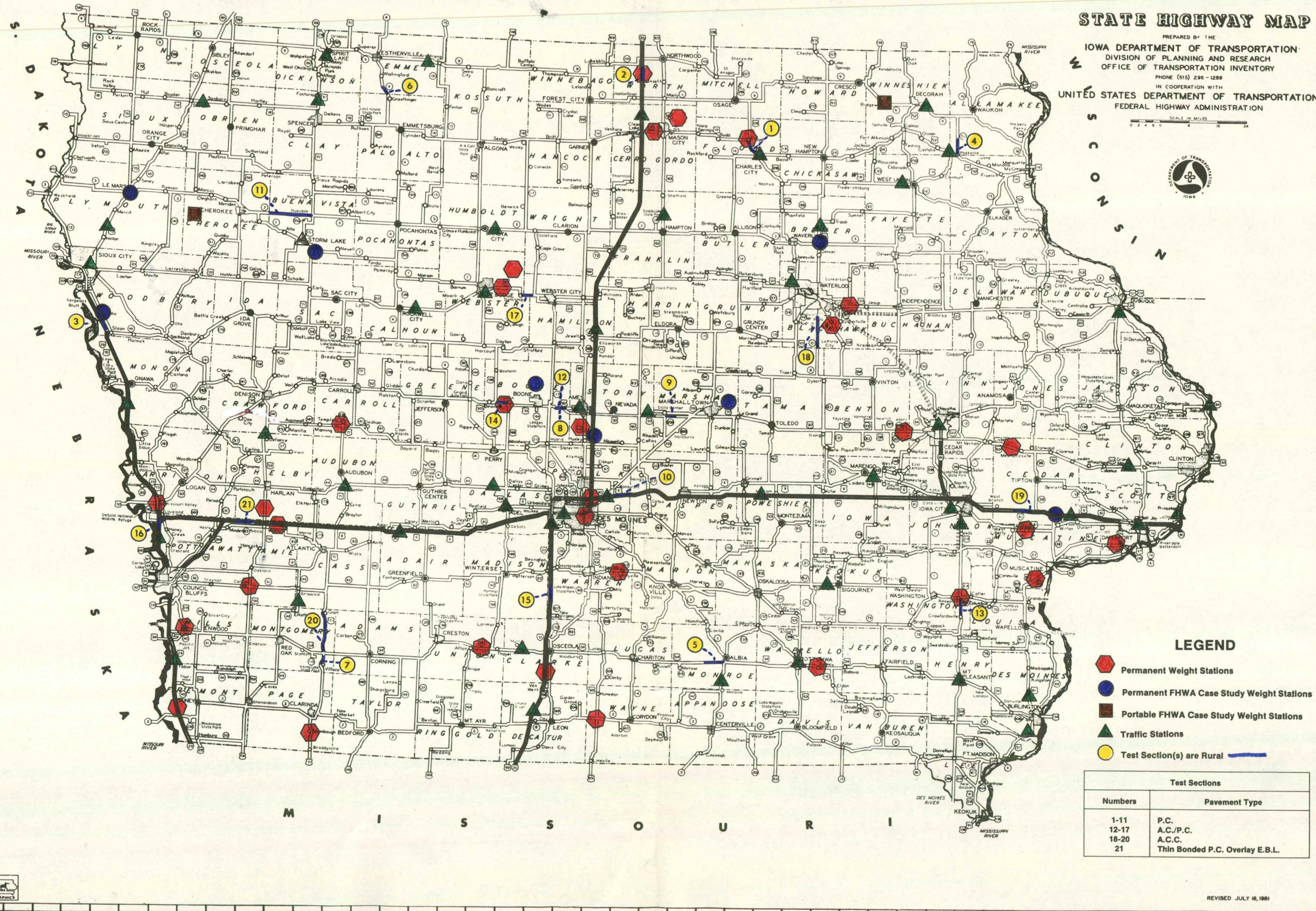
The weighting factors have not been determined at this time. The costs will be on a mile basis and deal only with shoulder to shoulder costs, i.e., pavement repair and shoulder repair. Will not include such routine maintenance costs as painting and mowing.

Appendix D
LTM Site Identification

County	Route	Location	Dir Surv	Beg MP	End MP	Beg Mpnt	End Mpnt	Materials Beg Test Sec	Materials End Test Sec	Trk Weight Sta.	Vehicle Count Location	Yr Constr	Surf. Type
Floyd	US 18	N Jct 218 - Beg 22' Section	WB	208.00	209.00	15.76	16.76	208.00	208.50	85J	ME-34-33-3751	1966	7001
Worth	I-35	Kensett - Ia 105 Intch	NB	211.00	212.00	9.22	10.22	211.00	211.50	94Q	ME-98-22-6726	1972	7222
Woodbury	I-29	Ia 141 - Salix Intch	NB	131.00	132.00	4.37	5.37	131.00	131.50	95R	ME-97-11-8568	1959	7222
Allamakee	Ia 51	NCL Postville north 4.63 mi	NB	2.00	3.00	2.04	3.04	2.00	2.50	85J	ME-03-11-4733	1968	7001
Monroe	US 34	Co Rd H-35 - WCL Albia	WB	162.00	163.00	9.59	10.59	162.50	163.00	85J	ME-68-22-3173	1963	7001
Emmet	Ia 4	Palo Alto Co Line - Beg 24' Sec	NB	128.30	129.30	1.31	2.31	128.30	128.80	85J	ME-32-12-1522	1936	7011
Montgomery	US 71	Villisca - US 34	SB	27.00	28.00	2.86	3.86	27.00	27.50	85J	ME-69-14-4649	1972	7001
Boone	US 30	Asph Div Sec - Conc Div Sec	EB	141.79	142.79	23.68	24.68	142.00	142.50	85J	ME-08-24-8164	1973	7001
Marshall	US 30	Conc Reinf Sec - Non Reinf Sec	EB	174.00	175.00	5.12	6.12	174.00	174.50	24B	ME-64-21-6567	1963	7333
Polk	I-80	Altoona - Mitchellville Intch	EB	146.50	147.50	24.04	25.04	147.00	147.50	92N	ME-77-24-8653	1960	7222
Buena Vista	Ia 3	Cherokee Co Line - US 71	WB	75.00	76.00	5.41	6.41	76.00	75.50	76M	ME-11-32-1703	1958	7001
Boone	US 30	Asph Div Sec - Conc Div Sec	WB	140.00	141.00	20.90	21.90	140.00	140.50	85J	ME-08-24-8264	1930	6706
Washington	US 218	Crawfordsville - Ia 92	SB	63.00	64.00	5.91	6.91	63.00	63.50	24B	ME-92-24-1253	1930	6706
Boone	US 30	W Jct US 169 - Beg Conc Sec	WB	123.00	124.00	3.88	4.87	123.00	123.50	74H	ME-08-31-0192	1929	6706
Warren	I-35	Truro - St. Charles Intch	SB	49.00	48.00	6.15	5.15	49.00	48.50	97U	ME-91-21-3309	1958	6708
Pottawattamie	I-29	Honeycreek - I-680 Intch	SB	66.50	67.50	22.92	23.92	67.00	66.50	96T	ME-78-41-3169	1958	6708
Hamilton	US 20	Webster Co Line - W Jct Ia 17	EB	135.00	136.00	0.78	1.79	135.00	135.50	24B	ME-40-41-0235	1929	6706
Black Hawk	Ia 21	Tama Co Line - SCL Waterloo	NB	91.00	92.00	3.97	4.97	91.00	91.50	85J	ME-07-12-4757	1968	6202
Cedar	I-80	Springdale - Atalissa Intch	EB	260.50	261.50	6.90	7.90	261.00	261.50	91S	ME-16-12-6737	1962	6202
Montgomery	US 71	Jct US 34 - SCL Grant	SB	31.00	32.00	6.87	7.88	31.00	31.50	76H	ME-69-24-3143	1971	6202
Pottawattamie	I-80	E Lts Shelby - E Lts US 59 Intch	EB	38.00	39.00	37.96	38.96	38.00	38.50	93P	ME-78-45-8957	1966	7730

NOTES: MP - milepost; Mpnt - milepoint; Dir Surv - Direction of Survey

LONG TERM PAVEMENT MONITORING TEST SECTION LOCATIONS



Test Sections	
Numbers	Pavement Type
1-11	P.C.
12-17	A.C./P.C.
18-20	A.C.C.
21	Thin Bonded P.C. Overlay E.B.L.