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SD Department of Transportation
Office of Research

Review of SDDOT's Field Collected Roadway Data

Study SD96-03
Final Report

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DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the South Dakota Department of Transportation, the State Transportation Commission, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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This work was performed under the supervision of the SD96-03 Technical Panel:

John Adler .... Operations Support
Jon Becker .... Research
Ken Eschmeyer .... FHWA
Rocky Hook .... Data Inventory
David Huft... Research
Pat Kappenman .... Mitchell Region
Kenneth Marks......................... Data Inventory
Mark Leiferman....Planning and Programming
Dennis Winters .... Information Service

Additional assistance was provided by many people within the South Dakota Department of Transportation, who sat for interviews, provided additional information whenever needed, and promptly responded to questionnaires. The list is too long to acknowledge each separately, but their contributions are gratefully acknowledged. Several other agencies also submitted to lengthy questioning and their time is appreciated. Assistance in writing and reviewing portions of this report were provided by Ms. Katie Zimmerman, Mr. Kurt Smith, and Mr. Monty Wade of Applied Pavement Technology, Inc., and internal review was provided by Dr. Samuel H. Carpenter. Finally, the assistance of Ms. Virginia Ripley of the SDDOT Office of Research throughout this project is acknowledged and deeply appreciated.

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16. Abstract

The South Dakota Department of Transportation (SDDOT) collects and processes a vast amount of roadway data to support internal and external analysis and design systems. These data are collected by different offices within the SDDOT, are collected by a variety of techniques, and are used for many different purposes.

This report presents findings from an evaluation of the SDDOT's roadway data collection procedures and processes. The following roadway data elements are considered: traffic, roughness, rutting, friction, falling weight deflections, videolog images, distresses, faulting, and geometrics. Current practices within the Department are evaluated, as are practices within other agencies and Federal initiatives. Within the Department, issues such as data accuracy, timeliness, and value are assessed by soliciting input from a broad range of data users through a series of interviews and a widely distributed questionnaire.

The data collection *process* is examined, with the objective of identifying procedural means of improvement. Each data element is tracked, including steps such as data collection, reduction from raw data into summary data, data entry, data use, and feedback. Components of the process that can benefit from streamlining are identified, and areas where improvements can be effected are also indicated. Process improvements include additional training for data collectors and modifications to the quality control efforts that are currently in place. Automation of the distress survey data collection is an alternative that should be considered if the Department wishes to implement a comprehensive pavement data collection plan.

Specific recommendations regarding improving the SDDOT's data collection procedures are also presented. These include the development of a manual for each data collection effort that either includes or references protocols for the data item.

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1. Executive Summary

INTRODUCTION

Over the years, as a result of both internal needs and as a response to external forces, the South Dakota Department of Transportation (SDDOT) has developed analysis and design systems for which a vast amount of roadway data is collected. These data are collected by different offices within the Department, are collected by a variety of techniques ranging from manual to automated, and are used for many different purposes.

The specific data types of interest in this project are:

- pavement distress
- traffic
- pavement friction
- roughness from profile
- rutting
- sufficiency rating
- videolog images
- falling weight deflections
- verification of vertical and horizontal curves and other geometric data

Ultimately, the collected data are an integral part of the decision-making process within the Department. And, inevitably, these data have an enormous impact on the fiscal decisions made by the SDDOT. The value of accurate and timely data to facilitate making these decisions is incontrovertible.

The various data collection processes developed to meet the Department's needs have tended to evolve independently, and not as part of an effort to achieve explicitly stated Department objectives. At the same time, because of the nature of the data or, in some cases, the methods of data collection, the accuracy of the collected data and the uses to which the data are put have not necessarily evolved together. As an example, profile data are collected by automated means but distress data are manually collected. Is this a reflection of the most cost-effective means of collecting these data, the most accurate means, or the state of the art? As another example, profile and deflection data are both collected with automated equipment, but different procedures are followed in the calibration of this equipment. Are the procedures for each the best, or is one set of data inherently more accurate than the other? If there is variability, how does it affect the decisions that are based on the output?

Effective decision making is most likely to take place when the information upon which decisions are based is accurate, useful, and timely. However, not only must this information be all of these things, but users of the data must also recognize and acknowledge that the data have these attributes. Within the SDDOT there are implied concerns about roadway data. Some Divisions are collecting their own pavement data. Some data users have complained about either the timeliness or the accuracy of the data that they receive. There has been a change in the way several types of data are collected, without an evaluation of whether or not the changes are desirable.

In May 1996, the SDDOT initiated a project to assess the status of their roadway data collection processes, considering them both individually and as a system. The Department's objectives are summarized below:

1. Determine the Department's need for field-collected roadway data and its value and cost.
2. Review present methods for acquiring and ensuring the quality of roadway data.
3. Assess the accuracy of field-collected roadway data, excluding traffic data.
4. Coordinate the Department's data collection program with the FHWA's project to develop data collection protocols.
5. Recommend a comprehensive policy and procedures for roadway data collection.

Each of these objectives was achieved during the course of this project. The primary sources of information included interviews in person and over the telephone with data users and questionnaires. These sources provided information on the need for data, present methods of acquiring that data, and the data's accuracy. In addition, a literature review and interviews with representatives of other State Highway Agencies provided valuable information for use in this project.

SOUTH DAKOTA'S ROAD DATA COLLECTION PRACTICES

Roadway data collection efforts within the SDDOT were evaluated as both a coordinated process and as a series of discrete activities. The process review highlighted several opportunities to improve the flow of information within the Department. In most instances data are collected and processed by the same staff. Therefore data processing (and the subsequent availability of the results) are not available until late in the fall. Another observation is that seasonal employees or interns, who are not available for hire until May, collect the data. The use of full-time employees in this role would permit the data collection efforts to begin in April and continue until October. In turn, this could lead to more processed data being available sooner in the year. Another potential benefit is that full-time employees are more likely to be responsive to the Department's needs for accurate data.

Each of the collection practices was also studied and the individual procedures were outlined. This information is presented along with the feedback received from users of the data. Considering the data types one by one it was concluded that most data collection procedures are sound, carried out correctly, and provide accurate data for use throughout the Department. Exceptions to this general conclusion include the skid data, which are not being collected, and the sufficiency rating, which is no longer being calculated. Where there were concerns with data accuracy, delving further into the causes of the concerns usually revealed that it was the users' lack of familiarity with how the data are collected or summarized that resulted in the perception of inaccuracy rather than bad data that were being collected.

ROADWAY DATA USERS' NEEDS

The conclusion that the data were sufficiently accurate for most Department uses was verified by a questionnaire on data accuracy, value, and timeliness that was distributed throughout the

Department. The results failed to distinguish any single data type as inaccurate, without value, or untimely. Furthermore, the value of the collected data appeared to be in line with the costs expended to collect the data. This was especially the case when the impacts of the various decisions made from the data were considered.

OVERALL RECOMMENDATIONS

There are a number of recommendations that emerged from this project. Data collection procedures and protocols were found to be acceptable in most cases, although in almost every instance they lacked documentation. Developing documented procedures for each data type that cover collection, measurement, reporting, and quality control procedures would benefit both the data collectors and the data users. With the exception of pavement distress, this entails documenting and implementing existing procedures. For pavement distress, a detailed quality control procedure was developed and proposed to the Department. The FHWA's Draft Data Collection Protocols were found to be useful for rutting and roughness, but of limited applicability for pavement distress.

Considering existing practices, it was recommended that the Department discontinue the use of the Sufficiency Rating and recommence collection of skid data. Roughness, rutting, and pavement distress should all be collected at the same frequency. The videolog survey results would be more useful throughout the Department if they could be made more accessible. This is feasible if the equipment is converted to digital format and some additional image processing and handling capabilities is added. The costs of this were estimated to be around $450,000, with an additional expense of $2,000 for each viewing station that is needed.

One of the project tasks was to propose a comprehensive data collection policy. A policy is described that addresses principles which should guide the data collection practices of the Department. In includes an approach to prioritizing among the different data collection efforts, (based on subjective valuations of the data), and makes recommendations regarding data accuracy and the efficiency of the data collection effort. Implicit in this policy is the need to perform data validation (QA/QC) so that data are of the highest possible quality. As part of the comprehensive policy, it is argued that data be collected in a <u>consistent</u> manner from type to type, that the different data types be of similar <u>quality</u>, and that data be collected in a more <u>timely</u> manner. These objectives can be achieved by documenting procedures, developing or adopting data collection protocols, and moving to permanent rather than seasonal employees to collect roadway data. To implement this comprehensive policy, existing resources can be used, modified by the specific recommendations that are summarized below. As an alternative, the Department could acquire a single vehicle that collects distress, roughness, rutting, and faulting. This equipment could also be used to replace the videolog survey if properly configured. The costs of adding distress survey capabilities to existing equipment was about $110,000; no estimate was made of what it would cost to add the videolog capabilities as well. If new equipment were considered, costs of equipment acquisition alone would be over $300,000.

The move to automated distress surveys is not recommended at this time. Until the Department is sure how the needs of their pavement management system are to be met, it is more cost-effective to improve the existing procedures as recommended below.

SUMMARY OF SPECIFIC RECOMMENDATIONS

The following are the specific recommendations that are made to the Department regarding their current data collection practices. Implementing these changes would meet the objectives of a comprehensive data collection policy within existing fiscal constraints.

Recommendation 1: Data collection should be considered as a comprehensive process, governed by the principles stated in chapter 7. These can serve as a guide in making decisions about each data collection activity, as well as in determining how to allocate resources among the various data collection activities.

Recommendation 2: The Department of Transportation should perform annual surveys of pavement roughness, reporting an International Roughness Index in both wheel paths. The survey should be performed in the outer lane in both directions on divided highways and in one direction on undivided highways. Both static and dynamic calibration procedures should be adopted to ensure data quality.

Overall, no problems were found with the roughness data collection. The recommendations are intended to standardize the data collection procedure and to ensure its quality.

Recommendation 3: Rutting data should continue to be collected with the three-point rut bar mounted on the ARAN van. Rutting should be measured annually in the outer lane in one direction on undivided highways and in both directions on divided highways. Improvements in the quality of the data will be obtained from operating the equipment over test sections with known rut depth statistics and by performing an on-board comparison of rutting measurements with previously collected data. This on-board check can be manual, does not need to be run on all sections, and can be completed with minimal additional effort.

The current procedures are satisfactory, but there is an opportunity to standardize practices and raise the level of quality by performing quality control checks on a regular basis.

Recommendation 4: There are several opportunities to enhance the FWD data collection practice. It is recommended that the Department start by developing a comprehensive data collection manual that covers the FWD equipment use in all of its applications, including an annual calibration. The Department should stop performing network-level surveys, perform project-level surveys for rehabilitation projects, and continue special FWD studies. Road where it is known that there is minimal change in deflections need not be tested on a regular basis (e.g., high quality PCC pavements).

Overall, the development and use of documented standardized procedures for the FWD that include regular calibration will improve the quality of the data and the use of the equipment. The recommendations regarding which pavements to test are based on how the data are used. The FWD is most effective as a project-level tool and it should be used where the data can have an effect on the decision-making process.

Recommendation 5: The South Dakota Department of Transportation should resume the use of its skid-testing equipment by investing the estimated $40,000 needed to return the equipment to operation. The equipment should be maintained in working order and follow a regular calibration schedule, such as every other year. No network level use of the equipment is needed. There are several project-level applications for the equipment, including new material performance, evaluation of the effectiveness of construction or rehabilitation methods (e.g., diamond grinding, tining patterns), and accident investigation.

There is enough demand for friction data that the Department needs to have some means of providing these data. The Department already has equipment that can be restored to operable condition for approximately one-quarter of the cost of new equipment and that should be sufficient to meet the Department's needs.

Recommendation 6: Currently videologs are compiled over a third of the network annually. No changes are recommended to the current practice of videolog surveys. The videolog survey should be updated to a digital system and the video images made available over the Department's network when technology permits. This is expected in approximately 2 years.

If the technology is not used for distress data collection, there are several enhancements that should be considered and are discussed in the body of this report. These include increasing the frequency of the surveys and acquiring more than on image every 8 m (25 ft). The concept of using automated methods to obtain images of the pavement from which the distress survey can be performed is addressed as part of the comprehensive data collection policy.

Recommendation 7: The calculation and use of the Sufficiency Rating is no longer needed and should be discontinued.

The Department's list of upcoming projects is now developed from other indices and the Sufficiency Rating no longer serves any purpose.

Recommendation 8: Traffic data collection is performed in accordance with widely accepted practices. No changes are needed other than publicizing the existence of the reports that document the traffic monitoring process.

The Department has already prepared documentation that describes the traffic data collection procedure. The Department has also implemented a traffic data acquisition system that performs numerous quality checks as the data are collected. This documentation should be made available to those interested in acquiring a better understanding of the process. Any dissatisfaction with this process appears to stem more from a lack of understanding of current procedures than from any shortcomings in the procedures themselves.

Recommendation 9: Reporting of geometrics data in the *Needs* book should be altered so that the minimum roadway shoulder width and the predominant width are available to users. If there is also variation in the reported width for the driving lane and left shoulder these should be added as well.

What initially appeared to be a question of data accuracy turned out to be unfamiliarity with what was actually being reported. The predominant width that is reported is a value of some interest to users, but the minimum width (such as of a roadway or shoulder) may actually control more decisions. Reporting both values should address the needs of more users.

Recommendation 10: The distress survey should be performed over the entire network on an annual basis. This report proposes a Quality Control procedure for distress data collection. This procedure should be implemented and validated using actual survey results. Based on the outcome of field trials of the procedure, the Department should make revisions to either the QC procedure, the data collection procedure, or both.

The distress survey has the greatest potential for inaccurate results because it is essentially a manual process, while all users use data collection or measuring instruments. Furthermore, the survey is performed by seasonal employees who receive minimal follow up on their work after their training is completed. A QC procedure that checks the survey results against those of experienced raters is proposed. This can be used to verify data accuracy and identify areas of weakness that can be corrected with additional training.

Recommendation 11: The Department should require that all data collection procedures be documented so that they are thoroughly understood by anyone involved in their data collection, processing, or application. The documentation should be in the form of manuals of practice that address how data are to be measured, collected, manipulated, and stored. These manuals should also cover QC procedures as described above.

Many of these data collection practices are very individualized practices, dependent upon the knowledge and skill of either one or a small group of people. If the individual(s) involved in these data collection efforts were to become unavailable suddenly, the Department would be highly susceptible to a total loss of the skills required to collect or analyze certain data types. The availability of documented procedures not only helps to protect the Department against this loss, but it also helps to improve the standardization of the procedures and the repeatability of the results.

Recommendation 12: Hire a full-time employee to be in charge of the annual distress surveys. This employee's responsibilities would include updating the RES file.

Adding a full-time employee addresses several issues, including data quality, the timing of data entry, and the timing of data availability. The minimal costs associated with this are well worth the returns.

2. Project Objectives

The objectives of the project were defined in the Request for Proposals and are summarized below:

1. Determine the Department's need for field-collected roadway data and its value and cost.
2. Review present methods for acquiring and ensuring the quality of roadway data.
3. Assess the accuracy of field-collected roadway data, excluding traffic data.
4. Coordinate the Department's data collection program with the FHWA's project to develop data collection protocols.
5. Recommend a comprehensive policy and procedures for roadway data collection.

Each of these objectives was addressed during the course of this project. A brief description of how the objectives were met follows.

Determine Data Collection Needs

The Department's need for roadway collected data was evaluated in several different ways. Interviews were conducted with data users identified both by the Office of Research and by the data providers. Data users were asked what data they use and what data they would like to have. These interviews were followed up with questionnaires and, in some cases, with additional questions over the phone or in person. Value was measured through a questionnaire that solicited feedback on the value of different data elements to job performance. A subjective assessment of the data value was also made by considering all of the different decisions that are based on the field-collected roadway data. Data collection costs for 1995, 1996, and 1997 were supplied by the Department.

Review Present Methods of Acquiring and Ensuring the Quality of Data

To learn how roadway data are presently collected, interviews were conducted with roadway data collectors. Where available, any manuals or other instructional or reference material on the data collection activity were provided by the office responsible for the data collection. A literature review provided some initial information about data collection practices outside South Dakota. Telephone interviews were also held with Department staff involved in roadway data collection at a number of other agencies. This provided a basis for reviewing the Department's approach and for learning about the steps that others are taking to ensure data quality.

Assess Data Accuracy

This project did not include collecting roadway data and comparing it to some "ground truth" or baseline data for accuracy. Data accuracy was evaluated through several subjective measures, however. Both data users and data collectors were asked for their opinions about data accuracy. These questions were then repeated in the questionnaire mentioned earlier. During the interviews, some data users commented about the amount of corrections that were needed for different data types and this feedback provided another subjective evaluation of data accuracy. A draft quality control plan was developed for the pavement distress survey, but it was not verified in the field.

Coordinate with the FHWA's Data Collection Protocols

There is no specific project task that addresses this objective. However, the protocols themselves have the potential to address at least two of the project's objectives: ensuring quality of roadway data and being part of a comprehensive procedure for roadway data collection. The latest available draft versions of the protocols were supplied by the Department and reviewed for their applicability in South Dakota.

Recommend a Comprehensive Policy and Procedures

Several recommendations regarding data collection are found in the conclusion to this report. Only one of the data collection efforts—distress data—was found to be lacking procedures for quality control. A quality control procedure is recommended to the Department, but it requires field testing and refinement. For other data collection efforts, a number of recommendations are made that should, if implemented, improve the overall quality of the effort with minimal additional expense or effort. Most recommendations are in the form of incremental improvements to the existing procedures. These are fiscally conservative and acknowledge the existing trend toward reducing expenses. As an alternative, recommendations are also made to acquire a single survey vehicle that can collect distress, roughness, rutting, and faulting, while also providing video images. Acquisition and use of such a vehicle would help to further consolidate the data collection activities in a single location.

Summary

This project is a comprehensive evaluation of the roadway data collection practices within the SDDOT. The project objectives were largely met by examining and analyzing practices in South Dakota, as well as around the country.

3. Project Tasks

The technical panel established ten tasks which, when successfully completed, would meet the project's objectives. The project tasks are repeated here, and are followed by a brief explanation of the accomplishments that were made for each task and where in this report additional information is found.

Task 1. Meet with project's technical panel to review project scope and work plan.

A meeting between the technical panel and the Principal and Co-Principal Investigators took place in Pierre, South Dakota on May 13, 1996. During the meeting members of the technical panel shared their concerns about roadway data collection practices in South Dakota and discussed what they hoped this project would accomplish. The meeting itself did not result in any major changes to the work plan because feedback from the panel had already been incorporated into a revised work plan prior to the meeting. During the course of the project, the researchers met several more times with the technical panel to fine tune the direction of the project.

Task 2. Identify, describe, and prioritize the SDDOT's needs (including measurement definition, frequency, required accuracy, and value) for field-collected roadway data, including traffic data, by interviewing data users and reviewing regulatory requirements.

The data collection process included interviews, questionnaires, a literature search, and interviews with other agencies. The approach used to collect the information to complete this task is summarized below. The results of that data collection effort are found in chapters 4 and 5. Rankings of the Department's needs and the prioritization of those needs are found in chapter 6.

<u>Interviews</u>

The focus of this project is the field-collected roadway data that is used in the Department. The most important sources of information about these data are those individuals and Divisions who collect, process, and use the data. Therefore, an interview process was initiated to solicit feedback from this group.

Interviews were conducted over a 4-day period from May 13 to May 16, 1996. All but one of the interviews were conducted in person at the DOT in Pierre; one of the interviews was held at the Pierre Region office and one was held by telephone.

Sixteen different interview sessions were held over this period and at least 40 different Department employees were included in those interviews. The list of interviewees was selected with the intention of obtaining input from as many people as possible who have an interest in field-collected roadway data. While it was originally intended that everyone would be interviewed individually, once the list of people to interview was drawn up it became clear that many of the meetings would be held in groups. Even so, some of the people that might have been able to contribute were not available and others were interviewed instead. A list of those who participated in the interviews is presented in Appendix A.

There was no formal interview procedure although, within reason, each group of interviewees was asked similar questions. Those who collected data were asked questions such as the following:

- What data do you collect?
- How do you collect it?
- How often?
- What procedures are followed?
- Are there calibration or QC procedures?
- Are there any problems associated with the data?

There wasn't really any office that was solely responsible for "processing" data, so this did not constitute a distinct group. Data processing is usually done by the data collectors, and is occasionally done by data users.

Data users were asked about the data that they receive and how they use it. The types of questions they were asked included the following:

- What roadway data do you use?
- How accurate is it?
- How timely is it?
- Do you manipulate the processed data in any manner, including verification or quality assurance?
- Do you collect any of the data available elsewhere on your own?

Several of the interviews were followed up with additional questions, either in person or by telephone.

Questionnaires

Shortly after the interviews were completed, the research team distributed a questionnaire to several of the interview participants. Their responses indicated that a broader distribution of a follow-up questionnaire would be beneficial to the interpretation of the responses. Consequently, while not originally a part of the proposed approach to this problem, a questionnaire was added to address the lack of quantitative feedback. The questionnaire was especially helpful in addressing issues of relative cost and benefit of data elements. The results of the questionnaire are discussed in chapter 6, and the individual responses are provided in Appendix B.

Literature Search

A literature search was performed as part of the proposal preparation process. This search helped to identify recent activities in this area, but it was noted that the topics covered in this project span the pavement field, and it proved difficult to focus in on the specific interests of this project through the literature search. The research team was made aware of several key studies of interest to this project, including an ongoing study by the Federal Highway Administration (FHWA) and a recently completed National Cooperative Highway Research Program (NCHRP) Synthesis. Key elements of the literature search are summarized in chapter 4.

External Interviews

Representatives from several other State Highway Agencies were contacted for input on their data collection activities. The purpose of these interviews was to benchmark South Dakota practices against agencies in the region and agencies elsewhere in the United States who have long been active in data collection. For this report, representatives from seven other State highway agencies were contacted and interviewed either by telephone or in person. Summaries of these interviews are provided in chapter 4.

Task 3. Review literature, other States' practices, and federal initiatives to establish common data collection protocols to identify best practices for collection of roadway data, excluding traffic.

Key sources in the literature were reviewed for the project team's proposal submittal. The review of States' practices is described in this chapter and detailed results are described in chapter 4, as are the Federal data collection protocols. The applicability of the Federal protocols is discussed in chapter 7.

Task 4. Conduct a process review of SDDOT's roadway data collection program (including traffic) to assess its effectiveness, efficiency, resource requirements, and cost. Include interviews of data collection personnel.

The review of data collection processes is described in chapter 5 and the interview results are presented throughout the report, but concentrated in that chapter. The most comprehensive interview summaries are found in chapter 4. Some conclusions from the process review are found in chapter 7.

Task 5. Propose measurement and quality control procedures needed to satisfy the Department's need for roadway data (excluding traffic), preferably avoiding large capital investments.

The review of the existing data collection practices showed that quality control procedures were, for most data collection activities, already developed. What was lacking in some cases was the adherence to a strict policy of implementing the already existent quality control procedures.

Proposals for improvements to data collection procedures and processes are discussed in chapter 7.

Task 6. Provide an interim report and presentation to the project's technical panel describing the recommended measurement and quality control procedures and a plan for their evaluation.

An interim report was submitted to the technical panel in October 1996, and it was followed by a meeting between the project team and the panel. This report summarized the research findings up to that point. It did not include a recommended measurement and quality control procedure, but did provide recommendations for improving the data collection process. Following that meeting, an evaluation of the data collection procedures was completed, leading to the recommendations for a quality control procedure that are described in chapter 7.

Task 7. Upon the technical panel's approval of the recommended procedures and evaluation plan, validate the quality control procedures using measurements collected by Department staff.

Because of the nature of the recommendations emerging from this project (specifically, to change the distress survey), it was not possible to validate the quality control procedures. The 1997 survey did not start until May, when the quality control procedure was being completed. However, recommendations for validation of the procedure are made in chapter 7.

Task 8. Develop recommendations for a comprehensive data collection policy for setting data priorities and coordinating collection of roadway data, including traffic. Apply the policy to propose one data collection program that fully addresses the SDDOT's roadway data needs. If present resources are insufficient to support the complete collection program, propose another program that best addresses the needs within current research constraints.

The Department currently has good practices, but some of the data collection procedures could be improved by minor changes. Such changes are described in chapter 7. A more substantial change is also described, which would result in increased costs but could also lead to more efficient data collection and lower annual collection costs. This is also described in chapter 7.

Task 9. Prepare a final report and executive summary of the literature review, research methodology, findings, conclusions, and recommendations.

This report constitutes the completion of this task.

Task 10. Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.

A presentation to the Research Review Board was made on June 12, 1997.

4. Review of Data Collection Practices Outside South Dakota

INTRODUCTION

This chapter provides an in-depth evaluation of the data collection practices outside the State of South Dakota. This evaluation includes the results of an extensive literature review, interviews with selected State highway personnel, and a review of Federal protocols. The literature review provides insights from the experiences and research conducted by others in this area. The review of the practices in other States provides a means of comparison to South Dakota's practices, as does the examination of data collection protocols.

The findings from each of these efforts are summarized in the respective sections within this chapter. The information in this chapter, in conjunction with the evaluation of data collection practices in South Dakota, provides the framework for making recommendations to improve data collection practices.

LITERATURE REVIEW

An extensive literature review uncovered many studies that are relevant to this research effort; however, it should be cautioned that this is a very dynamic field. Developments in roadway data collection, particularly in automation and computerized systems, have heralded many changes over a short period of time. As an example, the automated pavement distress equipment addressed as part of a 1987 report bears little resemblance to what is available today (Hudson 1987). That report considered devices produced by four companies: Gerpho, PASCO, ARAN, and Laser RST. However, just a few years later at a seminar on automated pavement distress data collection equipment, the following manufacturers presented information on devices (Cable and Marks 1990):

- ARAN (Highway Products International)
- AREV (Pavement Management Services)
- ARIA (MHM Associates)
- KJ LAW 8300A (KJ Law Engineers, Inc.)
- Laser RST (Infrastructure Management Services, Inc.)
- PAS-1 (Pavedex, Inc.)
- Pavetech (Pavetech, Inc.)
- PDI-1 (Roadman-PCES Inc.)
- Road Profiler (South Dakota DOT)
- Roadrecon (PASCO USA Inc.)
- Videocomp (Videocomp)

Today, some of these devices are no longer available, are not marketed in this country, or have undergone significant modifications in their capabilities since the 1990 report. Still other devices not on this list have been introduced and are being widely promoted. And although a recent survey of State practices showed that only a handful of highway agencies use automated distress collection technologies, this situation is changing rapidly (Gramling 1994).

Distress Data Collection

Throughout the years, many standards have been developed to provide a consistent means of collecting and reporting pavement distress data. The latest and likely the most comprehensive method was developed as part of the Strategic Highway Research Program (SHRP) and is currently being employed in the Long-Term Pavement Performance (LTPP) study (SHRP 1993). The *LTPP Distress Identification Manual* describes each distress, severity level, and measuring technique and is divided into asphalt concrete pavements, jointed concrete pavements, and continuously reinforced concrete pavements.

As part of a comprehensive NCHRP synthesis, a questionnaire regarding pavement data collection practices was completed by all 50 States, the District of Columbia, and 9 Canadian provinces (Gramling 1993). One of the questions dealt with the type of manual used to collect the distress data. Of the 60 agencies responding, 49 agencies indicated that they use some sort of manual. A large majority of those agencies (41) use manuals that were developed specifically for their agency. Figure 1 provides a summary of the type of manuals being used.

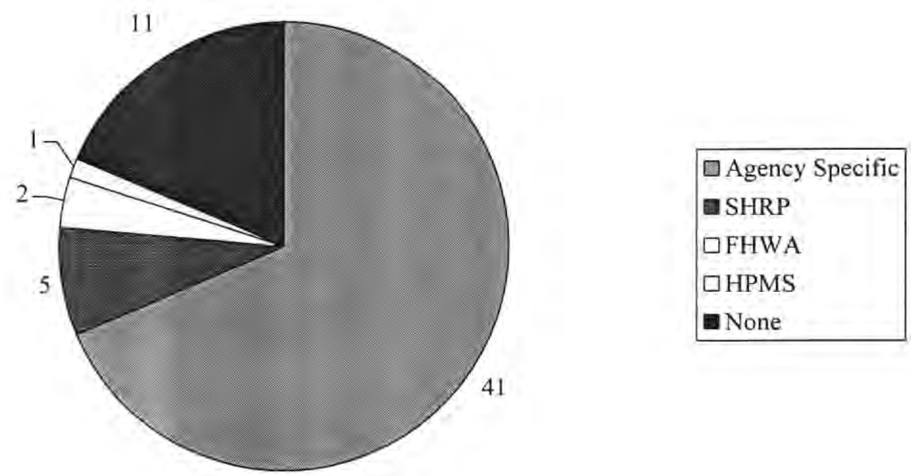

Figure 1. Distress manuals used by agencies (Gramling 1994).

In terms of the method used to collect the data, there is little consensus among the agencies. Windshield surveys, shoulder surveys, walking surveys, and automated surveys are all widely conducted. Table 1 summarizes the findings from a recent questionnaire survey. At the time of the survey, eight States were using automated data collection techniques, although it is believed that more States have now switched to an automated method. The use of automated techniques is much more widespread for the collection of rut depth measurements, with nearly half the agencies using automated methods. A comparative study of three collection methods recommended the South Dakota Profiler for collecting rut depth data at the network level (DuBose 1991). Automated methods for collecting faulting data are used by less than 30 percent of the States (TRDF 1994).

Table 1. Summary of distress data collection methods (Gramling 1994).

Data Collection Method	Number of States	Number of Provinces
Windshield	14	4
Shoulder	9	0
Walking	9	1
Combination	8	4
Automated	8	0

For the most part, the cost of the equipment bears a direct relationship with the accuracy of the equipment. At least one study reports that automated methods tend to rate the severity of some distress types lower than ratings obtained by manual methods (Smith et al. 1996).

Some agencies survey 100 percent of the pavement, while others designate a predetermined representative sample (Gramling 1994). Most of the agencies survey the pavements annually, whereas some conduct surveys biannually. Less than 10 percent of the agencies conduct surveys less frequently than every other year. The agencies record the data either on paper forms or on computers. The few remaining agencies record the data on video or film (likely those using automated techniques).

Distress data collection is viewed as the most costly part of the data collection effort. Some agencies find it easier to contract for distress data collection, so they do not have to devote agency personnel to the effort (Smith et al. 1996). Contracting out this activity also allows data collection using automated methods without the agency having to purchase expensive equipment. When contracting out this activity, the FHWA (1993) recommends that the agency define the required data and let the market forces define the methods for collecting the data.

Two other issues that require consideration in any distress data collection program are training of the survey crew and quality assurance. Training helps ensure that the data are collected accurately and consistently. Quality assurance, on the other hand, provides validation of the data collection and input process. Figure 2 illustrates the degree of training provided by the various agencies. Over 80 percent of the agencies provide some degree of training to the survey crews. However, the amount of training varies significantly from less than a day to several months. About one-third of the agencies indicated that they do not provide any quality assurance. The other agencies either perform random resurveys, compare the results to previous years, or perform checks in the office.

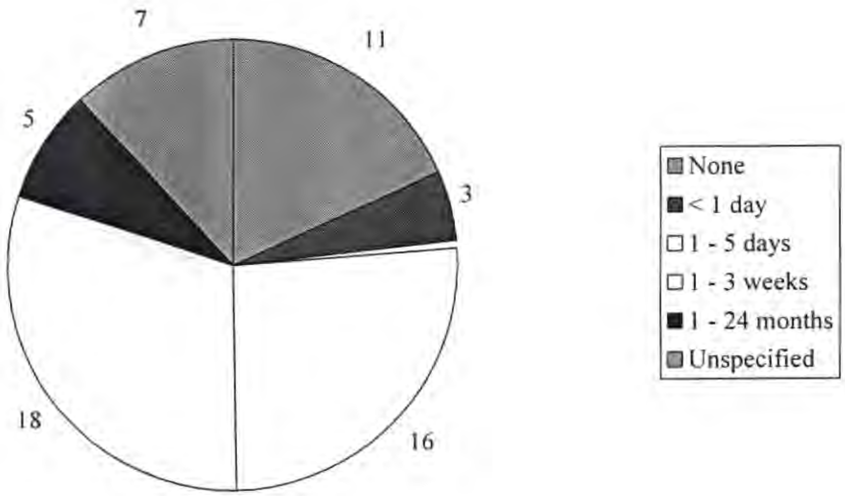

Figure 2. Amount of training provided to survey crews (Gramling 1994).

Roughness Data Collection

Although the collection of other forms of data are important, the collection of roughness data should be viewed as one of the more critical elements of a roadway data collection program, as it is roughness that ultimately affects highway users. The equipment for measuring roughness can be categorized into two general types: response type road roughness measuring systems (RTRRMS) and profilers. RTRRMS determine the pavement roughness by measuring the effect of roughness on the movement of a vehicle or wheel. Profilers, on the other hand, produce a continuous signal or trace related to the true profile of the pavement surface.

Comparison of surveys conducted in 1986 and 1991 (see table 2) indicate that more States are moving toward the use of noncontact (acoustic or laser) road sensors (Sayers et al. 1986; Gramling 1994). Of 18 States indicating that they planned on purchasing new equipment, none planned to obtain RTRRMS (Smith et al. 1996). Automated equipment is capable of surveying at speeds of 72 to 80 km/hr (45 to 50 mph). The accuracy of profiling equipment has been mixed (Perera et al. 1996).

Table 2. Comparison of the use of roughness measuring equipment (Gramling 1994).

Equipment Type	Agencies Using in 1986	Agencies Using in 1991
GMR Profilometer (K.J. Law)	4	3
South Dakota Road Profiler	1	25
K. J. Law 8300	0	3
Cox CS800 Ultrasonic	0	8
Mays/PCA/Cox Ride Meters	32	22
ARAN	0	10
BPR Roughometer	4	0
Others	0	2

As with distress data collection, most agencies collect roughness data over the entire system either annually or biannually. Gramling (1994) indicates that the current trend is to survey the higher systems, such as Interstates, annually and to survey the rest of the network either annually or biannually. On two-lane roads, the common practice is to survey only one direction, whereas on four-lane roads, the outside lane in both directions is typically surveyed.

Several quality assurance measures are being used by the States to ensure the accuracy of the collected data. These measures include the following (TRDF 1994):

- Replicate testing of calibration sections.
- Manufacturer's daily equipment check procedures.
- Review by supervisor.
- Certified training of equipment operators.

These measures are used both alone and in combination.

The International Roughness Index (IRI) is the most common means of reporting roughness. From a recent survey, nearly 70 percent of the agencies reported the use of IRI, with either the Ridescore or Root Mean Square Vertical Acceleration noted as other means of reporting the data (Gramling 1994). The data are typically collected in both wheelpaths, with the average of the two values being reported. Of the agencies collecting data in only one wheelpath, the left wheelpath is used twice as frequently as the right wheelpath. One study reported that roughness measurements are more stable for the left wheelpath than for the right wheelpath (Hadley and Roper 1991).

Friction Data Collection

Friction between the tire and the pavement (commonly referred to as skid resistance) must be maintained at adequate levels to provide safe operating conditions for vehicles. Many pieces of equipment are available to measure pavement friction. A survey of 60 agencies in the United

States and Canada found over 80 different pieces of equipment being used (Gramling 1994). The locked-wheel trailer is the predominant type of equipment, reportedly used by 85 percent of the agencies. However, a wide range of manufacturers of locked-wheel trailers is represented in this 85 percent, as illustrated in figure 3. The use of a ribbed tire is much more widespread than a bald tire.

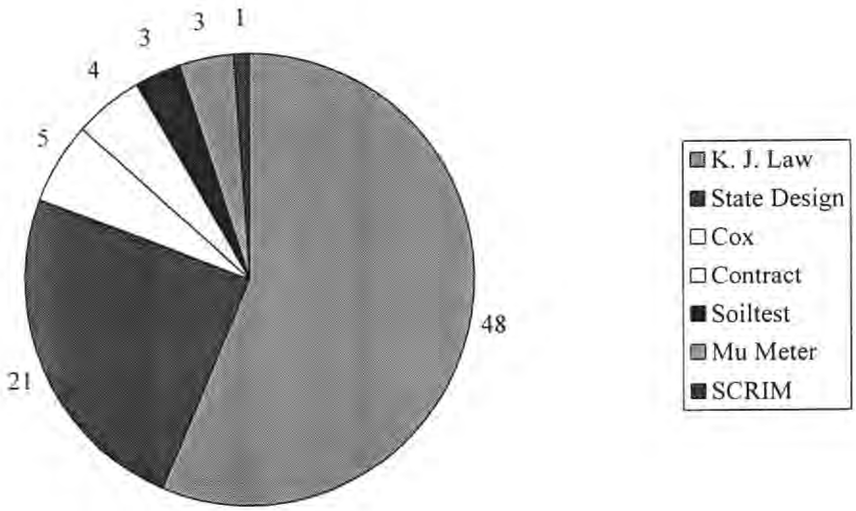

Figure 3. Manufacturers of friction testers being used (Gramling 1994).

The left wheelpath is generally considered the most critical because it receives more passes due to vehicles switching lanes. As a result, the left wheelpath is preferred when measuring pavement friction. As with other types of collected data, friction testing is typically conducted only in the outside lane on four-lane roadways. On two-lane roadways, however, it is more common to test both directions (in contrast to the collection of distress or roughness data, which is collected in only one direction).

Calibration and correlation of friction testing equipment is required to ensure accurate and consistent results. Most agencies reported the use of calibration methods with force plates employing air bearings, ball bearings, or other devices (Gramling 1994). Other means of calibration include the use of torque devices and selected test surfaces. Regional test centers are available for correcting equipment, and an ASTM/ARML program provides similar service at the agency's site. Such corrective actions are usually conducted every 1 to 3 years.

Deflection Data Collection

Deflection data are collected to measure the structural or load-carrying capacity of the pavement. Three types of equipment are available to measure pavement surface deflections (with examples of each provided in parentheses):

- Benkelman beam (California Deflectometer and La Croix Deflectograph).
- Falling weight deflectometer (Dynatest, KUAB, and Phoenix FWD).
- Vibratory load (Road Rater and Dynaflect).

Table 3 presents a summary of the type of equipment being used, as reported from a survey of 60 highway agencies in the United States and Canada (Gramling 1994). The most common type of equipment being used is the falling weight deflectometer (FWD). A strong shift toward the use of the FWD is observed in comparison to a previous survey conducted in 1986 (Epps and Monismith 1986). The FWD equipment contains rather complex instrumentation, which requires a well-trained operator and periodic calibration. Many of the devices contain built-in calibration procedures and external sensor-check procedures.

Table 3. Types of deflection data equipment being used (Gramling 1994).

Type of Equipment	No. of Agencies*	No. of Units
Dynatest	20	39
KUAB	4	4
Phoenix	1	1
FWD (type not specified)	9	10
Dynaflect	18	30
Lane Wells – Geolog	2	5
Road Rater	5	7
Benkelman Beam	7	26

* Some agencies own more than one type of equipment.

The collection of deflection data is not as widespread as other data collection efforts. Only 15 agencies reported that deflection testing is conducted at the network level, whereas 48 agencies conduct testing at the project level (the reported data include 13 agencies that do both) (Gramling 1994). Testing is typically conducted at uniform intervals throughout the project or network; a practice employed in 90 percent of the agencies.

Agencies reported a variety of uses of the deflection data (Gramling 1994). Of 60 agencies reporting, 42 agencies use the data for design purposes, and 2 other agencies are planning to do the same. Nine agencies use the data to assist in establishing seasonal loads, and the same number use the data to set load limits. Joint load transfer data are used by eight agencies for rehabilitation planning.

Strategic Highway Research Program

Another area of research that has application to this study is the work initiated as part of the Strategic Highway Research Program's Long-Term Pavement Performance (SHRP LTPP) study (and continuing as part of the FHWA's LTPP efforts). The LTPP program has considered standardization issues for FWD, roughness, distress, and videologging using the PASCO equipment. Both published and unpublished reports document the falling weight deflectometer, profilometers, distress interpretation from film logs, and calibration procedures. Some of the relevant reports include the following:

- *Comparison of the SHRP Profilometers* (SHRP-P-639) compares pavement profile data collected by four profilometers used by SHRP's LTPP. The purpose of the comparison is to determine if the profilometers can collect repeatable data with respect to each other as well as individually at a given site, and whether they are collecting accurate data (determined by comparing the IRI computed from profilometer data with that computed from Dipstick data).

- *Manual for Profile Measurement: Operational Field Guidelines* (SHRP-P-378) describes procedures to be followed when measuring pavement profiles for the LTPP program using the K.J. Law Profilometer, Face Technologies Dipstick, and the rod and level. Field testing procedures, data collection procedures, calibration of equipment, record keeping, and maintenance of equipment for each of the profiling methods are described.

- *Falling Weight Deflectometer Relative Calibration Analysis* (SHRP-P-652) describes the SHRP FWD testing procedures. These procedures require that FWDs be calibrated on a regular basis. One aspect of this requirement is monthly relative calibration of the FWD deflection measuring system. The FWDCAL software documented in this report was developed to perform these analyses.

- *Manual for FWD Testing in the Long-Term Pavement Performance Program* (SHRP-P-661) documents the procedures to be followed in the conduct of the LTPP deflection testing. It provides detailed testing programs for tests within each of the LTPP experiments developed to date, as well as field quality assurance and data handling guidelines. In addition, the SHRP FWD Calibration Protocol provides the first generally applicable, independent procedure for verifying and refining calibration of FWDs.

SURVEY OF STATE PRACTICES

As part of the effort to identify the best practices in roadway data collection, knowledgeable engineers from other highway agencies were interviewed about their Department's activities. The interviews were conducted informally, both in person and over the telephone, following no set form.

The individuals contacted for information are shown in table 4. It should be noted that these individuals are not necessarily the person in charge of the data collection effort or the pavement management activities of their respective agencies. However, they are acknowledged to be very familiar with the issues associated with roadway data collection in general, and the processes as conducted within their agency in particular.

Table 4. Contacts for survey of other agencies' practices.

Contact	**Agency**	**Position**	**Telephone No.**
G. Norman Clark	Kansas Department of Transportation	Geotechnical Engineer (including PMS)	(913) 296-3008
Larry Scofield	Arizona Department of Transportation	Director—Arizona Transportation Research Center	(602) 407-2620
Tim Horner, Brad Wentz, and others	North Dakota Department of Transportation	Pavement Management Engineer	(701) 328-4406
Newt Jackson	Washington State Department of Transportation (retired)	Former State Pavement and Soils Engineer	(360) 923-9359
Gaylord Cumberledge	Pennsylvania Department of Transportation	Chief, Roadway Management	(717) 787-1199
Steve Sissel	Nebraska Department of Roads	Staff Engineer	(402) 479-4317
Matt Turo	Massachusetts Highway Department	Director of Technical Services	(617) 973-7266

For selected roadway data collection activities, questions such as the following were asked of the interviewees.

- What equipment is used?
- What types of crews (e.g., full-time, part-time)?
- How often are the data collected?
- Describe the data validation and verification procedures.

The results of these interviews are summarized by agency and by distress type.

Arizona Department of Transportation (ADOT)

Distress Survey

The distress survey is done manually by a full-time crew. The survey is conducted over 30 m (100 ft) of one lane, at the milepost marker of every mile. This survey is performed annually over their pavement network. The survey is done using their own survey procedure, which includes a rating scale for the pavements of 1 - 3 - 5 - 7 - 9.

Deflection Testing

The Dynatest 8000 Falling Weight Deflectometer is used for design and rehabilitation projects; no deflection testing takes place at the network level. Larry wasn't sure about the testing, but believes that there are about 3 tests/km (5 tests/mi) unless circumstances require more intensive testing.

Friction

Skid resistance data are collected with a Mu Meter. Tests are run either over 42 or 150 m (140 or 500 ft). The Department's goal is to collect data annually over the entire network, but this probably doesn't happen.

Roughness

ADOT uses a K.J. Law 690, and annually tests 100 percent of the network. The resulting value is appended to the starting milepost. An IRI is calculated by planners, but Larry wasn't sure how they came up with it. Arizona is also using the K.J. Law equipment to report a Mays number, because there already exists a substantial amount of historical Mays data.

Rutting

Rutting used to be measured every mile as part of the distress survey. It should be part of the K.J. Law data collection effort, but is not.

Regarding the accuracy of roadway data within ADOT, no special steps appear to be taken. The PMS database has an as-built inventory, but no one checks it. There is very little data validation or verification; what does occur is usually done by those who are collecting the data. There will be a study of the effect of ADOT's new smoothness specifications on the IRI.

Nebraska Department of Roads

Responses were provided by Steven Sissel, who had been on the job for 3 months. He was very knowledgeable about the Department's activities, however, and where he was not sure of an answer he was able to solicit input from others in his group.

Nebraska has five full-time equivalents (FTEs) that are involved in roadway data collection. They go through many of the same processes as South Dakota, as they are involved in data collection and putting together the inventory, the 1-year plan, and the 5-year plan. There is a Needs group that takes care of the real PMS.

Roughness

Nebraska uses a laser profiler bar mounted on a van. This equipment is 1 year old; before that they used the South Dakota profiler. They survey their interstate pavements, bituminous pavements, and AC pavements annually, collecting readings every tenth of a mile. The data are processed on board, but verified upon data entry. There is an informal calibration of the data daily and a thorough calibration annually.

Distress

Distress data are collected in a visual survey. They run their bituminous pavements and the interstate system annually, and the PCC pavements every other year. This same crew of FTEs does the survey. They are assigned to different Districts, but try to get back on the same pavements every other year. Their survey procedure is a modified SHRP procedure. For each distress they identify its presence, severity (light, moderate, high, and X), and extent (occasional, frequent, and continuous). Some of the distresses they count are:

- Alligator cracking.
- Transverse cracking.
- D-cracking.
- Edge cracking.
- Wheelpath distress.
- Between wheelpath distress.
- Faulting.
- Popouts.
- Patching.

The shoulder is given a rating from 1 to 10. Drainage problems are rated as Yes or No.

AC pavement is rated by driving over the entire mile and giving it a rating; for PCC, ten panels at the start of the MP are examined, faulting is measured, and the entire mile is driven to see if the initial section is representative of the entire section.

The raters receive some training and do some internal informal calibration. Everyone else has been on the group for over 10 years, and they tend to look at pavement conditions the same way. For verification, they'll go out and check their findings perhaps a month later.

Rutting

Rutting measures are obtained by the profiler.

Photolog

Nebraska has photolog equipment, but it is not used by the data collection staff. This equipment is under Dan Bruegman, and Dennis Baumfalk provided information on its characteristics and use. Nebraska uses the Mandli analog system, collecting data on disks that can then be read at monitors. It is used for the following purposes: accident records, intersections, design, legal, bridge maintenance, and so on. Each District has a monitor, and there are four workstations in the central complex.

Friction

There is one person who operates this equipment. Steven thought that this data is collected every 3 years over the network.

Deflections

Deflection data are not collected or stored by this group, as the use of the FWD is not considered a part of pavement management. It is part of Materials and Testing, under George Woolstrum (479-4791).

Pennsylvania Department of Transportation (PennDOT)

Pennsylvania is changing its practices as of 1997. The information presented here reflects both past practice and the new procedures that will be implemented.

Distress

Through 1996, the pavement distress survey was performed manually. PennDOT employed 200 students every summer and they surveyed 100 percent of the NHS and 50 percent of the non-NHS every year. Some of the students held the job for more than 1 year, but it was not an explicit goal of the Department.

Prior to starting the surveys, all survey staff went through a centrally run training program. This was followed by field training, which was performed by the Districts. Surveys are run by each of the Districts; the surveyors are on their own, but there is a supervisor on the District's staff.

The survey is similar to an LTPP distress survey, although it is somewhat modified to meet the constraints of a large-scale data collection effort. The surveyors collect their data either walking or driving along the shoulder. Two calls are made on severity (low and high) and the extent is rated 0 to 5 percent, 5 to 30 percent, and above 30 percent.

There are two quality assurance programs in this system. The first is a 5 percent random sample that is surveyed by staff from the central office. This survey helps the Department to verify accuracy, to identify the need for any changes in the procedure, and to coordinate the calls made by the different Districts. The second program is a comparison of all of the data with last year's data. With the exception of overlaid sections, this check examines whether or not the data trends are headed in the right direction (i.e., pavement conditions should worsen over time/trafic). This type of verification is possible because distress data are entered in the mainframe computer no later than 2 weeks after the pavement is surveyed.

In 1997 PennDOT is switching to a video distress survey using the ARAN. They intend to maintain the same level and frequency of data collection, but will change the distress definitions slightly to accommodate the equipment's capabilities. Specifically for AC surfaces, they have defined as edge deterioration any cracking within 0.3 m (1 ft) of the pavement edge, fatigue cracking is any cracking in the wheelpath, and miscellaneous cracking is any cracking between the wheelpaths. For quality assurance of the ARAN data, Roadware has been asked to submit their own QA plan. PennDOT will also perform its own checks.

Deflection

Deflection data are collected at a project level. PennDOT uses full-time staff to operate their KUAB, and typical functions include obtaining data for overlay design, void detection, and measuring joint efficiency. PennDOT has a SHRP calibration site and it is believed that the equipment is calibrated no more than two or three times a year.

Faulting

Faulting data have been collected manually in the past. They will not be collected with the ARAN.

Roughness

The collection of roughness data, like distress, is undergoing a change. In the past PennDOT used the SD Profiler. They owned four such vans; two equipped with ultrasonic sensors and two with lasers. The roughness survey was performed with the same frequency and over the same range of pavements as the distress survey. PennDOT maintained eight sites that were controlled with a dipstick in order to calibrate the profilers. The equipment ran over a control site weekly. They are now switching to using the ARAN to collect roughness data.

Rutting

Rutting data have been collected with both a visual assessment and using the 3-point sensors. However, the database only had a means of including the visual assessment and most of the data was collected with the sensors, so the database has not been kept up to date. Rutting will now be collected with the ARAN.

Friction

PennDOT has three ICC skid trailers. They run a wet weather accident program, test on the NHS, and perform skid testing by special request. They now rate the skid resistance level for all of their aggregates based on petrography and other lab evaluations and don't feel there is as much need to do extensive field testing.

Geometrics

Some geometric data (grade, curvature, and cross-slope) will be collected with the ARAN vehicle. The ARAN is also providing GPS data. Guardrail status is being obtained with two extra cameras, and PennDOT is especially interested in looking at the end treatments.

Massachusetts Highway Department (MHD)

Distress, Roughness, and Rutting are all collected with their ARAN vehicle.

Distress

The ARAN operator keys in distresses based on the MHD's own distress manual. Distresses have three extents and three severities. Most of their pavements (all except for about 16 centerline kilometers [10 mi]) are AC surfaced. MHD looks at longitudinal and transverse cracking and alligator cracking, primarily. Longitudinal cracking in the wheelpath is rated as low alligator cracking. The Department has moved away from looking at block cracking because it's hard to transition from the other types into block.

PCC pavements are actually not rated except for rideability. The limited number of miles of PCC pavement are ridden over often enough that the MHD knows their condition.

MHD's system consists of about 17,700 centerline kilometers (11,000 mi). Of these, 2,900 kilometers (1,800 mi) are in the NHS and about 2,400 km (1,500 mi) more are State-maintained. The Department surveys about one-third of their network each year. They could rate the entire system annually but their experience is that they shouldn't see much change that quickly. They end up surveying about 9,600 to 12,800 lane km/year (6,000 to 8,000 lane mi) with a dedicated staff of 4 to 5 people.

For validation of the survey, they print out the results and manually resurvey about 10 to 15 percent of the network as a check. The District Office also provides feedback when they find a discrepancy between what the report says and what they think are the actual conditions.

Rutting

Rutting is measured from the ARAN, using a 42-sensor rut bar. They are not measuring true rutting but reporting the deepest rut.

Roughness

Roughness is measured with the ARAN. The equipment generates an IRI, pavement condition index (PCI), and rideability index (RI) from the results. The Department also has a Present Serviceability Index (PSI), which is a function of both the PCI and the RI. If the PCI < RI, then PSI = PCI. Otherwise, if PCI > RI, PSI = RI.

The MHD is in the process of establishing a Correlation Center for road roughness, which will have 9 or 10 sites with different degrees of roughness. This will be used by different states in Region 1 to calibrate their roughness output. Currently, calibration of the ARAN roughness output is done over up to 10 sections that are checked with a FACE dipstick.

Friction

They have a K.J. Law locked wheel skid trailer and perform skid testing according to ASTM 274. However, it is not currently working. Their best means of identifying poor skid resistance is to find areas of surface flushing.

The skid testing program used to be active. All pavements with a posted speed limit greater than 40 mph were evaluated, along with the 25 highest accident areas, all experimental pavements, and some new pavements (for which they would expect to find values of high 40s to low 50s). They then moved to an as-needed or on call testing program and will go back to that when their equipment is operational again.

Calibration has been performed at the Ohio calibration center. After calibration they rerun some sections near headquarters and check the results. They do one major calibration of their equipment at the beginning of the season and a few minor ones throughout the season.

Washington State Department of Transportation (WSDOT)

Distress

Washington actually first set up the survey procedure that they use in 1965, and all other condition surveys have evolved from it. The condition survey is based on distress extent and severity. In the past, the Department just used a guide that they put together themselves; now they print a real distress guide that is used not only by the DOT, but also by cities and counties in the State. Both the distresses and the processes for collecting them are well defined.

The distress survey is conducted during March, April, and sometimes part of May by four two-person teams. These crews will always include one person who has done the survey at least the year before. In the past the crews typically included people with 5 to 8 years of experience.

A survey section is defined as a pavement with uniform characteristics (e.g., cross section, traffic, and performance). The survey of the section is conducted from the shoulder at 8 km/hr (5 mph), with values reported for that section (they used to do 61 m (200 ft)/section, getting out of the vehicle, but found this was not really working in practice). The entire network of 12,800 directional km (8000 mi) is surveyed annually. The cost is somewhere between $5 and $5.60 per km per year ($8 and $9 per mile). The output is a paper system, and they can carry last year's survey with them for the purpose of comparison.

Washington spends about 1 week of training to "normalize" the trainers. As part of this process, the trainees go out and rate, calibrate, and re-rate until the crews are all doing it right. For additional validation, a sample of about 2 to 5 percent is pulled for survey and comparison with the typical surveys. There is a secondary type of validation provided by the Districts. Districts are encouraged to ride with the survey team when in their area. Districts also review the data and can provide feedback for corrections. This keeps the Districts from doing their own surveys. It was noted that when the network was surveyed every 2 years the Districts did go out and collect their own condition data, but with the survey performed annually they have been satisfied with the results. With this approach, there is no hand measurement of rutting or faulting.

Roughness

WSDOT uses a South Dakota Profiler to measure roughness. The network is surveyed on a 2-year cycle. Ride is checked against panels of known roughness. The equipment is operated by full-time staff.

Rutting

Rut data are also collected by the SD Profiler's three-point rut bar.

Friction

WSDOT uses a locked wheel skid trailer and ribbed tires. The pavement network is surveyed on a 2-year cycle, and the equipment is calibrated in Texas every 3 years. While the equipment operator is a full-time Department employee, the survey only takes about 2 to 3 months per year. This allows the crew to work on other things.

Deflections

A Dynatest 8000 is used to collect deflection data. It is part of Pavement Design and not Pavement Management. The FWD is used exclusively for project-level activities.

Geometric Data

There is no formal process of verifying geometric data. This information is carried by Planning and is available to the staff collecting field data. The field staff try to catch anomalies in the field.

Kansas Department of Transportation

Distress Data

Kansas performs a 100 percent survey of approximately 16,000 2-lane km (10,000 mi). Full-time staff perform this survey, but the staff are borrowed from Materials and Research. On divided highways they do both directions, but on two-lane highways they will survey only one direction. The survey is performed on 57 m/km (300 ft/mi): they look at 3 30-m (100 ft) sections per 1.6 km (1 mi). The survey is done from their profiler, with which they gather rutting, faulting, and profile data. A manual survey is performed for transverse and fatigue cracking. The Department also currently gathers block cracking information, but do not look at it. For PCC pavements, they do a manual survey to look at joint distress and especially D-cracking. The Department tries to check up on the survey, but this effort is variable. They still go out at random and check. The raters go through a training every year, even when they are doing the survey year after year.

Summary statistics are published and the appropriate data are also entered into their PMS. The Department puts out a performance level of 1, 2, and 3, for their pavement sections that combines the performance measures. Roughness controls the rating.

Norman did not believe that data are collected by others, with the possible exception that at the maintenance level some distress information may be collected for crack sealing. However, even in this case the need for crack sealing comes from PMS data.

As a result of the survey, about 1,900 to 2,400 km/year (1,200 to 1,500 mi) are scheduled for rehabilitation; the rest receive maintenance.

There is a manual that describes how to rate distresses and how to operate the equipment.

Friction

Skid information is collected by research but it is sensitive data. The equipment is likely a KJ Law device, and it is operated by a dedicated staff. They are on a 2-year cycle, and they try to do some percentage of each project. The skid data are not used in PMS.

Roughness

Kansas has an International Cybernetics Profilometer. They started with a Mays meter, progressed to the International Cybernetics with acoustic sensors, and now have laser sensors replacing the acoustic ones (they had problems with moisture and the results were not repeatable).

The survey is performed from March to June and 100 percent of their network is surveyed. Two people run the profile equipment and another pair does the distress survey. They have four vans, two of which are assigned to profile and two of which do the distress survey.

North Dakota Department of Transportation

Distress Data

North Dakota performs an annual distress survey, but whereas in the past they surveyed 13,500 km (8,400 mi); now it's over about 4,700 km (2,900 mi). Their focus is over the National Highway System (NHS) and heavily loaded pavements. They use the Pathways Road Profiler van, which has four cameras to film the pavement and also reads the profile. The video is viewed to rate the pavement and the rating is done by three full-time staff and some part-time employees.

Distresses are scored on the first 150 m (500 ft) of each 1.6 km (1 mi). The extent and severity of each distress are rated. The distress starts at 99 and is downgraded from there. The product of this evaluation is an overall index for the pavement.

The distress surveys start after construction and run through May or April. Sometimes work stops in January or February due to weather.

The van is also used to measure faulting, using laser sensors. HPMS data are pulled out of the distress survey.

For quality control, test sections are run every week to check the sensors. The users of the data also check the output and will provide feedback.

The information gathered in the distress survey is summarized in an annual report. The distresses are also used in their PMS.

Others are involved in distress data collection. For example, the Districts collect their own distress data, and Materials and Research also performs their own more detailed surveys for specialized purposes.

Friction

The friction survey is contracted out to a private company. Every 2 years a portion of the network is surveyed. However, this information is not released. With their profiler they do get something called a texture report. This is an area where they would like to work with South Dakota.

Roughness

Roughness is collected with their Pathways vehicle. It produces an IRI in English and metric units. The output is converted to a Ride Index using Minnesota's value. A weekly check is run on standard sections.

Rutting

Rutting is measured with the profilometer, using a three-point laser bar. The measurement is taken over the entire mile. The report can be broken down into smaller sections if desired.

Video

Their video equipment collects distress data. The tapes are also reviewed for safety, signs, right of way, and so on. They believed that they are the first users of a Pathways vehicle. It is developed by Rudy Blanco, who can be reached at (405) 366-7135.

FWD

Materials and Research collects deflection data for design. The data are collected on a project by project basis. The FWD goes out on upcoming projects to determine special details. The type of equipment used was not specified.

Geometrics

The Department can check geometric data with their video equipment. Geometrics are usually verified as part of a site visit, however. Districts are responsible for entering geometric data upon completion of the project. The Districts spend a lot of the winter making as-builts; they feel that the data are now accurate because of this.

Traffic

Traffic comes from the data collection section and from the data analysis section. They have two portable WIM and 24 sites that they do statewide per year. They have one or two piezos and one bending plate that works very well. They are making a big push statewide for classification.

The Districts used to collect data so that they would know what was going on, but do not anymore. Recently, State auditors did a survey of users of pavement data. Most said that the data were reliable. The most questionable were rutting and faulting. This group came up with their own action plan to improve data collection efforts.

Summary of State Surveys

The information obtained from the interviews with State highway personnel is summarized by data type in tables 5 through 9. These tables summarize the States' practices for collection of distress data, rutting data, roughness data, friction data, and deflection data, respectively.

Table 5. Summary of State practices for collection of distress data.

State	Method	Comments
Arizona	Visual	Developed their own rating system 100 ft surveyed at every milepost Surveyed annually
Nebraska	Visual	Use a modified SHRP procedure AC pavements surveyed every year PCC pavements surveyed every 2 years
Pennsylvania	Visual (switching to ARAN in 1997)	Surveyed annually or biannually Similar to LTPP distress survey Severity rated as low or high Extent broken into three categories Have training and quality assurance programs
Massachusetts	ARAN	Survey 1/3 each year Measure extent and severity for AC pavements Only measure rideability on PCC pavements Manually survey for validation
Washington	Visual	Surveyed annually Have developed a distress guide Have training and validation programs
Kansas	Visual	Survey three 100-ft sections per mile Have a yearly training program Have distress manual
North Dakota	Pathways Road Profiler	Surveyed annually Survey 500 ft within each mile Rate extent and severity

Table 6. Summary of State practices for collection of rutting data.

State	Method	Comments
Arizona	Manual	Measured every mile
Nebraska	Laser profiler	Surveyed annually Collect readings every tenth mile Thorough calibration collected annually
Pennsylvania	Manual and 3-point sensors (switching to ARAN)	Surveyed annually or biannually
Massachusetts	ARAN	Uses 42-sensor rut bar
Washington	South Dakota Profiler	Uses 3-point rut bar Surveyed every 2 years
Kansas	Profiler	Surveyed annually
North Dakota	Pathways Road Profiler	Uses a 3-point laser bar Surveyed annually

Table 7. Summary of State practices for collection of roughness data.

State	Method	Comments
Arizona	K. J. Law 690	Survey 100 percent annually Determine IRI and Mays number
Nebraska	Laser profiler on van (previously used South Dakota Profiler)	Surveyed annually Collect readings every tenth mile Thorough calibration collected annually
Pennsylvania	South Dakota Profiler (switching to ARAN)	Surveyed annually or biannually Equipment validated weekly (8 sites)
Massachusetts	ARAN	Determine IRI, PCI, and RI Establishing a Correlation Center (10 sites)
Washington	South Dakota Profiler	Surveyed every two years
Kansas	International Cyber-netics Profilometer	Survey 100 percent annually
North Dakota	Pathways Road Profiler	Determine IRI and RI Equipment validated weekly

Table 8. Summary of State practices for collection of friction data.

State	Method	Comments
Arizona	Mu Meter	Collected annually over entire network Tests run over 140 or 500 ft
Nebraska	Not specified	Collected every 3 years
Pennsylvania	ICC skid trailer Petrography	Specialized testing only Rate skid level based on petrography
Massachusetts	K. J. Law locked wheel skid trailer	Test sections with speed limits greater than 40 mph Also test accident areas and experimental sites Perform calibration annually
Washington	Locked wheel skid trailer and ribbed tires	Surveyed every 2 years Equipment calibrated every 3 years
Kansas	K. J. Law	Surveyed every 2 years Not used for pavement management
North Dakota	Not specified	Survey is contracted out Information is not released

Table 9. Summary of State practices for collection of deflection data.

State	Method	Comments
Arizona	Dynatest 8000	No network level testing 5 tests per mile
Nebraska	None	Not used for pavement management
Pennsylvania	KUAB	Collected at project level Equipment calibrated 2 to 3 times a year
Washington	Dynatest 8000	Collected at project level
North Dakota	Not specified	Collected at project level

SUMMARY OF CURRENT PROTOCOLS

The following sections describe current protocols used in the collection of the specified roadway characteristics. This is not a complete examination of the practices of highway agencies, but rather a summary of prevalent measurement standards and protocols currently available.

Roughness from Profile

Table 10 provides a summary of current protocols for obtaining roughness from profile. Two protocols are summarized — the SHRP/FHWA protocol and the ASTM E950 protocol. A new protocol is currently being developed by the FHWA. The items of interest in these protocols include the following:

1. Equipment Type—the type of equipment specified or used in the protocol.
2. Calibration Procedures—the type of procedures used to calibrate the equipment.
3. Extent of Network Surveyed—extent of network surveyed using the roughness-measuring equipment.
4. Frequency of Surveys—time frequency in which the roughness measurements are conducted.
5. Lanes Surveyed—lanes in which roughness measurements are obtained.
6. Measurement Location—location on the road in which measurements are obtained (e.g., right wheelpath, left wheelpath, or both wheelpaths).
7. Section Survey Length—length of evaluation section.
8. Survey Speed—speed at which roughness measurements obtained.
9. Longitudinal Sampling Rate—frequency with which profile measurement is taken in the longitudinal direction.
10. Vertical Resolution—accuracy of the vertical profile measurements (static).
11. Roughness Unit—roughness unit in which surface profile expressed.
12. Filtering—filtering requirements to reduce profile attenuations/amplifications.
13. Data Storage—how the roughness data are stored.
14. Uses of Data—how the data are used or specified for use.

Table 10. Summary of protocols for pavement profile measurements.

Element	SHRP/FHWA	ASTM E 950
Equipment Type	K. J. Law 6600	Not Specified
Calibration Procedures	Acceleration: Bounce Test Displacement: 1 in block	Acceleration: internal Displacement: 1 in block Distance: compare to premeasured distance
Extent of Network Surveyed	Not Applicable	Not Specified
Frequency of Surveys	Annual	Not Specified
Lane(s) Surveyed	Test Lane (generally right lane)	Not Specified
Measurement Location	Both wheelpaths	One or both wheelpaths
Section Survey Length	500 ft	Not Specified
Survey Speed	55 mi/hr	Generally higher speeds; avoid speeds less than 15 mi/hr
Longitudinal Sampling Interval	1 in	Class 1: ≤ 1 in Class 2: $1< x \leq 6$ in Class 3: $6< x \leq 12$ in Class 4: > 12 in
Vertical Resolution	0.1 mm	Class 1: ≤ 0.1 mm Class 2: $0.1< x \leq 0.2$ mm Class 3: $0.2< x \leq 0.5$ mm Class 4: > 0.5 mm
Roughness Unit	IRI	Not Specified
Filtering	Internal	Must be provided to permit computation of measured profile with no amplification or attenuation of wavelengths at least 200 ft long at test speeds of 15 to 60 mi/hr
Data Storage	Personal Computer	Personal Computer
Use of Data	Monitor roughness of pavement section	1. Provide profile data. 2. Used to simulate outputs of other devices

FHWA has recently developed a "Roughness Protocol," which defines standard procedures for measuring longitudinal profile and calculating IRI. The purpose of such a protocol is to help produce consistent estimations of IRI for network level pavement management. The protocol was developed specifically for use on the National Highway System and should thus be used with caution on other roadways.

The FHWA protocol recommends measuring the roughness in both wheelpaths and calculating an IRI. The roughness is reported as the average of the two IRI values. The following additional guidance is also provided:

- Surveys should be conducted in the outside (travel) lane.
- Surveys should be conducted in one direction on undivided highways but in both directions on divided highways.
- The same direction of travel and the same lane should be surveyed for each survey cycle.
- The length of the data collection section should be between 100 and 1,000 m (330 and 3,300 ft).

The protocol also recommends an extensive quality assurance plan. The plan should include a certification and training program, maintenance and calibration of equipment, and periodic quality control.

Three-Point Rut Depth

There is an ASTM protocol for the measurement of rut depth in asphalt concrete pavements for manual measurements only. This protocol is summarized in table 11. Items of interest for the measurement of rut depth include:

1. Equipment Type and Technology—type of equipment and technology used for measuring rut depth.
2. Calibration—calibration procedures for ensuring accuracy of the rut depth measurements.
3. Frequency of Surveys—time frequency over which rut depth measurements are recorded.
4. Frequency of Measurements—spatial frequency of measurements along a project.
5. Measurement Location—transverse location across the pavement where rut depth measurements are obtained.
6. Section Survey Length—length of section over which rut depth measurements are recorded.
7. Production Rate—rate at which rut depth measurements are obtained.
8. Data Storage—method in which rut depth measurements are stored.
9. Uses of Data—how the data are used or specified for use.

Table 11. Summary of protocols for three-point rut depth measurements.

Element	ASTM E 1703
Equipment Type and Technology	Straightedge
Calibration	Trueness of Straightedge $\pm$0.005 in/ft
Frequency of Surveys	Not Specified
Frequency of Measurements	Not Specified
Measurement Location	Each wheelpath
Section Survey Length	Not Specified
Production Rate	Not Specified
Data Storage	Manual Recording
Uses of Data	Indication of pavement performance

A "Rut Depth Protocol" is currently being developed by the FHWA under an ongoing research contract. The protocol is being developed for the National Highway System but may be applicable to other roadways. As with the ASTM protocol, the FHWA method recommends a three-point method for estimating the rut depth.

The reported value is the average rut depth in both wheelpaths in relation to the height at the center of the lane. The overall average is computed and used to rate the rutting into one of four severity levels. Measurements should be taken at maximum intervals of 15 m (50 ft). The recommended guidelines with respect to testing locations (lanes and directions) are the same as the "Roughness Protocol." A quality assurance plan should be developed which includes a certification and training program, maintenance and calibration of equipment, and periodic quality control.

Pavement Distress Surveys

Table 12 provides a summary of current protocols for performing pavement distress surveys. Only two protocols were identified: the SHRP/FHWA protocol and the Corps of Engineers (COE)/American Public Works Association (APWA) protocol. The items of interest include the following:

1. Distress Manual—distress identification manual used in the protocol.
2. Distress Survey Method—whether the distress survey is conducted using automated means or manual methods.
3. Frequency of Survey—time frequency with which the distress surveys are conducted.
4. Section Length—length of section for conducting the distress survey.
5. Sampling Rate—proportion of the section length over which a distress survey is conducted.
6. Production Rate—rate at which distress surveys are conducted.
7. Data Storage—method in which distress survey results are stored.
8. Uses of Data—how the results of the distress surveys are used or specified for use.

Table 12. Summary of protocols for pavement distress surveys.

Element	SHRP/FHWA	COE/APWA
Distress Manual	SHRP/FHWA 1993	COE 1979
Survey Method	Automated/Manual	Manual
Frequency of Surveys	Annual	Not Specified
Section Length	500 ft	AC: 2500 ft^2 ± 1000 ft^2 PCC: 20 ± 8 slabs
Sampling Rate	100 percent	Network: 10% Project: 85-100%
Production Rate	Automated: 50-55 mi/hr Manual: 500-1000 ft/hr	Not Specified
Data Storage	Regional/National PC Databases	MicroPaver Database
Uses of Data	Distress Modeling	Pavement Modeling and Forecasting

Although the FHWA does not specifically have a protocol for distress surveys, four protocols incorporating distress measurements are under development:

- Cracking Protocol for Asphalt-Surfaced Pavements

- Cracking Protocol for Jointed Concrete Pavements
- Cracking Protocol for Continuously Reinforced Concrete Pavements
- Faulting Protocol

The cracking protocols are not restricted to transverse and longitudinal cracking. Other forms of cracking, such as fatigue cracking on AC pavements and spalling, durability cracking, and punchouts on PCC pavements, are also measured. For AC pavements, the length of distress for each severity level is recorded. For PCC pavements, distresses are defined by the number of slabs or joints for each severity level. Either automated or manual data collection surveys can be used with the cracking and faulting protocols. A quality assurance plan should be developed and should include a certification and training program, maintenance and calibration of equipment, and periodic quality control.

Falling Weight Deflection Testing

Table 13 summarizes two protocols for conducting falling weight deflectometer (FWD) deflection testing: SHRP/FHWA and ASTM D 4694/4695. Items of interest for this topic include:

1. Type of Equipment—type of equipment specified by the protocol.
2. Calibration—calibration procedures to ensure accuracy of measurements.
3. Intensity of Testing—spatial frequency of FWD testing within test section.
4. Test Section Length—length of test section over which FWD testing conducted.
5. AC and CRCP Testing Location—FWD testing locations on asphalt concrete and continuously reinforced concrete pavements.
6. JCP Testing Locations—FWD testing locations on jointed concrete pavements.
7. AC Sensor Configuration—horizontal distance from the load plate of the deflection-measuring sensors on an AC pavement.
8. PCC Sensor Configuration—horizontal distance from the load plate of the deflection-measuring sensors on a PCC pavement.
9. Load Sequence—target weights and sequences for FWD testing.
10. Data Storage—method in which the FWD data are stored.
11. Uses of Data—how the FWD data are used or specified for use.

Table 13. Summary of protocols for FWD deflection testing.

Element	SHRP/FHWA	ASTM D 4694/4695
Type of Equipment	Dynatest	Not Specified
Calibration	Absolute: Regional Calibration Centers Relative: Stacking Sensors	Load Device Sensor Relative Calibration Sensor Absolute Calibration
Intensity of Surveys		Level 1: 500–1500 ft (5–10 tests/section) Level 2: 100–500 ft (10–20 tests/section) Level 3: 10–100 ft (10–20 tests/section)
Test Section Length	500 ft	Not Specified
AC and CRCP Testing Locations	Outer wheelpath	Level 1: Outer wheelpath Level 2: Outer wheelpath Level 3: Outer or both wheelpaths
JCP Testing Locations	Slab centers and transverse joints	Level 1: Slab centers and joints at 5% of slabs tested Level 2: Slab centers and joints at 25% of slabs tested Level 3: Every slab and joint
AC Sensor Configuration	0, 8, 12,18, 24,36, 60 in	Not Specified
PCC Sensor Configuration	0, 8, 12, 18, 24, 36, 60 in	Not Specified
Load Sequence	12 kip, 9 kip, 12 kip, 16 kip (three drops at each level)	Not Specified
Data Storage	PC	Not Specified
Uses of Data	Backcalculation of Material Properties Load Transfer	Structural capacity of existing pavement for evaluation or overlay design

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5. South Dakota's Roadway Data Collection Practices

INTRODUCTION

Roadway data in South Dakota is used for many purposes. For example, selected data are used as inputs to pavement design and rehabilitation, to comply with Federal reporting requirements, and to identify sections of pavement that should have posted spring load limits. One very important use of roadway data is to generate the information that is used to develop the Statewide Transportation Improvement Plan (STIP), a list of highway projects for each year that is used to program projects and to plan construction for the upcoming year.

While roadway data collection within the Department is a very centralized effort, it is best characterized as a series of discrete data collection tasks that are organized and summarized in one location. This interpretation is appropriate because data collection is handled by different equipment and different staff, and each specific activity is, by definition, independent. However, viewing each element of roadway data independently ignores the interrelationships between the data collection efforts and the common needs of a disparate group of users.

In this project, while each component of the roadway data collection effort is evaluated independently, it is also considered as a complete process. This approach recognizes the interdependence of many of the data collection activities, as well as acknowledges the shared benefits and shortcomings of the process.

SDDOT ROADWAY DATA COLLECTION AS A PROCESS

This section looks at the data collection process. The objective of the process analysis is to assess SDDOT's overall roadway data collection program in terms of effectiveness, efficiency, resource requirements, and cost. At the present time there is no discrete data collection process that addresses all data items as a system.

Overview

The physical collection of roadway data is done within the Data Inventory office of the Division of Planning/Engineering, except for pavement distress data, which are collected by Planning and Programs. Most data collection efforts occur during the summer when the pavement surface is readily visible with the exception of traffic.

After collection, the data are input to the Roadway Environment System (RES) by the Data Inventory Office of Planning/Engineering; distress data are input by the Planning & Data Analysis office of Planning and Programs (also referred to as the Pavement Management section). Key portions of the roadway data are analyzed within the Department's pavement management system (PMS) and database (dROAD and dTIMS), from which various values, distress indices, types of work and priority numbers for each segment of the State Highway

System are computed. A comparison with historical data is part of the data processing, and values that are anomalous (such as improvements in pavement condition over time when no improvement projects have occurred) cause an error report to be issued. The Data Inventory office is responsible for resolving any identified discrepancies in the data.

The Data Analysis section produces an annual report that summarizes the condition of each roadway section and when that section is programmed for improvement. This report, formally titled *Highway Needs Analysis and Project Analysis Report for State Administered Highways*, is hereafter referred to as the *Needs* book. The *Needs* book is used by almost every office within the SDDOT, and this use is a secondary source of quality control: as users study the report's content and apply it in the performance of their jobs, additional quality control activities are initiated and updates to the RES file are made if warranted.

Timing

The start of data collection activities has largely been determined by weather conditions and the availability of seasonal labor, with the exception of traffic data collection, which takes place throughout the year. Figure 4 depicts the timing of data collection as it relates to the comprehensive Project Programming cycle. In the first step, roadway data collection generally starts in early May when weather conditions are predictable and seasonal help and interns are available following the school year. The Distress Data Collection effort is most affected by this constraint because it uses university students during their summer break and seasonal employees.

Starting in September, the collected data are keyed to the RES system from the different data collection processes. Each data type is collected by different devices and stored on a different medium. This process takes place over several months, and then during January the data from dROAD are loaded. The significant delay between when data is collected and when it is uploaded to the RES should be noted. One reason for this lag time is the manual processing that is necessary to convert the native format of the collected data items to a format that can be uploaded to the RES System. Another reason for the delay between data collection and data entry is that the data are entered and edited by the same staff that collects the data. This delay compounds the difficulties associated with performing an effective quality control check on the data at subsequent steps in the process.

Consider the three components of the data collection process shown in Figure 5. The first group is the data collectors, those who are in the field collecting data throughout the year. The second group is the data processors, those who receive data and either manually or automatically process that data for use by the end users. In the third group are the users of the data. The distinctions shown in Figure 5 suggest the existence of three distinct groups to match the distinct operations, but often data collectors and data processors are the same person. While there may be some benefit to this combination of functions, it can also contribute to delays (for example, data must be collected before they can be processed).

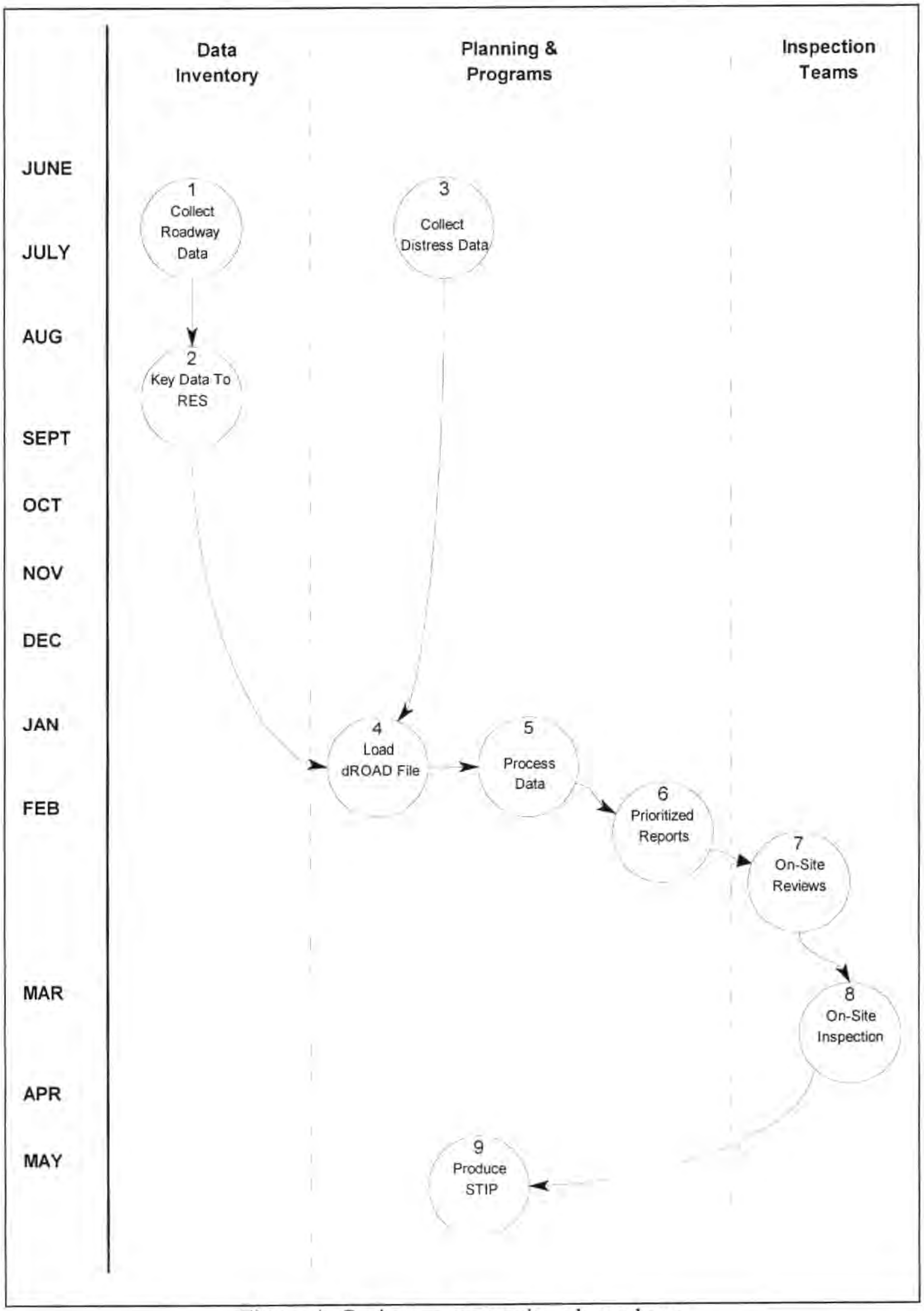

Figure 4. Project programming chronology.

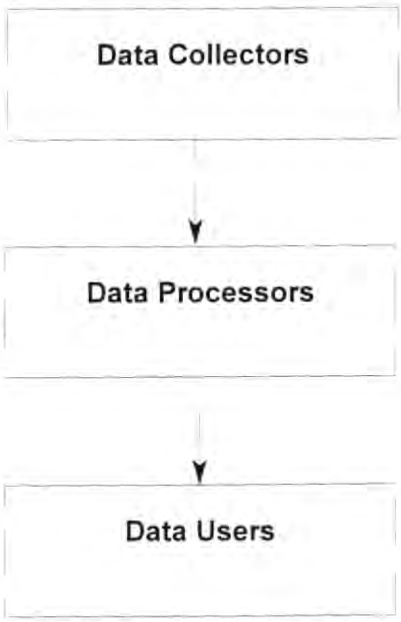

Figure 5. Components of the data collection process.

Also in January the data are analyzed to produce a hierarchy of needs for the State's highway system. Then, in early February "needs" reports are produced that help to focus Department review teams performing visual inspections of highway sites. February is also when management teams visit selected locations throughout the State to confirm needs and conditions as indicated in the computerized priority reports.

In March, management teams again inspect the physical locations to further qualify and quantify priorities for transportation construction activities. When the priorities for transportation projects have been confirmed, the State Highway Improvement Plan (STIP) is produced. This report outlines the South Dakota's proposed transportation improvement plan for the next 5 years.

Project Programming Cycle

As outlined above, the process of roadway data collection is the first step in what eventually becomes the STIP, although the data are also used in many other places. For example, HPMS and Surfacing use the roadway data, Operations uses roadway data as well as the overall condition rating, and the data are frequently accessed by the Division Director. Data Inventory and Research also have access to and use these data. Thus, the accuracy of the data is extremely important and serves as the foundation for the entire project programming process. The flowchart shown in Figure 6 depicts the project programming cycle that occurs every year.

The project programming cycle includes data collection activities, data processing, and data use. The overall interrelationship of these processes is shown in Figure 7.

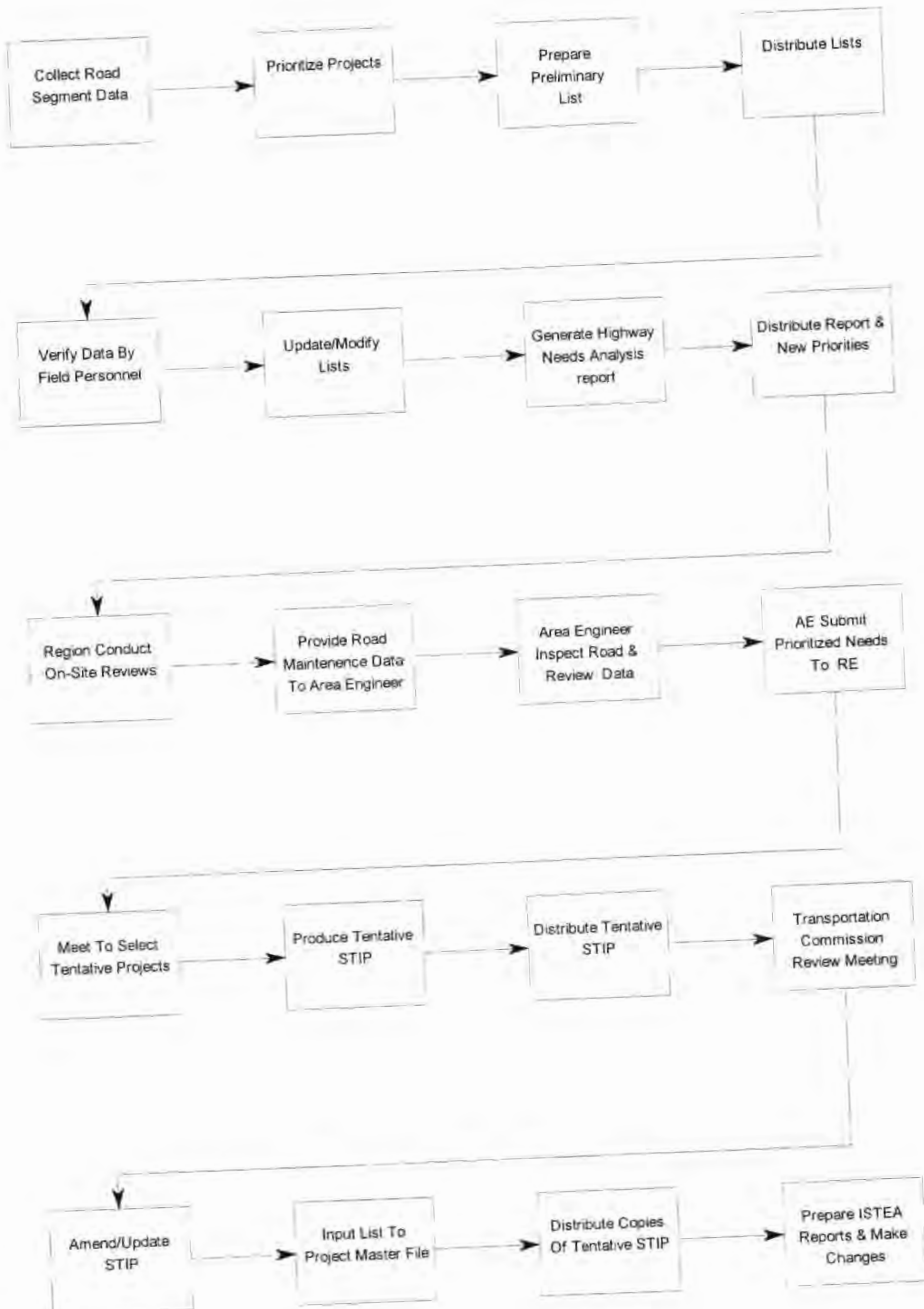

Figure 6. The project programming cycle.

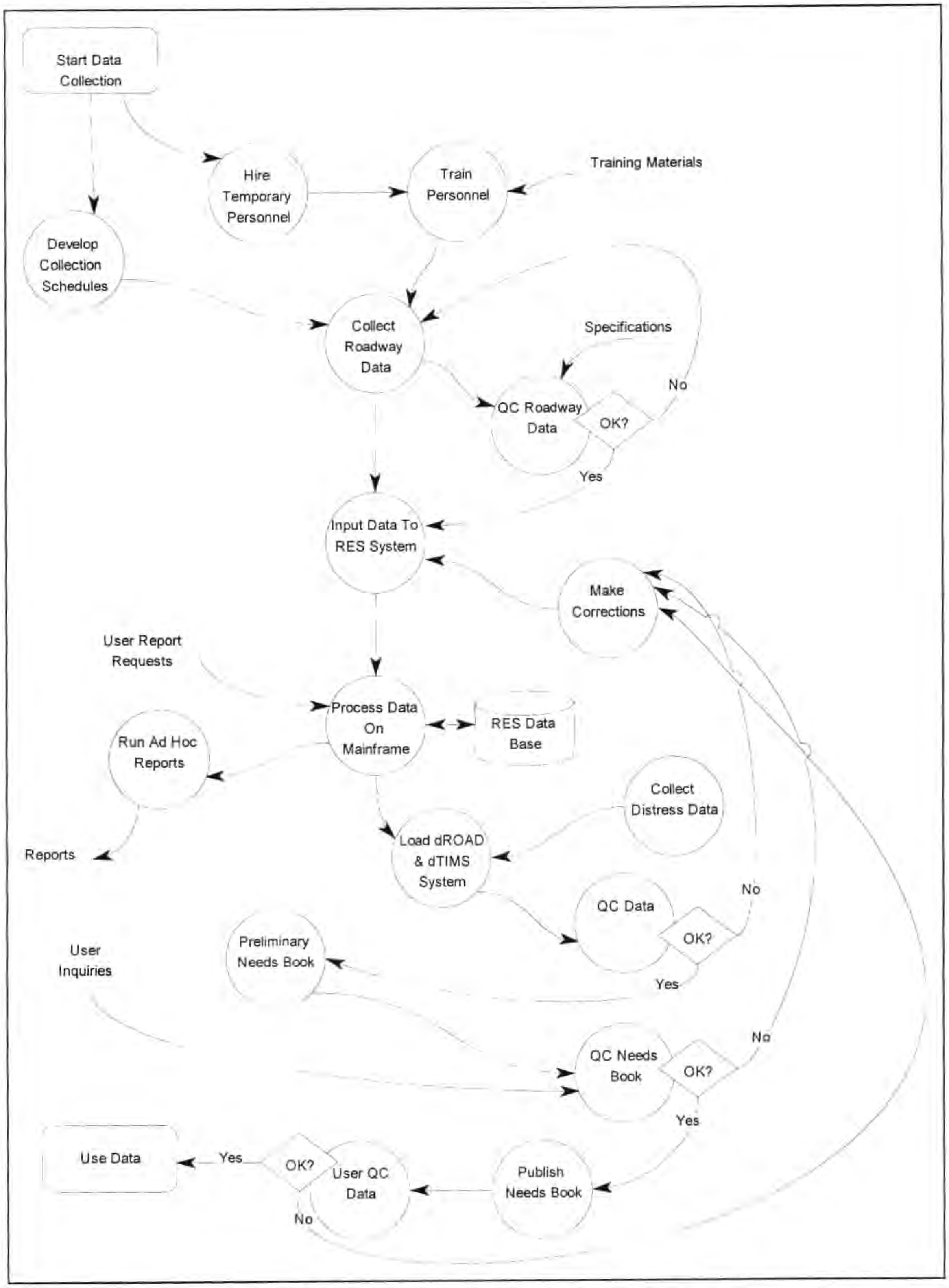

Figure 7. Current data collection process flow.

The *Needs* book is another major product of the data collection process and it is utilized throughout the Department. The process of creating and updating the *Needs* book is shown in Figure 8. Feedback about the performance of roads and perceived conflicts between actual pavement condition and the condition as reported in the *Needs* book typically come to the Pavement Management section. The Pavement Management section also maintains the Department's pavement management system (dROAD and dTIMS).

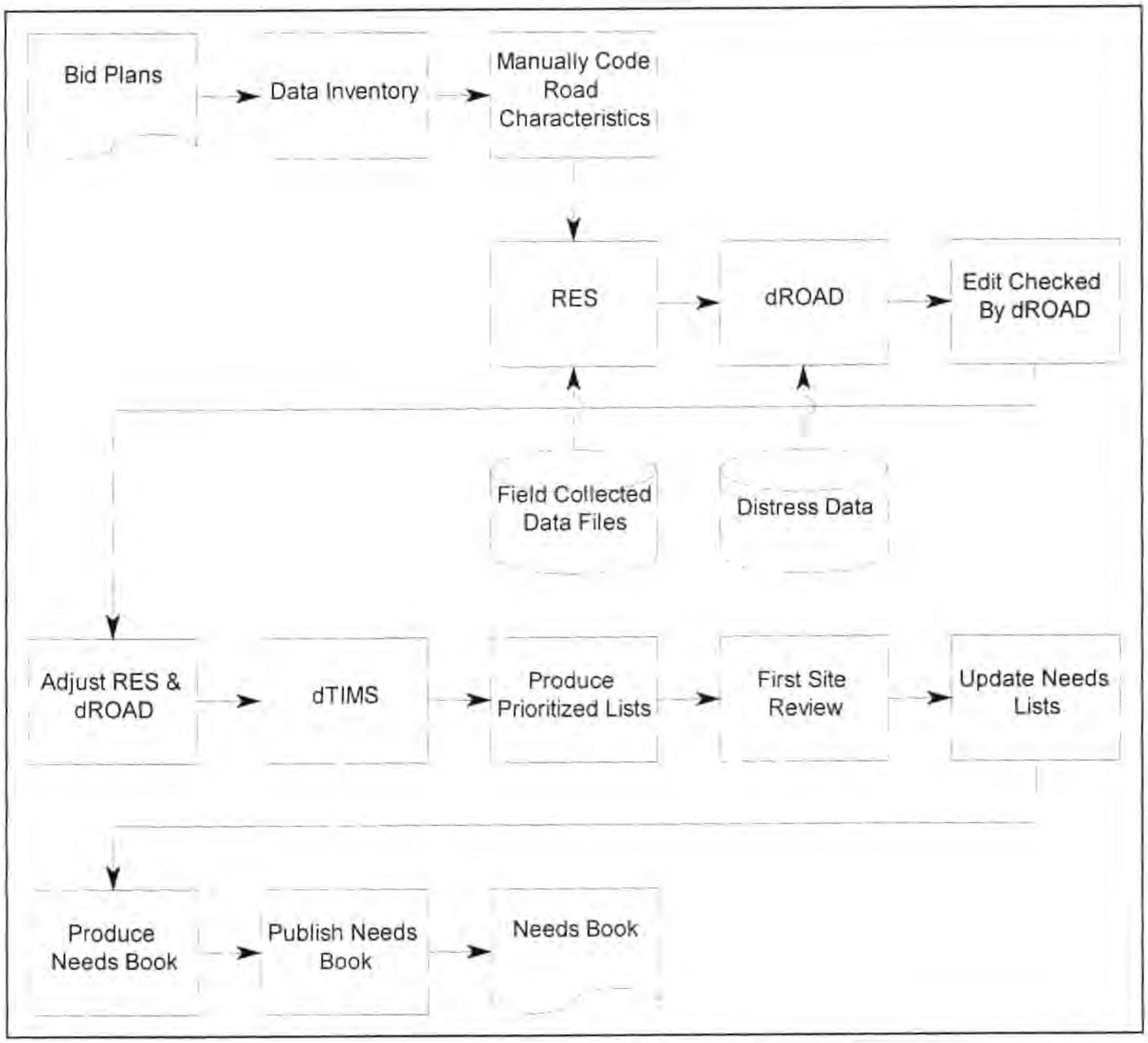

Figure 8. Processing and updating pavement data.

Roadway data are loaded into various computer programs for each type of roadway data for subsequent upload to the RES system. With many types of data this is a very long and tedious task, in which the data must be loaded floppy disk by floppy disk. RES data are passed on to the dROAD program; distress data are loaded directly into dROAD. Exception reports are kicked out of dROAD when edits are not passed. The Pavement Management section then manually researches inconsistencies and adjusts RES and dROAD systems.

Prioritized lists are generated to help schedule the first site visits by staff and management. The on-site visits provide insight that directs changes to the lists and an updated needs list is generated. The needs list is used to produce the Needs Book that is published and used throughout the Department. When projects are bid, the Office of Project Development sends plans to the Data Inventory section to adjust the RES data base. Actual updates are not done, however, until the projects are completed and signed off.

Information Services' role in this process is system development and maintenance of existing programs. One of the primary functions of this group is to get data into and out of the mainframe system. All roadway collected data types, except for Distress data, are fed into the RES system. Those data are processed by RES and are downloaded to dROAD. Distress data are loaded directly into dROAD. The data are then downloaded to an Informix data base for production of the Needs Book. The RES ALL-Data ADABAS file is a RES subfile that is used to generate ad hoc reports on request.

The goal within Information Services is to continue to expand the use of graphical information to include more data representation in the form of maps. This will continue to evolve as SDDOT moves toward Geographic Information Systems (GIS). The schematic shown in Figure 9 outlines the roadway data processing flow through the RES System.

Summary

The South Dakota roadway data collection and programming process begins in May/June with actual data collection activities, and concludes the following April/May with the development of the STIP. A variety of data are collected, and these are processed and analyzed to determine the condition and needs of the highway network. By examining the overall process, there are several opportunities to make this activity more efficient and effective. The process could begin earlier in the year if it were not dependent upon hiring summer interns after school ends in May. If data were processed while it was being collected, a long delay could be eliminated. An added benefit of this is that any errors could be identified and their cause pinpointed before a lot of effort had been expended. By the same token, earlier processing would also make it easier to improve the quality of the data. These ideas are discussed in greater detail in chapter 7.

SPECIFIC SDDOT DATA COLLECTION PRACTICES

This section describes the current data collection practice for each of the following data types:

- pavement distress
- traffic
- pavement friction
- roughness from profile
- rutting
- sufficiency rating
- videolog images
- falling weight deflections
- verification of vertical and horizontal curves and other geometric data

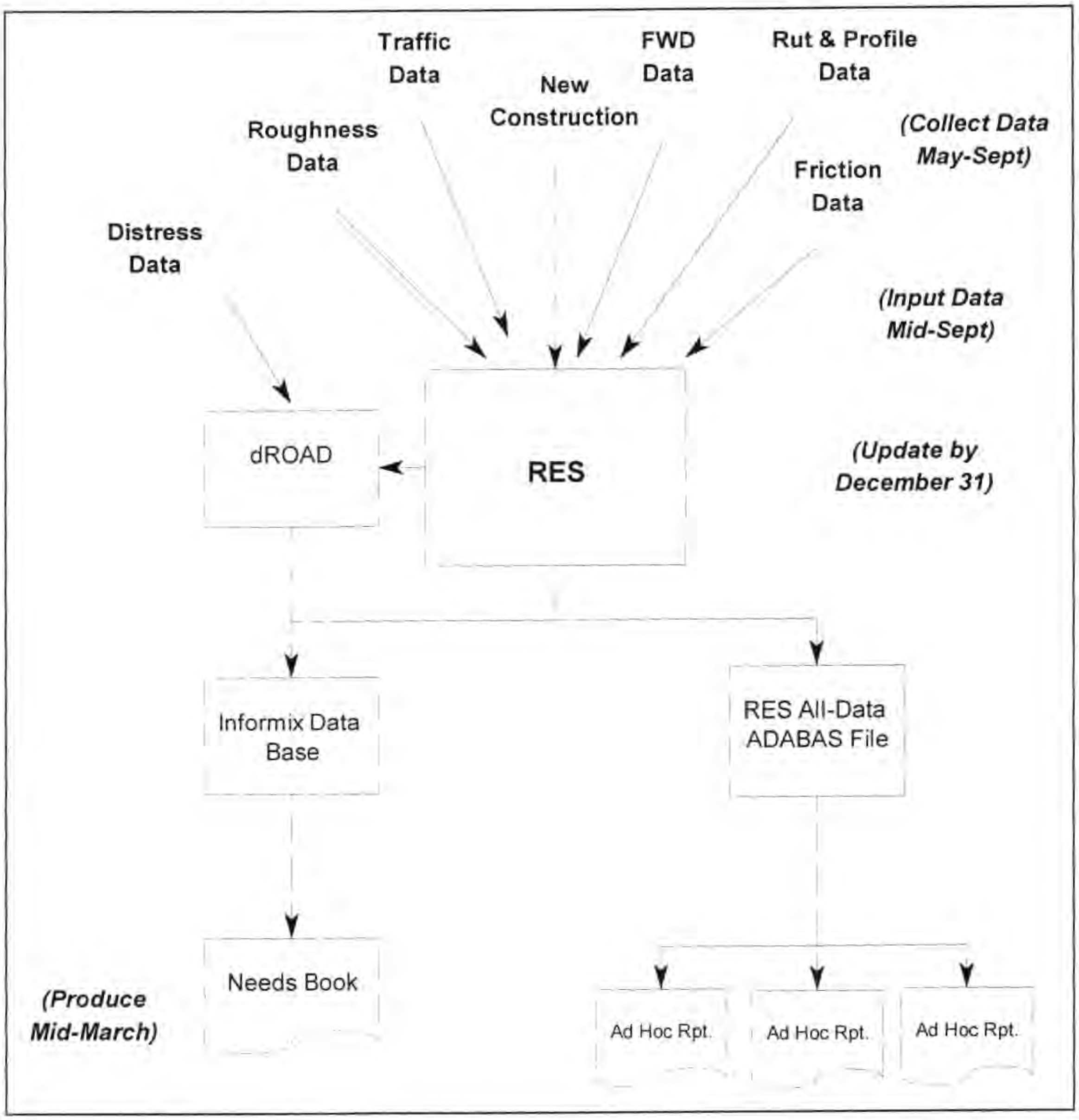

Figure 9. Flow of roadway data in and out of the RES.

Where appropriate and available, information is presented on the type of equipment, the crew size, how the data are collected, what types of data are produced, and where the data are stored. Feedback from users of the data is also provided.

Roadway Data Collection

Pavement Distress

The Pavement Management section of Planning and Programs collects, assembles, and reports pavement condition data. At the heart of the PMS is pavement distress data, so distress data collection is a primary responsibility of the Pavement Management section. Two people have full-time responsibility in this area, a third person works about 70 percent in pavement management, and a fourth is about at 30 percent. A manager spends about 10 percent of his time in this area as well.

Data Collection and Processing

Two two-person crews of seasonal employees perform the pavement distress survey. In the past 2 years these employees have been college interns, hired during the spring to travel around the State and collect pavement condition data. The interns receive 1 week of training and then do 1 week of surveys with an experienced staff member accompanying them before heading out on their own. About one day of the first week's training addresses safety issues, different distresses, and pavement types.

Permanent employees of Planning and Programs try to perform regular verifications of the quality of the collected data by going out with the survey crews, but they usually don't get out as often as they would like. Other work obligations, in conjunction with geographical constraints (it is just too far to drive to meet the survey crews easily once they leave the Pierre area), means that this quality control step does not always take place.

The distress calls are based on a modified SHRP distress identification definition; the primary modification is the elimination of distresses that don't apply in South Dakota. The distresses that are considered are shown in Table 14.

Table 14. Distresses noted in South Dakota's surveys.

Flexible Pavements	Rigid Pavements
Transverse Cracking	D-Cracking and ASR
Fatigue Cracking	Joint Spalling
Block Cracking	Corner Cracking
Rutting	Faulting
Roughness	Joint Seal Damage
Patching/	Roughness
Patch Deterioration	Punchouts

The observed distresses are keyed into an onboard laptop. This laptop is loaded with files that actually contain the results of the previous survey, so that the pavement rater can see what distresses, severities, and extents were recorded. The procedure's genesis, distress descriptions, and issues related to distress data collection are addressed in a draft *Visual Distress Survey Manual* and in the final *Enhancement of SDDOT's Pavement Management System (SD93-4-F)*. The distress survey process is shown in Figure 10.

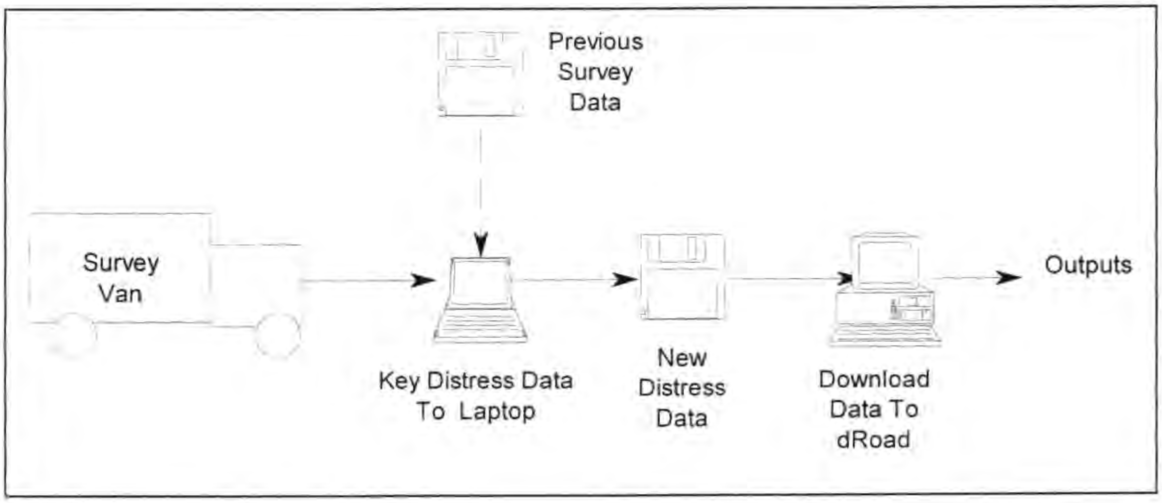

Figure 10. Distress data collection process.

The length of the survey section is about 0.4 km (0.25 mi). For PCC pavements, faulting is part of the survey and is measured on at least four joints in the right wheel path at every uniform mileage reference marker (MRM). Faulting is currently being measured with a Georgia Faultmeter, which measures faulting to a resolution of 0.03 mm (0.001 in); however, beginning in 1997 it will be measured using the ARAN® (Automatic Road Analyzer) vehicle.

The distress survey is conducted in a van that is driven along the shoulder at 13 to 25 km/h (8 to 15 mph). The van has a driver and a rater and they don't switch back and forth. However, the driver is trained to identify the distresses because occasionally there is no shoulder and the driver rates the pavement from the windshield view while driving over the section. A 100 percent visual survey is performed every year, and this level will be maintained on the interstate pavements. Roughness and rutting are reported as part of the survey, but are attached from the RES. The distress survey only loads into dROAD and does not go into the RES.

In the proposed new version of the *Needs* book, pavement distress data are all reported in the form of indexes. These indexes are on a 0 to 5 scale, with 5 being Excellent and 0 being Poor. The indexed values are computed by calculating the average measurement of interest for a particular pavement section and identifying the associated deduct (from a perfect score of 5.0). This process is described in greater detail in the new *Needs* book.

Distress Feedback

The results of the pavement distress survey are not well-suited to all potential users of this data. For most research projects, for example, specific performance information or particularly timely information is needed, which isn't available from a network-level survey. Similarly, the Regions need project-level summaries of cracking and other distresses on pavements that are scheduled for maintenance or rehabilitation. For this application the distress information should be current and the extent should be correct: if the results aren't timely they aren't of much use for their day-to-day purposes.

Another office, Local Government Assistance, raised questions about the subjectivity of temporary labor to collect certain distress data, but was not aware of any specific problems with these data.

Traffic

The Division of Planning/Engineering's Office of Data Inventory coordinates the traffic data collection effort, which includes vehicle volume counts, vehicle classifications, and axle loads. Traffic data are collected year-round by a full-time staff that includes six traffic technicians located in the Regions. The resultant traffic data are part of the RES, but are maintained by Data Inventory staff.

Data Collection and Processing

The State owns and operates 51 Automatic Traffic Recorder (ATR) sites from which data are fed back to Pierre by telemetry. The State also has short-term counters that are maintained by six traffic data technicians. The FHWA's *Traffic Monitoring Guide* and *HPMS Monitoring Guide* serve as the basis for the Department's traffic data collection activities. From these, the Data Inventory office has summarized its practices in its own documentation, *South Dakota Traffic Monitoring Documentation* (rev. 2/13/97).

Vehicle counts are obtained from over 6100 short-term count locations located around the State. A sampling plan for the counts is developed each year based on the functional classification of the pavement. The overall objective is to collect data at the following frequencies:

- Non-interstate HPMS sections every year.
- State trunk highway locations sampled every 2 years.
- Interstate HPMS sections every 3 years.
- Non-state trunk highways every 6 years.
- Roads in urban areas every 4 years.
- Small cities and towns every 6 years.

Classification data come from approximately 250 classification sites throughout the State. These sites are also sampled on a regular schedule, satisfying both Federal reporting requirements and State needs. The Department considers seasonal variation in vehicle counts by comparing spring, summer, and fall data. Each location is sampled three times a year: over two weekdays and one weekend.

The State uses weigh-in-motion (WIM) to collect vehicle weight data. There are currently seven active sites that consist of a combination of piezo, bridge, and bending plate data collectors.

Ultimately there will be 15 permanent sites installed. Where WIM data are collected, they are also used to provide traffic counts, which eliminates the need for separate counting sites.

The Data Inventory office processes traffic data. It collects the data, performs the quality control, analyzes the data, and prepares and distributes the data, such as in the form of traffic maps. Clients (or users) of its product include Design, Planning, Accident Records, the public, MPOs, the FHWA, and the urban areas and counties. Data Inventory also publishes summaries of some of its data. The most recent version is the *1994 Highway Traffic Report*, which includes classification and weight data among others.

Data quality is verified in several ways. The first check is with historical data. The State trunk highway data are collected every 2 years, so this serves as a useful verification process. Counties are surveyed every 6 years, so checking historical numbers is not as meaningful (the urban network is done every 4 years and Highway Performance Monitoring System [HPMS] traffic data are collected annually). All counts that come in are looked at manually. Then traffic is loaded into the RES traffic file. Again it is checked for typographical errors and again it is checked against historical data. Some data, such as that collected by WIM, also has automated validation in addition to a manual check.

In 1997, the Department acquired and implemented TRADAS, traffic data management software. This software coordinates the collection, inspection, and reporting of traffic data through its Data Collection Management System (DCMS) subsystem, while its Standard Traffic Monitoring System (STMS) performs inspection, analysis, and reporting on the collected data. Based on nationally accepted standards for monitoring traffic, TRADAS works as both an automated data collector and data processor. An integral part of this software is its extensive checks on data quality, which "filter questionable data from the analysis process."

The data collection and processing procedures for the State's HPMS sections is different from that on the State sections. HPMS has its own procedures and it has to come from specified mileage. The State uses the HPMS data to develop VMT and to find errors that come from some of their checks.

Figure 11 depicts the traffic data collection process. As is seen in this figure, traffic volume and classification data are handled separately from the weight (WIM) data. One significant difference is the manual editing that takes place with the volume and count data versus the automatic editing of the WIM data.

Traffic Data Feedback

Feedback from interviews supports the fact that traffic data are widely used throughout the Department. Almost every office reported using at least some component of traffic data, and many made widespread and frequent use of this information. To summarize traffic data feedback, the most common comment was that the counts for a specific location were sometimes not believed to be accurate, or that short or special counts were less accurate than regular counts. A second group of comments was that published data, such as in the *Needs* book, were not accurate enough for specific applications so that special requests were often made to Data Inventory. Where there existed concerns about the accuracy of traffic data, they stemmed more from a lack of familiarity with the rigorous procedures involved in extrapolating from limited counts. However, any office appears to be able to request special counts for their specific needs.

Friction

The SDDOT owns a K.J. Law Model 1270 trailer for measuring skid. The Department's equipment was acquired in 1975 and rebuilt in 1985.

Data Collection and Processing

Skid data have been collected haphazardly in recent years. While the original intention of the Department may have been to collect friction data on some subset of their pavement network annually, that has not been accomplished. In 1996 the equipment was not operational and no

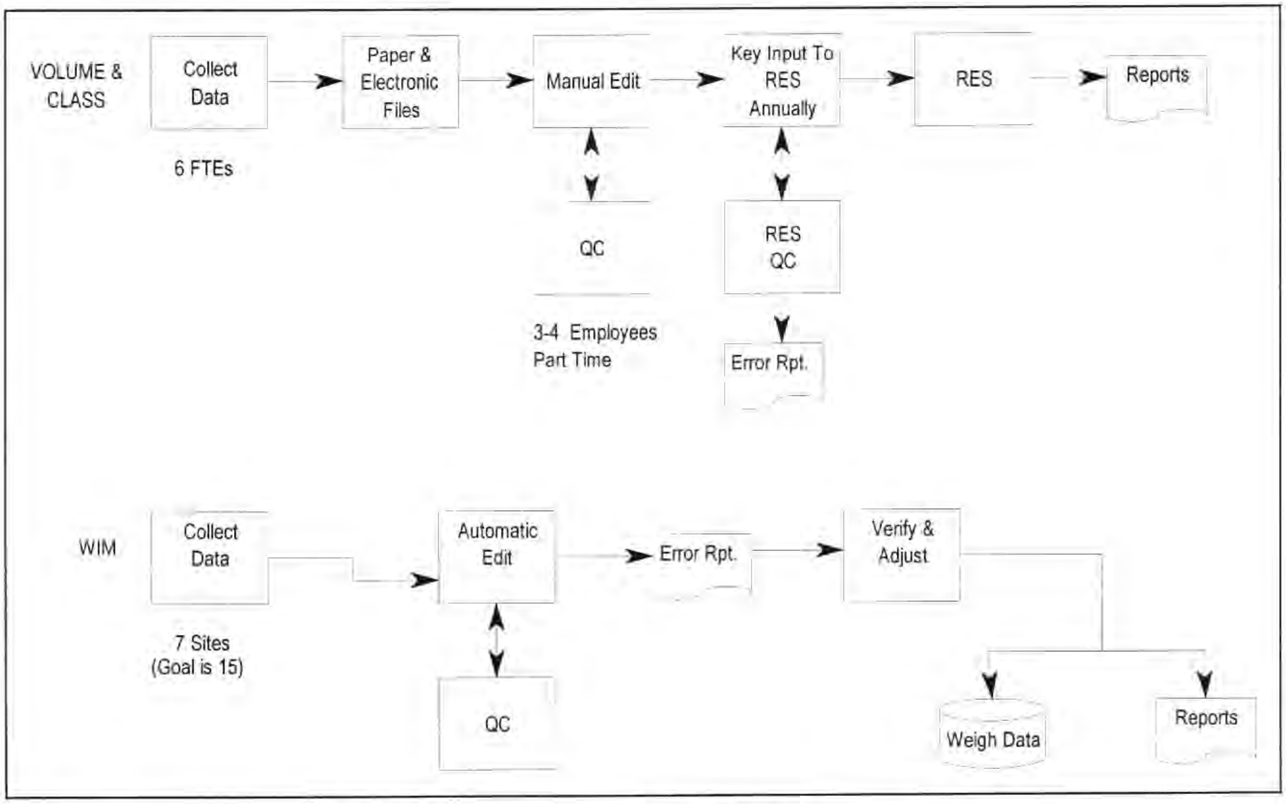

Figure 11. The traffic data collection process.

data were collected. There were plans to restore the equipment to operational condition in 1997, but it is not known if that will be accomplished.

Originally, the equipment had an operator assigned to it, but in 1991 that changed and seasonal employees have been used to collect friction data since then. The handling of the equipment also underwent a change over time. From 1981 until 1989 it was calibrated annually at a calibration center, and now it is calibrated every 4 years. The last calibration was performed in 1994. When it was in working condition, local calibration of the equipment included daily sensor and water calibration. The trailer was also tested weekly over a test strip in Pierre. Figure 12 depicts the skid testing process utilizing the K.J. Law Skid Tester.

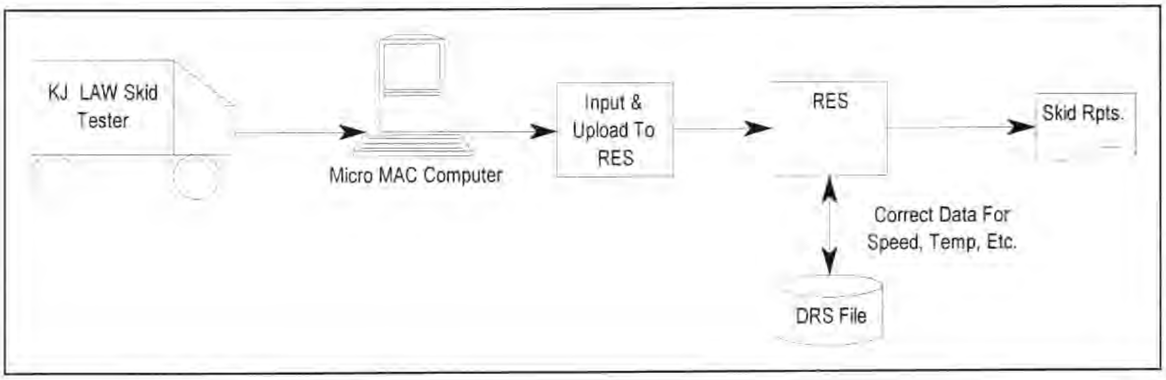

Figure 12. Skid testing data collection process.

Friction Data Feedback

Although there are many potential good uses of friction data, such as those listed below, these data are rarely used:

- Assessing the effectiveness of maintenance.
- Identifying candidates for functional overlays.
- Accident assessment.
- Evaluating effectiveness of chip seals.
- Evaluating effectiveness of experimental treatments.

In the past, Operations considered the surface friction properties to be a driving force in their resurfacing program. These data were also used to determine whether roads were being maintained properly. Several Regions noted that the data could be used to post warning signs, but they know which roads require such warnings anyway (such as from accident data or experience) and can post them without testing.

Aeronautics uses the skid testing equipment to measure skid resistance, primarily on commercial airports, where having good skid numbers is an important part of safe aircraft operation.

To obtain meaningful results with the equipment, the driver needs to operate the vehicle precisely in the wheelpath. Some users reported a potential source of error to be the inability to place the equipment in exactly the right location, exacerbated by the shift to part-time employees operating the equipment.

Roughness

At the time that information was collected for this report, the South Dakota Road Profiler was used to collect profile and rut depth data, and to develop the sufficiency rating. The equipment measures and records elevations; the data are used to calculate the South Dakota Index (SDI) and the International Roughness Index (IRI).

Data Collection and Processing

The entire network is surveyed every 2 years, and the portion that is tested is usually covered between May and September. The data are processed and analyzed between September and December, at which point they are uploaded to the RES. Once entered into the RES there are no checks on the data, but feedback is provided from the PMS group and from HPMS; this feedback is then used to make corrections.

There is one calibration section in Pierre and the equipment is calibrated weekly. If the difference in SDI readings is greater than 0.05 then a more in-depth look at the equipment is undertaken. The distance measuring instrument (DMI) is also checked against standard sections and calibrated four times a year. Tire air pressure is checked every morning. For software checks, the most current MRM is downloaded.

The current rutting and roughness data collection processes are performed with South Dakota's ARAN vehicle, as shown in Figure 13.

Roughness Data Feedback

Several groups reported using roughness data directly, including Materials and Surfacing, Research, and the Office of Local Government Assistance (responsible for Non-State Trunk Highways [NSTH]). No problems were reported with the roughness data as it is provided.

Rutting

Rutting is measured using a three-sensor rut bar mounted on the profile survey vehicle. The center sensor measures the elevation of the "hump" between wheelpaths relative to the bar, while the two outer sensors measure the distance from the bar to the pavement in the wheelpaths.

Data Collection and Processing

Rutting is reported as a displacement, by Highway, MRM, and lane. The rutting data are made available to potential users in the *Needs* book, where they are combined in approximately 0.4 km (0.25 mi) segments, averaged, and converted to an index on a 0 to 5 scale (deducts are made to a perfect 5.0 score based on the average rut depth for a pavement section).

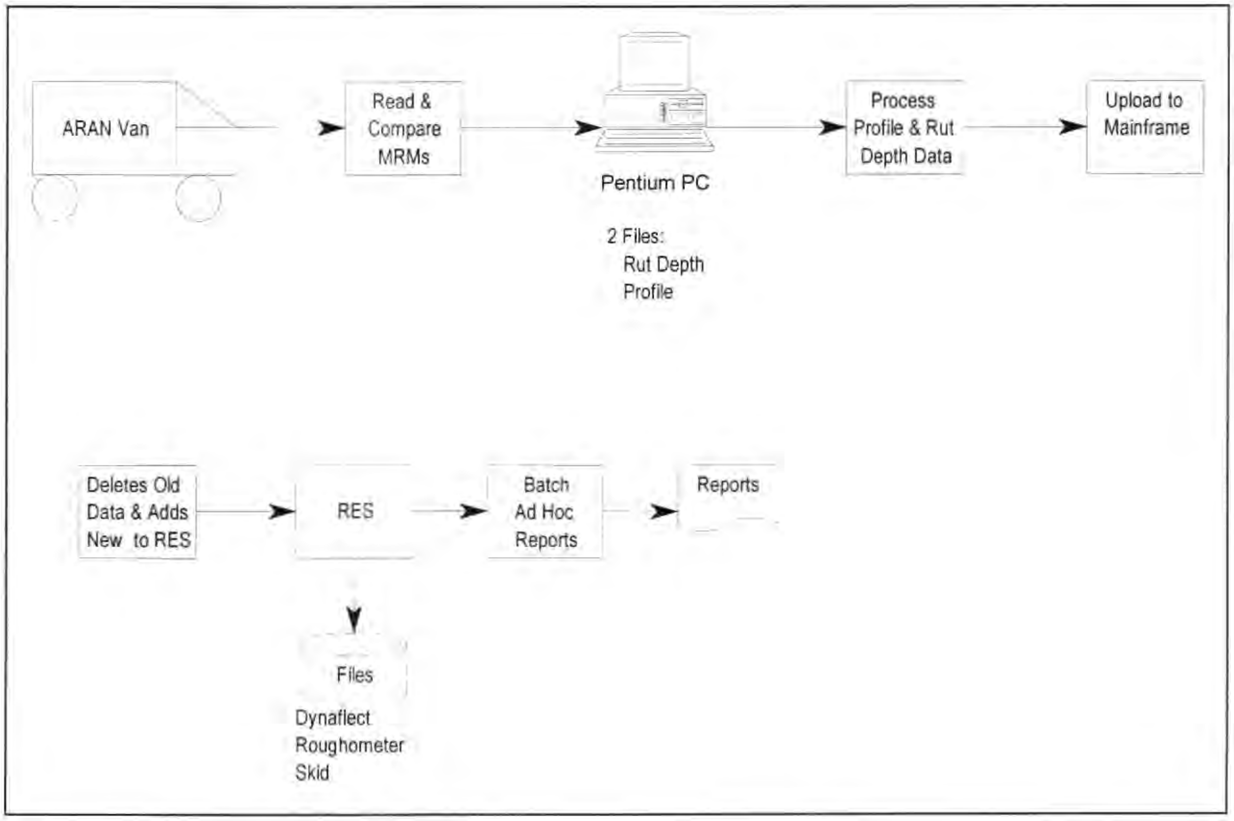

Figure 13. The rutting and roughness data collection process.

Rutting Data Feedback

Rutting data have been used to estimate quantities for rut filling, to identify the need for milling, and as a guide in determining whether to remove a surface layer. Rutting information is used by the Regions in their project planning and selection processes, and to trigger maintenance or milling. Rutting is also used by engineers in the Materials and Surfacing office to identify problem designs or mixes. Materials and Surfacing uses rut depth data for undersealing studies and for load studies. Research also examines rutting data to identify special projects where rutting is a problem. No dissatisfaction was reported with this data item.

<u>Sufficiency Rating</u>

Data Collection and Processing

The Sufficiency Rating is an indexed value that the SDDOT has used to quantify the relative or comparative adequacy of different pavements in their highway network. Based on a composite

100-point scale, the Sufficiency Rating includes components of pavement condition (40 points), safety (30 points), and service (30 points). Guidelines for calculating this index are summarized in *South Dakota Sufficiency Rating Process* (document dated 1/22/92). Over the years, attempts have been made to make the components of the rating objective. This has been partially accomplished by assigning measured values (such as those obtained with the Profiler) to certain ranges in the rating scheme.

Sufficiency Rating Feedback

In interviews conducted throughout the Department, there was some familiarity with the existence of the rating, but no one could state what was in it or how it was calculated, and few were sure what it was being used for. A likely explanation for this lack of familiarity with the rating is that as an index it does not represent a single physical property of a pavement. Decisions related to maintenance or rehabilitation are more commonly based on specific conditions with which decision-makers are more familiar. With the introduction of dROAD, the rating is not being calculated or used, and is not reported in the revised draft of the *Needs* Book.

Videolog Images

The Department uses a Mandli Video Image Capture System van to create a videolog of the pavement network. The equipment has been in use in South Dakota since 1991. Image acquisition is accomplished by a charged coupled device (CCD) camera, and the storage medium is 305 mm (12-in) optical laser disks. Each disk holds 290 km (180 mi) of records per side, for a total of 580 km (360 mi) per disk. An on-board DMI is connected to a computer that allows images to be tagged with the Region, Route number, date of the survey, and appropriate MRM and displacement.

Data Collection and Processing

The videolog survey van is operated at highway speed, generating 125 photographs per kilometer (200 per mile), and the entire pavement network is surveyed every 3 years. It is only possible to obtain a useful image when the pavement is clear and ambient lighting conditions are satisfactory, so the survey is run between late spring and fall, during daylight hours, when the weather is likely to be favorable and the pavement is likely to be dry. The camera is aimed so that an overview, or inventory, image is acquired. This image is appropriate for studying inventory location and condition information (such as bridges, guardrails, and signs) and some pavement information (e.g., number of lanes, pavement type).

One full-time Department employee is assigned to perform the videolog survey, process the data, and make the results available to the end users. There are six workstations located throughout the Department to access the videolog. These are located in Pierre in the offices of Data Inventory and Roadway Design, and in each of the four regions. Each region is given a copy of the videolog for their pavements, and a copy of the entire survey is stored at both Data Inventory and roadway design. The videolog image collection process is shown in Figure 14.

Videolog Feedback

Feedback on the videolog images was varied. Overall, the system is widely used, especially by those responsible for certain inventory tasks. For example, Road Design uses the images to look at the location and status of signs, the Office of Bridge Design uses the videolog to view guardrails for approach views, and Materials and Surfacing uses the Videolog file to see right-of-way and guardrail locations (although they reported that it was not very user-friendly, and would be more useful if it showed pavement distress and could be used to verify surface widths). The traffic engineer in the Region uses videolog for viewing guardrails and railroad crossings, and Project Development (environmental) uses the Videolog file to perform various functions, such as verifying approaches, and business and utility locations.

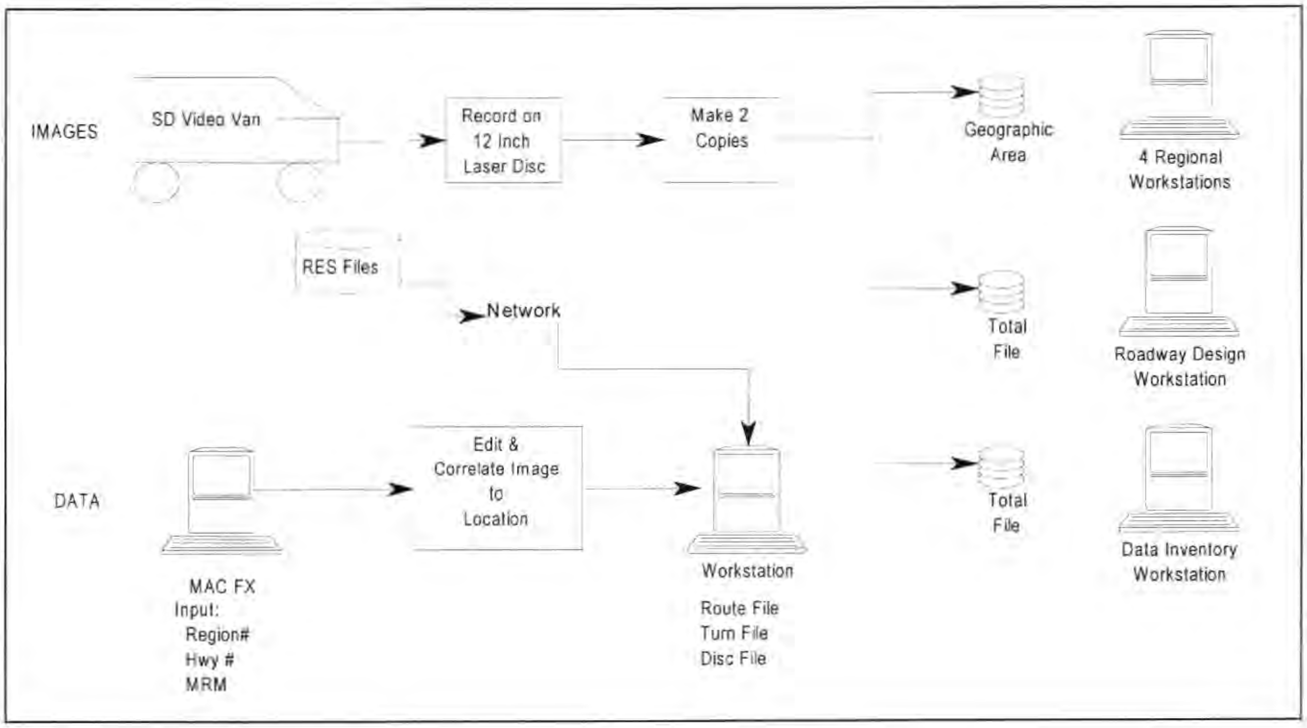

Figure 14. Videolog image acquisition process.

Each of the regions reported wide use of the videolog. Signs, billboards, delineation, and traffic signs were items that are studied on film, and if the equipment were more readily accessible it would likely be even more widely used.

Falling Weight Deflections

The Dynatest Model 8000 Falling Weight Deflectometer (FWD) is used to collect pavement deflections on roadway and airfield pavements. There is one full-time operator responsible for the equipment and all data collection activities. During the summer months, two temporary personnel are hired to assist in the data collection process.

Data Collection and Processing

The FWD is used for two types of data collection: network-level and project-level testing. Deflection data are collected for at least four types of projects. On AC-surfaced pavements, FWD data are used to identify candidates for spring load restrictions; the Regions currently make their decisions for posting load restrictions based on recommendations developed from FWD data. The restricted road information is also input into planning documents. FWD data are also used to identify candidate projects for the overlay program. Another use for deflection testing is in PCC pavement restoration projects, where the data may be used to identify the need for undersealing, load transfer restoration, and other rehabilitation needs. Finally, deflection testing is carried out on airport pavements to assess structural adequacy and design structural overlays. Use of the FWD can be summarized as follows:

- 8 weeks of PCC testing.
- 2 weeks of airport testing.
- 6 weeks of testing on materials-related work.
- 2 weeks of forensic testing for Operations.
- 8 weeks of inventory testing.

In the past, data from the FWD inventory testing process has been loaded into the RES system. There is also a location for FWD data to be stored in dROAD. Figure 15 depicts the FWD inventory data collection process:

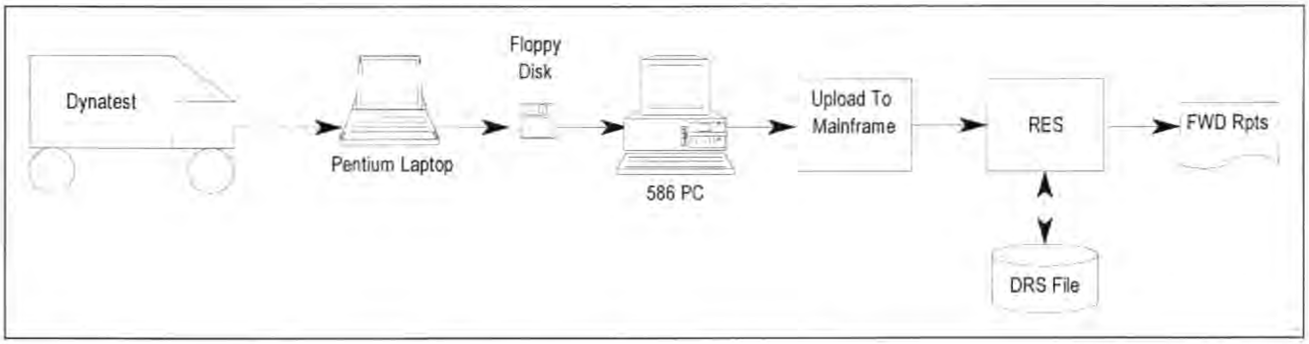

Figure 15. The FWD inventory process.

At airports, the typical testing pattern is every 150 m (500 ft) on the edges and at the pavement center. If there is a problem, the testing interval is decreased. Also, if there is a problem the testing is repeated before any rehabilitation project. The Aeronautics section would like to do an annual survey as well as spring testing to identify areas likely to weaken during spring thaw.

Testing procedures follow guidelines developed by other agencies and by the manufacturer. However, there do not appear to be documented procedures that govern the use of the equipment in South Dakota. In addition to internal data checks, the FWD is calibrated to SHRP specifications every 1 to 2 years. In between calibrations, there are online system checks of data quality.

FWD Feedback

Users of the FWD data readily acknowledged its value to their decision-making processes. Operations uses FWD data for spring load restriction postings. That same data are also used as a part of the process to consider projects for overlays in the region and to identify posted pavements that need strengthening. Occasionally, the Regions will also make special requests for FWD data to develop their maintenance programs. Aeronautics uses FWD data for assessing pavement strengths and in rehabilitation, and the data are occasionally used on the NSTH.

There was a concern expressed that that calibration of the FWD output is needed on pavements over a range of seasons to develop correction factors, which were available with the previous deflection testing equipment. However, the following corrections are already a part of the data processing:

- Test data from AC pavements are corrected to 25 °C (77 °F) using Asphalt Institute equations.
- Test data from PCC pavements uses software-specific parameter curves that are also based on temperature. Either a 5-day average or the previous 24 hour temperature is used.

Verification of Vertical Curves, Horizontal Curves, and Pavement Widths (Geometrics)

Data Collection and Processing

Vertical and horizontal alignment data are developed from the as-built drawings and summarized in a file in the RES. The width of various pavement features comes from plans, but are field-verified as possible. Field verification is performed by Data Inventory, and consists of measuring widths at a typical location. Where a different width continues for approximately 150 m (500 ft), the different width is entered.

Geometric Data Feedback

The greatest reported shortcoming of geometric data is the apparent inaccuracy of the reported pavement widths. Some *Needs* book users (particularly those in Road Design) report that pavement widths in the database do not correspond with what is seen in the field. However, the *Needs* book reports a predominant width for a section; a user may well be looking at a particularly narrow section and note a discrepancy that is not representative of prevailing conditions. Pavement cross slopes are another data item that some users desire but are generally not available. The only source of this information is from plans, and they may not be representative of what is actually found in the field. Those who need more accurate data evidently collect such data.

Summary

Data collection and processing activities for specific roadway data items are described in this section. These data items include pavement distress, traffic, pavement friction, roughness, rutting, sufficiency rating, videolog images, falling weight deflections, and geometrics. Collection and processing activities are described for each data item, and are followed by feedback from users on that data item.

There is a significant amount of variability in these data collection activities in terms of the frequency of data collection, how the equipment is operated and maintained, and how the results are perceived throughout the SDDOT. Recommendations regarding each of these activities are found in chapter 7.

OVERALL SUMMARY

An overview of South Dakota's roadway data collection activities is presented in which they are viewed as a process. The collection of the individual measurements of roadway data is also examined. This information serves as a useful backdrop to understanding current activities and developing recommendations for improvement.

Some of the data collection activities are in the process of changing, so that current practices evaluated in 1996 and early 1997 may not be representative of how the data collection is being performed. This is true at least for roughness and friction. Improvements are also being implemented in traffic data handling.

6. Roadway Data Users' Needs

INTRODUCTION

The review of data collection activities presented in chapter 5 focused on the experience of data collectors and data users. The emphasis of this chapter is on the needs of the data users, those who have a stake in the product of the data collection effort. The various concerns of this group are summarized, with the objective of identifying where in the data collection process efforts at improvements would be most worthwhile. This assessment is supported by a review of data collection costs and the results of a survey that solicited information on the relative benefits of different categories of roadway data.

PROCESS MEASUREMENTS

In analyzing the roadway data collection process, there are three major process measurements that can be considered:

- *Effectiveness* of the data collection process.
- *Efficiency* of the data collection process.
- *Adaptability* of the data collection process.

Effectiveness may be thought of as the extent to which the outputs of the roadway data collection process meet the needs and expectations of the users. A synonym for effectiveness is quality. Effectiveness also means having the right output at the right place, at the right time, and at the right cost. An ineffective process in this context is one that does not deliver the right data, or delivers the right data in a manner or at a time in which it cannot be used.

Efficiency is the extent to which the use of system resources is maximized and waste is eliminated in the pursuit of effectiveness. Productivity is a measure of efficiency. Examples of inefficiency include redundant data collection efforts and collecting data that are not used.

Adaptability is the flexibility of the data collection process to accommodate both future, changing user expectations and today's individual, special needs and future requirements. An adaptable system maintains or improves its level of effectiveness and efficiency, while a rigid system does not.

USER NEEDS AND EXPECTATIONS

From the interviews that were conducted in the Department, it was observed that user needs and expectations can be grouped into several different categories. These different categories are summarized below.

The **relevancy** or usefulness of the data must be considered. Are the data useful as collected or processed or is some other measurement more meaningful or relevant? Data users expressed a need for data that are appropriate for the user. The data collection equipment should also be capable of providing data of value.

The **form** in which the data are presented to the user is important. For example, is it raw data, a batch-processed report listing, a specific ad hoc report, or a relational data base with "what if" query capabilities? While the data may be collected and stored in a single format, users may require a range of processed forms. The following issues related to form arise:

1. The database must provide the ability to easily generate ad hoc reports and consider "what if" scenarios.
2. The data must be available in graphical form, such as in maps, figures, and graphs.
3. The data must have "hooks" that connect to other information such as supporting source documents or plans.

The **timeliness** with which the data are collected is also important. Are distress data collected in the summer after the winter damage, collected in the spring prior to any pavement rehabilitation activities, or collected 12 months previously so that the passage of time and traffic has affected data validity? A secondary issue is the timeliness with which the data are available to the user for processing. Does the time taken to collect and process the data into a usable form allow little time to use it? Users' needs regarding timeliness are summarized below.

1. The intervals for collection must be such that the data are still relevant when they become available to the users.
2. The data must be processed and available in time to meet the time constraints of the user.
3. The data must be directly available to the user without an intermediary or custodian.

The **accuracy** and **reliability** of the data are important issues to users. Are the data collected following well-defined and documented procedures and checked against quality standards? Are the data re-collected at the point of collection if they do not meet quality standards, with the collector held accountable for results? Are the data collected under the same controls and by the same personnel and equipment every time, eliminating variables and minimizing subjectivity? The data users' needs pertaining to accuracy and reliability are summarized in the following four requirements:

1. The data should not reflect the variability and subjectivity of collectors and collection equipment.
2. The data must reflect maintenance activities that change roadway characteristics.
3. The data must better reflect construction activities that change the RES database.
4. The data must be pinpointed to a specific roadway location.

The **usability** of the data is also an issue that was raised in interviews. Are the data in a form that can be readily used, or must the user undertake additional manipulating or processing of the data before it can be used? Issues relating to usability are listed below.

1. The data must be retrievable by multiple parameters such as MRM, intersection, condition, rating, and so on.
2. The data must be available at the users' desktop.
3. The data must be available from a single computer platform.
4. The data elements in the *Needs* book must be more inclusive, or the PMS reports should be made more available.

Finally, the **cost** to produce the data is a consideration. Data collection is a Department-wide function that draws on limited resources. Are the costs to collect and process the data in line with the value of the data to the end user? Users do not tend to express concern about individual costs, as costs are borne by the Department. However, overall the SDDOT is extremely interested in cost issues. The following summarizes some issues related to data collection costs:

1. The cost of data collection should reflect the value of the data to users.
2. The effort of the data user in quality checking, manipulating, or further processing of the data must be eliminated, and all such efforts and associated costs transferred to the data collection effort.
3. The costs of poor designs or inappropriate repairs to roadways because of erroneous data must be eliminated.

ROADWAY DATA USER VALUE SURVEY

In order to better quantify the value of different types of data to users, selected officials within several departments were asked to complete a survey on the collection and use of roadway data. A total of 54 department officials, representing a significant cross section of individuals with varying responsibilities, were asked to rate each data type that they use on a scale from 1 to 5, with 5 being the highest rating. The following questions were posed to the survey participants:

1. Importance of data accuracy (1 = Not Needed; 5 = Essential).
2. Actual accuracy of receipt (1 = Very Inaccurate; 5 = Error Free).
3. Importance of data timeliness (1 = Not Important; 5 = Must Be Timely).
4. Actual timeliness of receipt (1 = Never Timely; 5 = Always Timely).
5. Overall value of the data in their operation (1 = Not Needed; 5 = Essential).

A rating of 3 indicates that the data are of average importance or are generally accurate or timely enough to meet the needs of the user.

The overall results of the questionnaire survey are summarized in Table 15. This table provides the average rating for each data type in response to the above questions, as well as the number of respondents for each question. Because certain questions in the survey were not relevant to specific departments, not each question is answered by every respondent, and consequently the number of responses varies across the categories. Nevertheless, the number of responses and the cross section of individuals surveyed are believed to be more than adequate to provide meaningful insight on the value of road condition data to the SDDOT.

Table 15. Summary of overall questionnaire results.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of Receipt		Overall Value of Data	
	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating
Traffic Volume	47	4.0	43	3.1	47	3.6	44	3.9	48	3.8
Vehicle Class	45	3.4	39	3.1	44	3.0	37	3.8	48	3.3
Vehicle Weights	47	3.3	34	3.0	42	3.0	33	3.5	45	3.3
Pavement Roughness	46	3.4	36	3.1	42	3.1	37	3.7	46	3.3
Pavement Rutting	45	3.4	35	3.2	43	3.1	36	3.7	45	3.4
Friction	45	3.2	36	3.2	41	2.7	34	3.4	47	3.0
Falling Wt. Deflections	46	3.5	35	3.4	43	3.2	39	3.6	46	3.4
Videolog Images	44	3.1	38	3.3	44	2.8	40	3.6	46	3.0
Pavement Dist. Survey	44	3.3	32	3.2	41	3.0	34	3.8	41	3.1
Transverse Jt. Faulting	44	3.3	43	3.1	40	3.1	34	3.6	39	3.2
Geometrics	45	3.4	38	3.1	44	3.0	38	3.5	45	3.2

An example of the survey questionnaire, along with additional questionnaire responses, are given in Appendix B.

According to the data survey results presented in Table 15:

- The accuracy of the traffic volume data is significantly more important to end users than the other data items, presumably because of its widespread use.

- Accuracy is least important for friction and videolog, although these are not that different than some of the other items.

- The survey shows the relative accuracy of the different data items to be about the same (in the range of 3.0 to 3.4), with the accuracy of the FWD data the greatest. While this level of accuracy is generally adequate, increases in accuracy are possible for all data items.

- The importance of timeliness is also greatest for traffic volume data, with friction and videolog images again slightly less than the other items.

- The timeliness of receipt are greatest for traffic volume, vehicle class, and the pavement distress survey, followed closely by pavement roughness and pavement rutting. The timeliness for these items is generally good (ranging from 3.7 to 3.9), and are not that much different than the other data items (ranging from 3.4 to 3.6). These results indicate that the timeliness of the receipt of the data items is generally reasonable.

- Overall, traffic volume has the greatest value to the Department. From the questionnaire results, the rest of the data appear to have about equal value, with friction and videolog appearing to have the least overall value. It should be noted that the results from the distress survey as it is currently performed have only been available for the last 2 years; its true value may not be fully realized.

A separate table was constructed that reflects the value of data to the Regions. This summary is found in Table 16 below.

Table 16. Questionnaire results for regions only.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of Receipt		Overall Value of Data	
	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating
Traffic Volume	19	3.9	17	3.2	19	3.2	18	3.8	19	3.7
Vehicle Class	19	3.4	16	3.1	19	2.8	16	3.7	20	3.3
Vehicle Weights	19	3.3	15	3.1	18	2.6	16	3.6	19	3.4
Pavement Roughness	19	3.6	15	3.1	17	2.8	17	3.7	19	3.3
Pavement Rutting	19	3.6	15	3.1	19	3.0	17	3.7	19	3.6
Friction	18	3.8	17	3.4	17	2.9	17	3.7	19	3.6
Falling Wt. Deflections	19	3.7	14	3.2	19	3.3	18	3.7	19	3.6
Videolog Images	18	3.0	15	3.2	19	2.8	17	3.6	19	3.2
Pavement Dist. Survey	19	3.4	15	3.1	18	3.0	17	3.6	18	3.3
Transverse Jt. Faulting	19	3.4	16	3.2	18	3.0	17	3.6	16	3.4
Geometrics	19	3.5	16	3.2	19	2.8	18	3.6	19	3.1

According to the results presented in Table 16:

- Accuracy is most important for traffic volume, friction, and FWD data. It is least important for videolog, and of about equal importance for the remaining data items.

- All data items show about the same level of accuracy, with the average rating for friction slightly greater than the rest. However, as with the ratings shown in Table 15, the relatively low ratings for each data item (ranging from 3.1 to 3.4) again indicate that the accuracy is generally adequate but that improvements can be made.

- The importance of timeliness is about the same for all data items, with traffic volume having the highest rating of importance. Timeliness is least important for Vehicle Weights.

- The timeliness is about the same for all data items (only ranging from 3.6 to 3.8), and the ratings indicate that the timeliness is more than adequate.

- Traffic volume again has the highest overall value rating (3.7), followed closely by rutting, friction, and FWD (3.6). Geometrics has the lowest overall rating, followed by videolog.

In comparisons between Table 15 and Table 16, traffic volume is the data item of highest value, and it is of about equal value to both the Department as a whole (Table 15) and the Regions (Table 16). On the other hand, pavement monitoring data (rutting, friction, and FWD) are of greater value to the Regions than to the Department as a whole. Geometrics and videolog consistently are of lowest value to both groups.

The sufficiency rating was not included as part of the questionnaire survey, but based on the lack of familiarity with it, it is unlikely that its overall value rating would have been greater than 3.

QUALITY CONTROL CHECKPOINTS

During the interviews, some data users indicated that the reliability of some of the data items is questionable. To compensate for this, they verify the data manually or in some other way before they use it in their respective processes. Where the end user consistently feels the need to perform a check of data quality before use, it suggests that there are insufficient quality control checkpoints. However, the purported prevalence of unreliable data was not reflected in the questionnaire results. Furthermore, a review of the data collection processes suggests that there are already more than enough quality control checkpoints. Figures 16 (a and b) highlight where in the current process data are, or could be, checked for accuracy and quality:

A close study of the data collection process shows that the problem is not a result of there being <u>too few</u> quality control checks on the data; the problem is that the majority of the problems uncovered with the data are <u>too late</u> in the process flow.

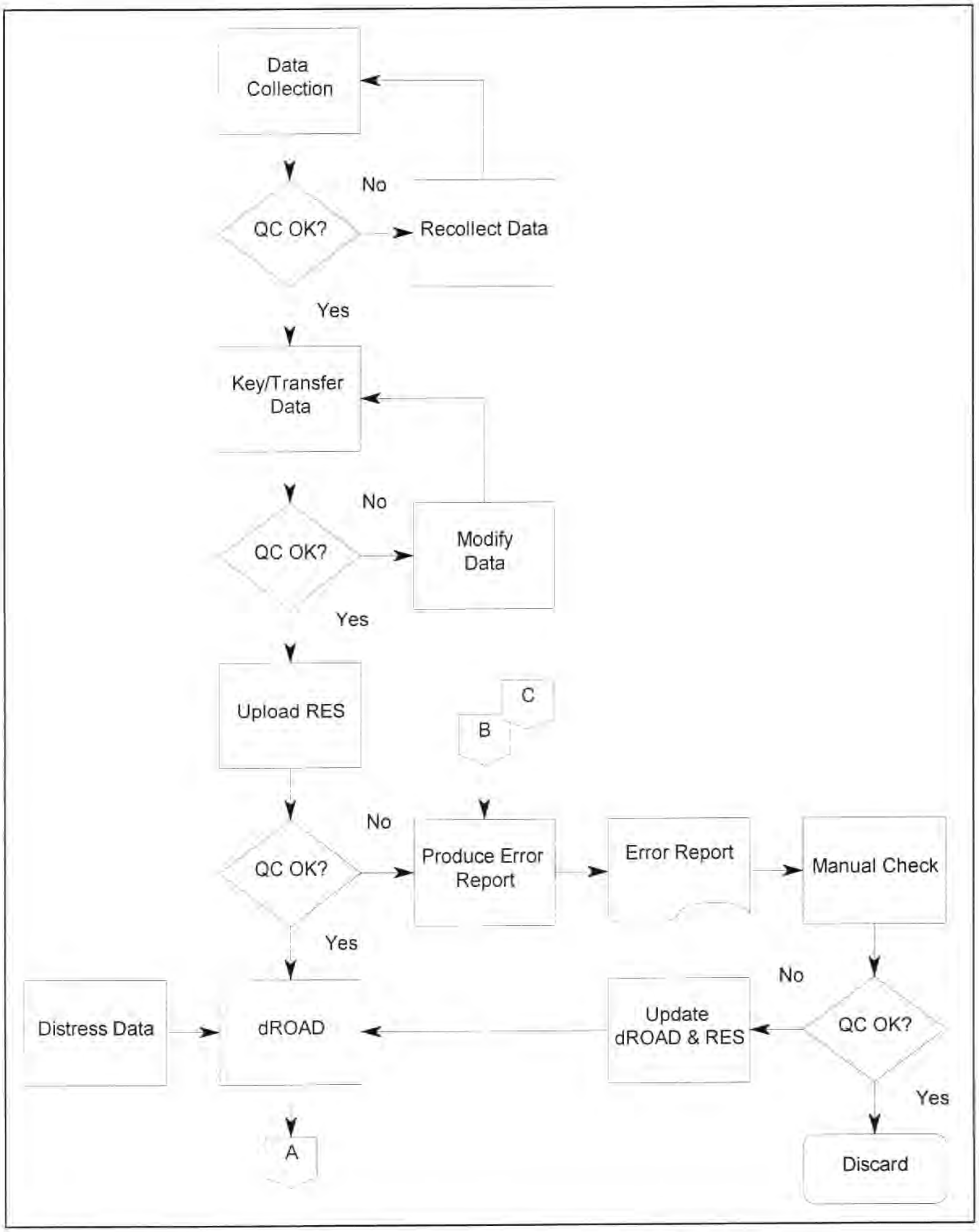

Figure 16a. Data collection quality control checkpoints.

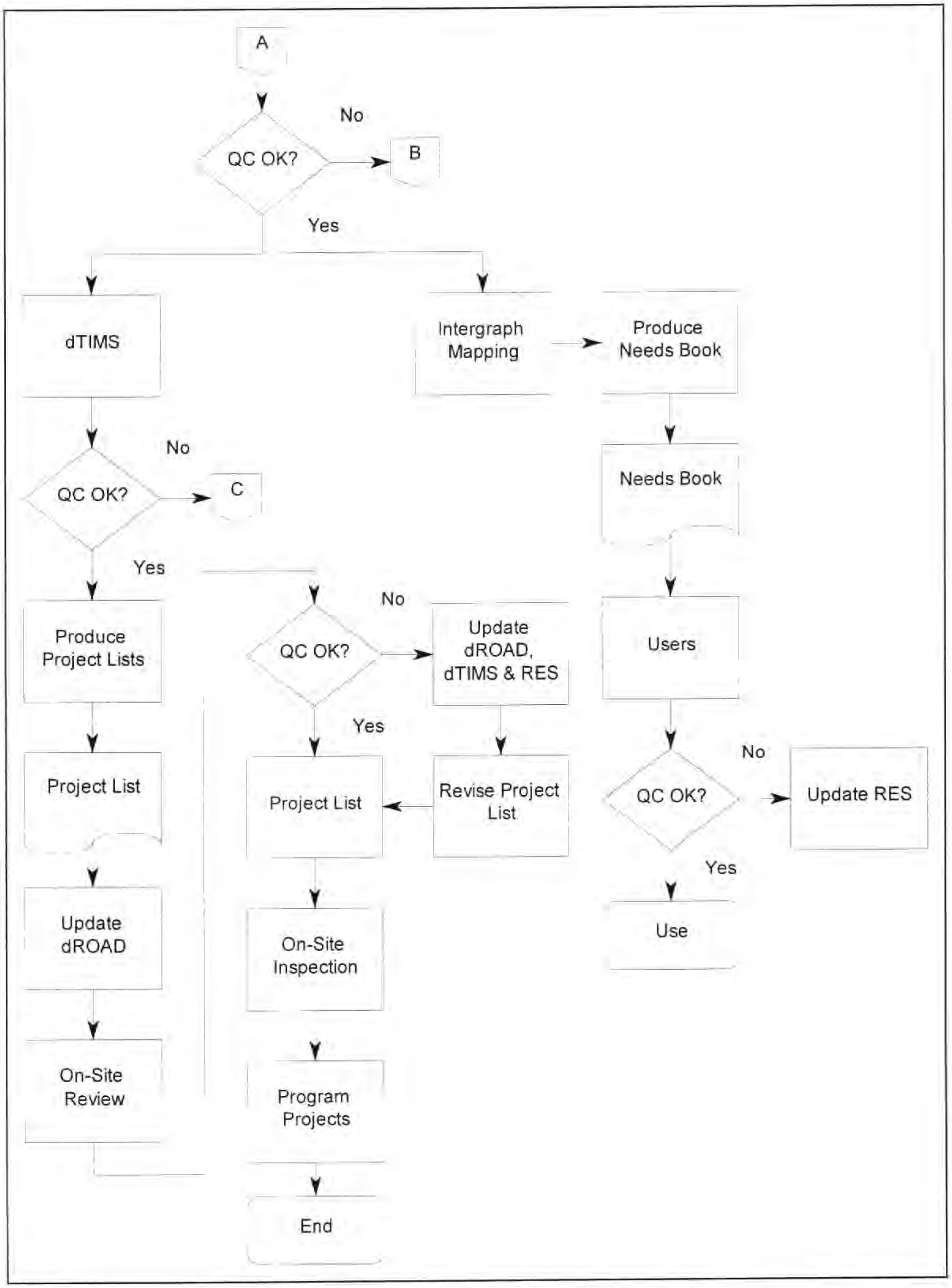

Figure 16b. Data collection quality control checkpoints.

For example, it is estimated by Data Inventory that 90 percent of the problems fed back to Data Inventory are uncovered by data users when they use the *Needs* book. However, it is also estimated that far more errors are discovered by data processors prior to the actual publication of the *Needs* book.

It is not practical to modify the *Needs* book once it is published to change the data that are found to be erroneous. At the same time, the *Needs* book is heavily used across the Department and other data users will either use the flawed data or go through the same productivity-robbing quality check routines. Either situation is very damaging to the efficiency and effectiveness of the data users and all processes that are fed by the data users.

One point to make regarding the use of the *Needs* book is that it is important that users realize what the information contained in the document represents. For example, it is possible that many of the data items that are thought to be inaccurate are actually average or representative values computed over an extended highway segment. In that case, it is important for the user to recognize what the data represent and the limitations of their applicability.

Effective Quality Control Checkpoints

For several data types virtually no quality problems are uncovered and corrected at the point of data collection. If data could be verified as accurate at point of collection, however, reliable data would flow to the users and to their processes that use the data.

Several possible reasons for not checking the quality of data at the point of collection are listed below.

1. In most cases the equipment that collects the data does not have the capability to verify data accuracy (e.g., skid, roughness, and rutting values may be collected correctly, but there is no check to verify that the measures reflect the actual pavement condition).

2. In the case of distress data collection, the collectors are seasonal employees that have no long-term accountability for quality and their classification of conditions is very subjective and inconsistent.

3. The data collection is often done under inconsistent environmental conditions.

4. Due to tight time constraints to collect the data during favorable weather conditions, the collectors are forced into a production mode. Quantity can overshadow quality as the primary goal.

If data collectors have no means to check the quality of their data, are not motivated to ensure the quality of the data as collected, are not held accountable for data quality, and know that downstream the data will be checked, the possibility of collecting reliable data is remote. The fact is that in keeping with good process design principles, the quality of a work product should be controlled at the point of production. It is almost impossible, and nearly always uneconomical, to add quality back into a product after it is created. A champion of the "quality" movement, W. E. Deming, observed that quality can not be "inspected in" to a product; rather, appropriate training and education must be a part of every production effort, whether the products are data or widgets. The producer of the work product must be held accountable for quality so it does not corrupt the processes it supplies.

DATA COLLECTION COST/VALUE ANALYSIS

The true effectiveness of each data item is evaluated by considering both data value to users and the costs to collect that data. Several tables are presented here summarizing the costs of collecting roadway data in South Dakota (as billed to data collection budget numbers by the SDDOT accounting system). Table 17 shows the FY 1995 costs to collect each data type, Table 18 shows the FY 1996 costs of collecting each data type, and Table 19 shows the FY 1997 costs of collecting each data type.

Table 17. Reported FY 1995 costs of collecting roadway data.

Data Type	COST BY CATEGORY ($)								Total Cost ($)	% of Total
	Personal Services	Travel & Subsist.	Rent & Utilities	Com. Rep. & Serv.	Other Costs	Supplies	Assets	Equip. Costs		
Vehicle Class	33,547	6,849							40,396	4.0
Weigh In Motion	5,093	169	2,354		32	141		108,571	116,360	11.5
Traffic Monitoring	286,185	45,997	21,274	5,880	1,546	58,470	10,992		430,344	42.6
Video-Logging	36,474	3,090		1,664	291	36,960	59,333	33,100	170,912	16.9
Profile and Rutting	43,732	7,159			944	534	259	12,000	64,628	6.4
Skid Test	15,776	4,865			1,426	561		8,900	31,528	3.1
Distress	34,768	16,994		32		309			52,103	5.2
Falling Wt. Deflections	65,760	17,604			1,470	1,006	2,861	15,000	103,701	10.3
TOTALS	521,335	102,727	23,628	7,576	5,709	97,981	73,445	177,571	1,009,972	

Table 18. Reported FY 1996 costs of collecting roadway data.

Data Type	COST BY CATEGORY ($)								Total Cost ($)	% of Total
	Personal Services	Travel & Subsist.	Rent & Utilities	Com. Rep. & Serv.	Other Costs	Supplies	Assets	Equip. Costs		
Vehicle Class	40,862	11,083		54		271			52,270	5.7
Weigh In Motion	14,283	159	2,417		46	475		108,571	125,951	13.7
Traffic Monitoring	282,132	42,832	22,563	1,602	1,861	71,394			422,384	46.1
Video-Logging	38,623	6,599		619	192	765	31,484	33,100	111,382	12.2
Profile and Rutting	18,170	1,725			143	130		12,000	32,168	3.5
Skid Test	10,036	1,208			352	48	278	8,900	20,822	2.3
Distress	29,236	20,086		65		200			49,587	5.4
Falling Wt. Deflections	66,483	16,897	6	1	1,488	1688		15,000	101,563	11.1
TOTALS	499,825	100,589	24,986	2,341	4,082	74,971	31,762	177,571	916,127	

Table 19. Reported FY 1997 costs of collecting roadway data.

Data Type	COST BY CATEGORY ($)								Total Cost ($)	% of Total
	Personal Services	Travel & Subsist.	Rent & Utilities	Com. Rep. & Serv.	Other Costs	Supplies	Assets	Equip. Costs		
Vehicle Class	26,754	8,055				30			34,839	8.5
Weigh in Motion	2,910	142	609					108,571	112,232	27.3
Traffic Monitoring	71,169	12,952	18,914	584	375	5,329	28,360		137,683	33.5
Video-Logging	10,986	4,665				62		33,100	48,813	11.9
Profile and Rutting	3,275	492						12,000	15,767	3.8
Skid Test	1,615	176						8,900	10,691	2.6
Distress									0	0.0
Falling Wt. Deflections	27,457	8,054		75		635		15,000	51,221	12.4
TOTALS	144,166	34,536	19,523	659	375	6,056	28,360	177,571	411,246	

An examination of these tables suggests the following:

- Traffic monitoring data are consistently the most costly data to collect, comprising 43, 46, and 34 percent of the total costs, respectively, for FY 95, FY 96, and FY 97.

- The next most costly data items to collect are weigh in motion, videologging and falling weight deflections.
- Vehicle class, skid (friction), profile and rutting, and distress consistently have the lowest costs associated with their collection.

Table 20 presents average annual collection costs for each data item for fiscal years 95 and 96 (for which the most complete data are available) and for fiscal years 95, 96, and 97. However, it should be noted that some of the information for FY 97 was unavailable, thereby making the averages reported for FY 95 and FY 96 more reliable.

Table 20 also contains the relative value of each data item (repeated from Table 15) and an estimate of the impact of the data item on resulting decisions (i.e., to what extent does a decision based on the data item impact the resulting activity?). This estimate is very subjective, but is an attempt to combine data value with a consideration of other factors. How many direct users of the data are there? What decisions does it impact? Are the data direct inputs to design with a resultant impact of tens of millions of dollars, or are the data used in a less "critical" manner? The development of these subjective ratings is shown in Table 21. It should be noted that with little exception, all of the data have an important impact.

Table 20. Summary of 3-year costs, overall value rating, and impact of data item on decision making for each data collection category.

	FY 95 and FY 96		FY 95, FY 96, FY 97			
Data Item	**Average Annual Cost ($)**	**% of Total**	**Average Annual Cost ($)**	**% of Total**	**Overall Value Rating**	**Impact of Data Items on Resultant Decisions (1 = Little Impact, 5 = Significant Impact)**
Vehicle Class	46,333	4.8	42,502	5.3	3.3	3
Weigh in Motion	121,156	12.6	118,181	14.9	3.3	5
Traffic Monitoring	426,364	44.3	330,137	41.5	3.8	5
Videologging	141,147	14.6	110,369	13.9	3.0	2
Profile and Rutting	48,398	5.0	37,521	4.7	3.35	3
Skid Test	26,175	2.7	21,014	2.6	3.0	3
Distress	50,845	5.3	50,845	6.4	3.1	5
Falling Weight Deflections	102,632	10.7	85,495	10.7	3.4	4
Grand Total	**963,050**	**100**	**796,064**	**100**		

Table 21. Assessment of use and impact of roadway data items.

Data Item	Used Directly By	Impacts Decisions	Impact Rating
Distress	Regions/Operations	Rehabilitation decisions, timing, maintenance	5
Traffic	All	Rehabilitation decisions, pavement design, planning and programming decisions	5
Roughness	Materials & Surfacing, Research	Rehabilitation decisions	3
Rutting	Regions/Operations, Materials and Surfacing, Research,	Materials selection, rehabilitation decisions	3
Friction	Regions, Aeronautics, Materials & Surfacing	Materials selection, posting, potential liability in accidents	3
Videolog	Bridge Design, Road Design, Materials & Surfacing, Regions/ Operations, Project Development	[saves trips to field to confirm inventory items]	2
Sufficiency		Project selection (not any longer)	1
FWD	Aeronautics, Research/ Operations, Regions, Materials & Surfacing	Maintenance vs. rehabilitation vs. reconstruction, overlay thickness, posting load limits, pavement design	4
Geometrics	Bridge Design, Road Design, Regions/Operations	Decision to reconstruct vs. rehabilitate	3

5 = highest impact, 1 = lowest impact

Combining data collection costs, value, and the impact of each data item is a good way of drawing overall conclusions regarding data needs. The data presented in this table suggest the following interpretations:

- While traffic monitoring has the greatest associated collection cost, it also has a high overall value to the users and has a great impact on resultant decisions. The cost appears to be balanced with user value.

- Videologging represents about 14 percent of the total cost, and has an overall value rating of 3 and an impact rating of 2.0. Respondents noted that they would use the videolog output even more often if it were more accessible and easier to use; additional investment in collecting this data seems justified. It should be noted that the low impact rating reflects that this technology saves time and money, but does not have a very large direct effect on decision-making.

- FWD data collection represents nearly 11 percent of the total cost and had a relatively high overall rating. In addition, it has a high impact rating due to the effect of the FWD information on pavement overlay designs, for example.

- Rut and Profile data represent only about 5 percent of the total data collection cost and also have value to users. The use of the ARAN vehicle to collect these data may increase the value rating even more.

- Although friction has a low collection cost, its value rating and impact rating appear to indicate that its overall worth is much greater than the current expense of collecting it.

SUMMARY

Input from roadway data users was sought through both interviews and a questionnaire. The interviews were used to develop an understanding of the needs of data users. The interview results helped to identify issues of importance to users and to solicit ideas for where improvements were needed. Overall, data collection needs can be better met by improvements to the quality of the data, the timing of data collection, and the ability of the entire process to recognize change.

Surprisingly, the questionnaire results did not provide as clear-cut a substantiation of the issues raised during the interviews as might be expected. The questionnaire results showed that all data were of at least average accuracy and timeliness, and no single data item had a "value" below an average rating. Traffic monitoring did have the highest value.

When data collection costs and a subjective assessment of the impact of the data are considered, there appears to be a high degree of congruency between costs and value. This does not mean that the process can not benefit from a greater effort to improve the quality of the data—especially when the processes are examined closely—but there is not a high degree of dissatisfaction with accuracy and timeliness reported by questionnaire respondents.

7. Procedural and Quality Control Recommendations to Improve Roadway Data Collection

INTRODUCTION

The review of data collection practices in the Department, in other agencies, and in standard practices elsewhere indicate that overall South Dakota's practices are sound. From insights gleaned during this review process, recommendations are provided to improve these practices. These recommendations are organized in the following manner:

- Presentation of a principles of a comprehensive roadway data collection policy.
- Procedural recommendations that affect each roadway data type.
- Alternatively, the implementation of a comprehensive data collection device that combines multiple data collection efforts.
- The development and implementation of quality control procedures for distress data.
- Summary of recommendations.

DATA COLLECTION POLICY PRINCIPLES

One of the objectives of this project is to propose a comprehensive data collection policy. Such a policy should help the Department to allocate existing resources to data collection. The policy should also allow the Department to prioritize data collection needs to address either a decrease in available activities or an increase in data collection needs.

There are several principles proposed for such a comprehensive policy. These are enumerated below:

1. Roadway data collection activities provide information that is used to drive decisions that have a large impact within South Dakota.

2. Each of the elements of the data collection practices of the SDDOT (e.g., roughness, friction, distress) should be collected so they are individually of the highest possible quality given the Department's resources. Similarly, different data types used to make decisions affecting South Dakota's pavements should be of similar quality.

3. Data that have no value to the Department should not be collected.

4. Data that have a "high" value and a large impact on decisions are worthy of a proportionally larger investment than data that have a "lower" value.

   An initial assessment of value is provided in Table 21, but this can and should be refined based on the Department's determination of its own values.

5. Data collection frequency for different data types should match usage. For example, if distress and roughness are used together in a performance index, they should be collected at the same frequency. If little change in roughness is noted from year to year, but a more noticeable change occurs every 2 or 3 years, than an appropriate frequency for collecting such data is every 2 or e years.

6. Needed roadway data should only be collected once. If the same data are used in different locations throughout the Department, the data should be collected and available in a timely and readily accessible manner.

   There are two approaches to accomplishing this. The first is to ensure that the data users are satisfied with data quality. The second is to ensure that users are receiving the data when they need it. This is primarily a processing and data distribution issue.

7. Both the technologies associated with roadway data collection and the uses of the collected data are changing rapidly. The SDDOT should regularly reassess its practices in the face of such changes, perhaps every 3 to 5 years

This chapter addresses each of the data elements in the roadway data collection activities of the SDDOT and suggests improvements that are possible with limited additional resources. This is an application of the first six of the preceding principles. After considering the individual data types, the applicability of automated distress data collection equipment is addressed. This addresses the seventh principle, evaluating new technologies.

PROCEDURAL RECOMMENDATIONS TO IMPROVE ROADWAY DATA COLLECTION ACTIVITIES

Recommendations for each data procedure are provided in this section. In most cases, these do not involve any substantial additional cost. For example, if the recommendation is to document the procedures, it is assumed that manuals can be assembled without significant effort and no costs are identified. If the recommendation is to use different equipment or to implement new technology, an attempt is made to identify costs.

Data Types

Roughness

Based on information provided by users and a review of technology and other practices, there is no problem with the roughness data collection procedure or the equipment used in this procedure. However, development and implementation of quality control procedures will help to ensure that the output continues to be useful. These include the development of control sections over which the equipment can be run on a weekly basis (see *Dynamic Calibration* below) and the required use of daily system checks of the equipment's hardware and software. The draft protocol on roughness that is being developed under the FHWA's sponsorship offers good guidelines for such procedures. The final version of this protocol should be integrated into a guide for South Dakota's roughness measurement program.

It is recommended that the roughness survey be performed annually over the same sections as the distress survey. An appropriate data collection segment is 0.4 km (0.25 mi) so that it corresponds with distress survey segment lengths. An annual survey of the entire network is recommended until performance model development is satisfactorily completed. The survey should be performed in the outer lane in both directions on divided highways and in one direction on undivided highways. Results should be reported as an IRI for each pavement management section. Roughness should be measured in both wheelpaths and the result reported as an average of the wheelpaths.

Static Calibration

Static calibration involves the evaluation of the accuracy of the sensors (displacement test) and an evaluation of the integrity of the accelerometers (bounce test). These tests should be conducted on a daily basis. Another test of interest is the evaluation of the DMI to ensure its accuracy, but this test does not need to be done daily.

In the displacement test, a thin block or plate of known thickness (typically 25 mm [1 in]) is placed beneath the sensor. After ensuring that the block is level, multiple readings are taken to ensure that the readings are within a specified tolerance (usually provided by the manufacturer). If they are out of tolerance, a new calibration factor must be calculated.

In the bounce test, the vehicle is rocked vertically and horizontally by the operator jumping on the bumper. During this test, the profile output should be flat and show very little variation. If it is not, the equipment is not operating properly.

Dynamic Calibration of Profiling Equipment

The dynamic calibration takes the actual profile measurements (or profile-generated roughness statistics) obtained from the equipment and compares them to those obtained from a baseline measure (usually rod and level survey or dipstick survey). The intent is to ensure that the results compare favorably to one another (again, within a specified tolerance). If significant differences exist, this may suggest an equipment error.

Two test sections, each 0.4 km (0.25 mi) long, should be established for AC and PCC pavements. Pre-measurement of the IRI should be made on these test sections, using either a rod and level or dipstick survey to establish baseline roughness measurements. Then the ARAN should be operated weekly over both sections. The costs associated with equipment calibration are minimal. It is not believed that additional staff or equipment would be required, nor should calibration require additional costs.

Rutting

Rutting is estimated from data collected with the three-point rut bar mounted on the ARAN van. A document that describes this practice, similar in format to the FHWA's *Draft Rut Depth Protocol*, needs to be prepared to describe this data collection activity. As noted in the *Draft Protocol*, specific quality control practices that are applicable include the following:

1. Establish test sections with known rut depth statistics for both pavement wheelpaths and rate these sections with the ARAN on a weekly basis. Ideally, test sections would cover a range of pavement classifications.

2. Develop and perform on-board checks that compare rutting measurements with previous values and validate measures against an allowable range. Rutting should never decrease, so even a manual examination of trends would be of value. By comparing new data with the previous survey, instances in which rutting decreased or increased by more than a specified reasonable amount would be flagged to be retested.

These validation procedures should not require a significant additional expense to perform. While creating the test sites may require several days, checking the equipment will not require a substantial effort. However, the FHWA's entire draft rutting protocol should not be implemented in its current form because the severity levels for rating rut depth are not refined enough to be useful to the SDDOT.

The rutting survey should be performed at the same frequency as the roughness and distress survey. In general, the three-point rut bar provides sufficient information about the size of a rut to model rutting, assess material performance, and identify safety hazards. No additional costs are required to adopt the recommended changes, although productivity may be slowed down slightly.

If the SDDOT is concerned about the ability of the vehicle operator to place the vehicle in the precise lateral position required to measure the deepest rut, one solution is for each operator to make a mark on the hood or windshield to assist in aligning the vehicle with edge or center markings. However, the wheelpath location does vary and in the end the mark may not be of much help. If the Department remains dissatisfied with rutting measure variability, they should consider adding sensors to the rut bar so that a more continuous transverse profile is measured.

Pavement Distress

Recommendations concerning pavement distress are discussed in the section on quality control and are not repeated here. In addition to the protocols already discussed, the FHWA has supported the development of draft protocols that address crack measurement on all pavement surfaces, and faulting on PCC pavements. The adoption of these protocols in South Dakota is not necessary at this time. They appear to have been developed to facilitate standardized automated distress surveys and perhaps even automated interpretation of the results. Adopting these would require significant changes in distress definition, which would in turn impact modeling deterioration. The current definitions used in South Dakota are more detailed and provide more complete information about the surveyed pavements.

Falling Weight Deflections

While there are no major problems identified with the FWD procedures, a review of the current practices in South Dakota suggests several opportunities for improvements.

1. There does not appear to be any documented procedure currently being followed for FWD testing. Although reference was made to the Texas DOT's procedure being used as a guide, it is not clear that these procedures are always followed. A manual should be developed that specifies how FWD testing is to be performed in South Dakota. Such a manual should describe the testing pattern, equipment settings, and testing frequency for the different pavement types encountered in the State, such as AC pavements, AC-overlaid pavements, jointed concrete pavements, continuously reinforced concrete pavements, and possibly surface treated pavements. This manual should also address what backcalculation procedures are used for the different pavement types. Limitations of the technology may be considered as well. The manual should include documentation for both highway and airport pavements.

   The graphical output in the existing FWD test reports is good. Providing explanations of the output and the different ways of presenting the data in the manual will help to educate potential users about the technology and how it may be used to their advantage.

2. Network level surveys are not needed and should not be performed. There is sufficient variability in deflections due to factors that are not well understood that the use of network-level deflection data is questionable. The estimated savings from eliminating this portion of the survey is somewhere between $19,750 and $39,500 (8/26 of the labor costs would be eliminated, but some travel time would still be needed). The testing plans for concrete and interstate asphalt pavements appear appropriate, based on SDDOT's experience.

3. Perform project-level surveys for pavements that are candidates for rehabilitation where a decision is being made between a structural and a functional rehabilitation. If it is known that a functional overlay will be constructed, no FWD testing is needed.

4. System calibration appears to be satisfactory, but there does not appear to be any standard that is being followed. Part of the State's FWD manual should address annual calibration at an approved calibration center, and the regular calibrations that can be done in the field. Field calibration sites are not needed, as it would be impossible to achieve any repeatability.

5. FWD data are ready to be stored in dROAD/dTIMS and the RES. Because these data are now being used at the project level, reconsider the need to store them with network-level data.

Special studies may also be established to continue to make the FWD a useful tool within the Department. The use of FWD data for assisting in posting spring load restrictions is one good application of such special studies. Because the regions are trying to post fewer and fewer roads each year and FWD data are only one part of the decision process, this program should be able to continue with a reduced testing effort. Other special uses of the data include assessing seasonal variability of deflections for different pavement types, field testing and calibrating AASHTO's nondestructive testing method of overlay design, and developing typical support values for different native materials.

Friction

Friction data collection, or the measurement of skid resistance, has been a problem in South Dakota for some time. Since 1991, seasonal employees have been used to collect these data, and variability in the results has been attributed to this shift to part-time employees.

The Department did not collect friction data in 1996, but has discussed restoring the equipment to operational condition and using it in 1997. While friction data collection efforts are greatly reduced, the need for these data remains. Areas where skid numbers are important include:

- Airport runway evaluation.
- Evaluation of new pavement materials and construction methods.
- Accident investigation and litigation defense.

The Regions also expressed a desire to continue to receive skid data. Because of the demand and the value of skid data, it is recommended that the Department continue to collect it. While the SDDOT could walk away from its commitment to maintain this equipment, such an approach does not serve the users of South Dakota's roadways. A well thought out program of friction testing, addressing new materials, performance of selected existing pavements, and both general and specific safety issues would benefit the State. There does not appear to be any demand for a network-level survey. Instead, the equipment can be used by Aeronautics, by the Regions and Research on an as-needed basis, and by Materials and Surfacing.

The importance of using properly maintained and calibrated equipment can not be over-emphasized, as was pointed out in discussions with the Massachusetts Highway Department. While non-calibrated equipment may be adequate for research or other in-house purposes, it can not protect the Department when lawsuits occur. Therefore, if the equipment is made operational again, the previously described daily and weekly calibrations should be retained. The equipment should also be sent to a national calibration site at least every 3 years. If the friction data are used in support of the Department in legal actions, the equipment should be calibrated at a national site every 1 to 2 years.

The cost impacts of resuming the collection of skid data are an important issue. The Department estimates that $40,000 is required to restore to working order their existing equipment;

replacement equipment wil cost approximately $170,000. Given the magnitude of this difference, it is recommended that the existing equipment be restored if it can be calibrated within acceptable limits. Operating costs are estimated at between $25,000 and $35,000 annually. Approximately $31,500 was spent in this area in FY 1995 and $20,800 was spent in FY 1996. No national calibration was performed in either of those years, which would have made the costs higher.

Videolog Images

The videolog survey is performed on State trunk highways on a 3-year cycle, with image acquisition controlled by good weather and the available light. The mission of this equipment is the collection of inventory data on roadway and roadway-related features. In interviews throughout the Department, it was found that there were many different users of this technology and almost as many ideas for additional uses if only the output could be enhanced in one way or another. For example, while images can be viewed they can not be "manipulated" or easily used in other applications. A move to the use of digital images would allow the images to be of greater value to the end users.

The videolog survey acquires an image approximately every 8 m (25 ft), but users expressed an interest in a more continuous survey (rather than discrete photos). A more continuous survey is possible with other equipment available on the market, but the Department has expressed an interest in identifying potential improvements to the data collection process that do not entail large capital expenditures.

For videolog output to be more useful throughout the Department, especially to those who need more detailed pavement data, the following capabilities are desirable:

- Automatic, accurate interpretation of the data.
- More frequent data collection than a 3-year cycle.
- Ability to operate under a variety of lighting conditions.
- Digital rather than analog output.

The technology for automatic interpretation of the data is not yet mature enough to be useful to the Department. Data could be collected more frequently than every 3 years and under a variety of lighting conditions, but not without some modification. This would include the addition of cameras that would allow image capture from the front and rear of the vehicle and external lighting systems. This equipment is not well suited to these changes and they are not recommended.

The manufacturer of the videolog equipment has introduced a digital upgrade system. Examining the platform, data storage and connectivity of the new system suggests that it would be completely compatible with desktop workstations that would support Electronic Document Imaging for project files. Those workstations would include 530 mm (21 in) high-resolution monitors as well as 2 to 4 Megabytes of VRAM.

The digital roadway images are stored as JPEG files on a dedicated server connected to the Department's Local Area Network (LAN). Those files are highly compressed from approximately 1 Megabyte (MB) to 70 Kilobyte (KB). The compressed image size would allow the Department to transmit the images over the Wide Area Network (WAN) as readily as 50 KB 216 x 280 mm (8.5 x 11 in) document images contained in the project files.

The manufacturer recommends that files be stored on Redundant Array Of Inexpensive Disks (RAID)-5 magnetic disk drives for rapid access. Data storage would be approximately 7 Gigabytes (GB) per 1,600 km (1,000 mi) roadway segment. The data could also be stored on optical discs in a jukebox as an option, but would offer slower retrieval time.

The approximate cost of a digital system to replace the analog system the SDDOT currently uses is $450,000. This includes a completely outfitted new van and central office processor. The price is for a complete system, including all processing equipment, hardware, and software. Casual users could view images using Adobe Photoshop at a small cost. Intensive users who need full image and associated data retrieval and manipulation capability would require workstation software at a cost of about $2,000 per seat.

By integrating the roadway images into a client-server network, every image-enabled user on the network, including field locations, could have convenient access to roadway images. The digital images could be manipulated by the user at the desktop to provide the most effective view.

Being able to view roadways from the desktop should reduce the number of trips taken to the field to verify data, eliminate costly design errors, and facilitate decision making. Predesign can be facilitated as well as the inventorying of signs, guardrails, and so on. The data collection process also supplies an attributes map as a by-product that can be incorporated into building a Global Positioning System (GPS). In addition, the system would provide the capability for interested parties to collaborate with the same roadway image displayed at the same time on multiple network computers.

Because of the high demand for the video images from many users throughout the Department, it is recommended that the Department make this transition if and when users' computer systems are updated to allow image access. However, for the present no changes from current practice are recommended. This includes modifications to the equipment and altering the frequency of the survey. Eventually, the Department should convert over to one vehicle that performs all of the automated data collection, including image acquisition, and that point is some time in the future.

Sufficiency Rating

With the introduction of dROAD the sufficiency rating is no longer being computed. It is recommended that the sufficiency rating no longer be calculated or used.

Traffic

The traffic data collection activities undertaken by the Department are the most comprehensive and costly of all the different roadway data collection efforts. However, the data generated by these efforts are an essential component of the decision-making process throughout the Department. This information impacts pavement characteristics (it is used in design and rehabilitation, and in the analysis of pavement performance) and funding (funds for many different purposes are allocated based on traffic data).

Overall, traffic data collection is being undertaken in accordance with standard accepted practices. Some of the problems with traffic data do not appear to result as much from shortcomings in the technology as they do from misconceptions related to its application. As an example, many of the procedures associated with providing traffic numbers rely on statistical principles. These include determining the required number of data collection sites and establishing the frequency of data collection. Because of the sampling techniques, there may be a perception that some traffic data are more than accurate than others. However, overall the principles are being applied correctly. The concerns seem to be related to interpolations, or estimations of traffic at one location based on measurements made elsewhere. However, without increasing the data collection effort substantially, this is the most effective means of determining traffic data where none have been collected. It is recommended that the Data Inventory office issue a final version of their traffic monitoring documentation and either distribute it to traffic data users or make them aware of its availability. Admittedly, this document may not be read by data users. But it should enable data users who are interested in becoming more familiar with how published traffic data are obtained.

Verification of Curves and Other Geometric Data

One of the greatest problems with data appeared to be with geometric data, and especially with pavement widths. The *Needs* book reports predominant widths for a section, including shoulder widths, pavement widths, and ROW widths. These do not necessarily correspond to a measure made at any given location along the section. While reporting a predominant width may be an appropriate means of presenting condition or traffic data, it is not adequate for some uses of geometric data. For example, users may be concerned about the minimum width, since it, more than a predominant width, controls safety and operations.

Two methods of improving pavement width information in the database are suggested. A "high tech" method is the addition of a camera to the videolog survey. This camera would be pointed down at the pavement and a scaled grid would permit a reasonable estimation of pavement width. An attempt is underway to determine if the current Mandli system supports such a technology. An alternative method is to consider adding a entry to the *Needs* book that reports the minimum width. This could be added to the same column by reporting "Predominant Width/Minimum," and presenting the data as "8/5" for example. No additional costs should be incurred in reporting this additional information.

COORDINATED SURVEY IMPROVEMENTS

In order to make effective decisions about pavements (for example, regarding type and timing of maintenance, rehabilitation, and reconstruction), it is imperative that data needed to make such decisions is available. The field collection of roadway data, however, is one of the most labor-intensive activities within a Department of Transportation. The ARAN vehicle is currently used to collect rutting, faulting, and roughness information, while the Mandli equipment is used to create a videolog of pavement inventory information. However, the ARAN vehicle has the capability of acquiring video images of both the pavement surface and inventory features, so that with some modification distresses could be acquired at the same time as roughness, rutting, and faulting data (as could videologs if this option were selected). These distresses would then be interpreted at a workstation operated in the office. In addition to the ARAN, there are several manufacturers that are marketing equipment that collects almost all of the roadway data used by the SDDOT, and new devices are being developed all the time. Even now, there are many states that have adopted this type of data collection and report very satisfactory results.

According to the manufacturer (Roadware), the projected costs to modify the ARAN and add a workstation so that it could collect pavement distresses are about $110,000. These include the addition of a vertical gyro system, a grade system, and survey calibration and software. The addition of another camera and associated equipment (at about $25,000) would allow the videolog to operate more frequently, and improve the efficiency of the distress survey.

There are several advantages to performing distress identification at the workstation. First, it reduces the amount of money spent on personnel in the field by eliminating the field trips currently being conducted by seasonal employees. One or two technicians or seasonal employees will still be needed to conduct the surveys at the workstation, but no costs are incurred for hotels and other travel expenses. Secondly, the workstation provides an opportunity for direct communication between the raters and experienced staff, which should improve the quality of the data being reported. The use of a workstation to examine pavement condition should not result in a loss of distress survey quality. In the current procedure, the rater seated in the van surveys 40 0.4 km (0.25 mi) segments while traveling on the shoulder. Their results are not anticipated to be significantly different from those obtained from reviewing a video taken by cameras aimed at the pavement surface.

The use of a workstation also creates an opportunity to involve other individuals in the data collection effort. The State of Illinois, for example, invites District personnel to the central office to conduct the condition surveys for the Interstates. The Interstates in each District take approximately half a day to rate, so all nine Districts are rated in approximately 4 to 5 days. Because both central office and District personnel are involved in the rating, there are no disagreements in the overall ratings. The Illinois Department of Transportation (IDOT) has purchased workstations for each of its Districts, as well as for the central office, so that the Districts conduct the non-interstate condition surveys. Approximately 10 percent of the sections for each District are reviewed in the central office for quality control purposes.

The ARAN vehicle could also easily be adapted to be used for videologging efforts through the addition of a video camera in the front of the vehicle, should the Department be interested. This approach is used by a number of states, including Pennsylvania (as discussed previously). This would further reduce the number of passes required over each pavement section. The workstation would provide an opportunity for anyone in the central office to view the video for sign inventory, striping, or any other purpose.

Using a video-based distress survey also provides SDDOT with the flexibility to incorporate new technology as it becomes available. The protocols being developed by the FHWA appear to be moving toward procedures that accommodate the collection of distress data using automated vehicles such as the ARAN. These protocols involve the classification of distress based on its location within a pavement lane. For example, distress located within the outer third of a pavement lane is classified as alligator cracking. Distress located in the middle third of the lane (between the two wheel paths) is classified as block cracking or transverse cracking depending on the crack pattern. The implications of these protocols on the condition rating approaches being used by state highway agencies is unclear since the reclassification of distress based on location rather than pattern has not been studied. However, SDDOT could modify its existing procedures to accommodate the protocols, should they be adopted. Even if the SDDOT purchased a workstation for conducting condition surveys, it could still be used for reviewing unusual pavement sections or verification of the automated survey results.

It is recommended that the SDDOT not adopt the use of automated distress surveys at this time, however. While the need for data for performance modeling is still being evaluated, it would be premature to change the distress data collection procedure. This approach should be reconsidered in 2 to 3 years, at which time initial performance models will be available, new (and perhaps less expensive) equipment will be available, and the Department's needs should be firmly defined.

MEASUREMENT AND QUALITY CONTROL PROCEDURES TO IMPROVE ROADWAY COLLECTED DATA

Introduction

One of the original objectives of this project was to identify quality control procedures that could be implemented to improve the overall quality of the collected data. When the project began, there appeared to be a widespread belief that certain elements of roadway data were frequently inaccurate or otherwise flawed. The researchers hoped that these flaws could be identified and that a system-wide solution could be identified to improve the quality (i.e., accuracy and reliability) of the roadway data.

Through interviews, the process evaluation, questionnaires, and studies of the literature and the practices of other agencies, it became clear that accuracy of South Dakota's roadway data was not the real problem. Furthermore, in almost every case there already existed good quality control procedures for the data collection process. For example:

- The equipment used to collect roughness and rutting undergoes hardware and software calibrations on a regular basis.
- The FWD is regularly calibrated and its software detects errors while the data are being collected. It is also calibrated at a SHRP/FHWA calibration center.
- The friction equipment, when used, is calibrated on control sections on a regular schedule and has been tested and calibrated at a national test site.
- The traffic data undergo numerous software and manual checks. The Chaparral system will make this process even more efficient.

The concept of quality control procedures does not really apply to South Dakota's videolog image collection or to the verification of vertical and horizontal curves, and the sufficiency rating is no longer calculated. This leaves only the pavement distress data process for consideration. This section describes current and proposed quality control procedures for the pavement distress data collection effort.

Overview of Distress Data Collection

Each year, seasonal employees are used to collect pavement distress data. Starting in the spring, these employees are hired, trained, and then travel in vans in two groups of two to collect pavement distress data around the State from May to August. The data are keyed into computer files and in November the data are downloaded into dROAD. In the newly revised version of the *Needs* book, pavement distress data are reported as indices and thus become a part of the road-related decision-making process throughout the State. The pavement distress data also drive pavement deterioration models that have an impact on many critical design and rehabilitation decisions.

Because of the importance of pavement distress data, it is critical that accurate and meaningful distress data be collected. In order for this to be accomplished, an appropriate distress data collection *process*, including proper training, effective survey techniques, and periodic checks and verification, must be in place. The following recommendations address these needs and introduce a quality control procedure that will improve the overall accuracy of the data with minimal additional effort or expense.

Recommendations

<u>Training</u>

Since seasonal employees are used to collect the distress data, it is imperative that they be properly trained in distress identification. The following are specific recommendations regarding the training of the seasonal employees. Most of these steps are already being followed.

1. Before conducting any surveys, spend a minimum of 1 week training the crews in pavement distress identification. This training should consist of both office training (reviewing pavement distress types and distress survey procedures) and field training (using nearby roads for practice). The training should be based on SDDOT's *Visual Distress Survey*

Manual (Draft), which itself should be periodically reviewed to ensure that the photographs and their descriptions remain applicable.

a. After spending about one day reviewing distress types and pavement distress survey procedures, conduct pavement surveys on nearby roads of each pavement type that is found in South Dakota. The results of the two crews will be compared to one another and to the results obtained from an experienced rater. (An experienced rater is defined as either the instructor from the above-noted training or any other individual identified by the Department as qualified to make accurate distress calls.) Any differences in the results shall be discussed to determine why those differences exist. These roadways should be resurveyed until results obtained by both crews agree. Where necessary, establish ground rules as to how to classify unique or unusual distress conditions that may be encountered.

b. Part of the training session should be devoted to safety issues in relation to conducting pavement surveys under traffic on high-speed pavement facilities.

c. To provide the seasonal employees with an idea of how the data are to be used (and consequently to emphasize the importance of accurate distress data collection), a portion of the training should include a review of the development and use of the *Needs* book and the STIP. The use of pavement data in general and distress data in particular in prioritization and actual decision-making should be emphasized.

d. The training should conclude with a test that covers the key concepts believed by the Department to be essential for pavement raters to master.

2. Survey crews should be trained to document and discuss with the experienced raters any unique or unusual distress conditions. Over the course of the data collection activities, the supervisor should share any such information with the other crew as needed to ensure consistency and accuracy in the overall collection of the data.

Field Surveys

After the 1-week training period, the distress crews will begin their distress surveys. The following are recommended features of the distress surveys:

1. Begin both survey crews on an initial survey trip of about 1 week in length. These trips can be to a location of the Department's choosing; the important part is that each crew is accompanied by an experienced rater. Each crew conducts surveys on their respective assigned pavements, with guidance and supervision provided by the experienced rater. The experienced rater should work with both crew members to verify their ability to correctly identify and rate pavement distresses on all the pavement types that will be encountered.

2. The driver and the rater should be encouraged to discuss distress identification issues, or even to periodically change roles to reduce some of the tedium of the surveys.

3. Raters should not use the results of the previous year's survey as the starting point for data entry. This is especially the case with inexperienced raters, for whom the temptation to modify last year's results might be too strong. If ASR and D-cracking are consistently miscalled, consider providing the previous survey's results.

4. A cellular phone should be made available to each crew so that they can easily contact the experienced raters in Pierre with questions on distress identification and collection procedures. A camera could also be useful (a digital camera might be even more useful) for photographing questionable calls and discussing them back in Pierre with the experienced raters.

Validation Procedures

Validation is needed to ensure the reliability of the data that are collected under the program. For pavement distress data collected by humans in an admittedly subjective process, this is highly problematic. The following procedure is not perfect, but does go a long way toward improving the data collection process. It is premised on the notion that the trainers and other experienced DOT staff will correctly identify pavement distresses every time they evaluate the pavement. Therefore their evaluations can be said to constitute "baseline values" or the actual condition of the pavement. While this will not always be the case, this quality control procedure requires that the collected data be compared to what is believed to be the actual measure. With this in mind, recommended validation procedures are outlined below:

1. Selected segments of the surveyed network are to be grouped together into "control" sections. A control section is made up of 40 pavement management segments; the total number of control sections shall cover approximately 2 to 5 percent (280 to 700 two-lane km [175 to 435 two-lane miles]) of the pavement network. They should include segments from each pavement type found in South Dakota and should contain a representative sample of the types and severity levels of all of the pavement distresses associated with that pavement type (based on the current version of SDDOT's *Visual Distress Survey Manual*).

2. Control sections are rated by the experienced raters. With these sections distributed throughout the State, these initial surveys by the experienced raters can be done either in one long trip or as part of several shorter trips throughout the summer (simply staying ahead of the scheduled stops of the survey crews). The shorter the delay between the experienced raters' and the survey crews' evaluation of the control, the less likely there is to be a discrepancy due to an actual change in pavement condition.

3. Control sections are spaced throughout the State so that each survey crew will pass survey control sections according to the following schedule:

   - During the first 3 weeks of the survey, each survey crew will rate one control section a day.

- For the remainder of the survey each survey crew will rate one control section a week.

4. It is imperative that the location of control sections remain unknown to survey crews, although they should have a general understanding of their existence and purpose. The schedules will be drawn up by the survey coordinator in order to include the required control sections but without revealing any information about their location to the survey crews.

There are three components of the survey to compare as part of the quality control check: the distress type, severity, and extent. The survey crews' results are evaluated by first looking at the distress type. The survey crew should have at least 90 percent of the distresses properly identified to be accepted. Consider the example survey sheets for the experienced rater, shown in Figure 17, and the survey crew, shown in Figure 18 (which only include 10 segments for simplicity's sake, rather than the 40). In the experienced rater's control section 21 distress types were identified, so the survey crew must get at least 18 correct (0.9 x 21, rounded to the nearest integer) to pass. In this example, the survey crew made 2 incorrect distress calls (shown by an "X" in the distress box) so the distresses are identified within acceptable limits.

Next look at distress severities. For each <u>correctly identified</u> distress, the survey crew can correctly identify the severity level, miss by one level, or miss by two levels, depending upon whether the experienced rater has scored either a L, M, or H (i.e., if the rating is M, the most the survey crew can miss is by one rating; for a L or H they could miss by two). Using the experienced rater's form, count the number of possible misses (for each experienced rater's M, the count is –1; for each L or H it is –2). In this example, the maximum number is –33. However, the –33 is corrected to –31 because of the one missed distress in segment 9 on the survey crew's sheet. An acceptable score is to rate correctly at least 70 percent of the total possible, which in this example is 22 (0.7 x 31). Count the number of actual misses by counting 1 point for each severity that is off by one level and 2 points for each severity off by 2 levels. In this example, there were a total of 8 points counted. The actual score is then 23 (31 – 8), so the severity ratings are identified within acceptable limits.

Finally, consider the distress extents. Again not counting the distress types that were mis-identified, ignore the severity rating and calculate the sum of missed points by the survey crew. For example, if the survey crew rated an extent of 4 and the experienced rater had a 2, then a –2 is added to the missed points. Calculate the missed points for each segment and total them. Then add up the maximum amount that the survey crew could miss, using the scheme shown below:

- If survey crew extent is 1 or 4, maximum miss is 3
- If survey crew extent is 2 or 3, maximum miss is 2

If the survey crew has at least 60 percent correct then the results are acceptable. In Figure 17 the maximum amount missed could be –50 (again, the transverse cracking extent is not counted because the distress type was missed) so that the survey crew's extent rating is acceptable if it is

ASPHALT DISTRESS SURVEY FORM

DATE: 5/20/97 RATERS: EXPERIENCED RATER

HIGHWAY	TRANSVERSE CRACKING			FATIGUE CRACKING			PATCHING AND PATCH DETERIORATION			BLOCK CRACKING		
SEGMENT	L	M	H	L	M	H	L	M	H	L	M	H
1		2					1					
2	1				3							
3						4		2				
4	2											
5		2		1			1					
6		1			2					1		
7											3	
8		2							1			
9			3	1				3				
10						4			3			

INSERT DISTRESS EXTENT RATING UNDER THE PROPER SEVERITY COLUMN FOR EACH DISTRESS

DISTRESS TYPE	EXTENT RATING			
	1	2	3	4
Transverse Cracking	>50 ft spacing	25 ft to 50 ft	< 25 ft	
Fatigue Cracking	1 to 9% of wheelpath	10 to 24% of wheelpath	25 to 49% of wheelpath	≥ 50% of wheelpath
Patching and Patch Deterioration	1 to 9% of area	10 to 24% of area	25 to 49% of area	≥ 50% of area
Block Cracking	1 to 9% of area	10 to 49% of area	≥ 50% of area	

DISTRESS SEVERITY LEVELS			
DISTRESS TYPE	LOW	MEDIUM	HIGH
Transverse Cracking	< ¼ inch wide	> ¼ inch width & < ¼ inch depressions	> ¼ inch width & > ¼ inch depressions
Fatigue Cracking	Fine parallel hairline cracks	Alligator pattern clearly developed	Alligator pattern clearly developed with spalling and distortion
Patching and Patch Deterioration	Little or no defects with smooth ride	Clear signs of cracking on notable roughness	Heavy cracking or other distress with distinct roughness
Block Cracking	6 ft to 10 ft block sizes	3 ft to 6 ft block sizes	< 3 ft block sizes

Figure 17. Example of an experienced rater's survey sheet for a control section.

ASPHALT DISTRESS SURVEY FORM

DATE: 5/27/97 RATERS: SURVEY CREW

HIGHWAY	TRANSVERSE CRACKING			FATIGUE CRACKING			PATCHING AND PATCH DETERIORATION			BLOCK CRACKING		
SEGMENT	L	M	H	L	M	H	L	M	H	L	M	H
1		2						2				
2	2				3					1		
3						3		1				
4	2											
5		3		1				1				
6	2					1					2	
7										2		
8		2						1				
9				2			3					
10						4			2			

INSERT DISTRESS EXTENT RATING UNDER THE PROPER SEVERITY COLUMN FOR EACH DISTRESS

DISTRESS TYPE	EXTENT RATING 1	2	3	4
Transverse Cracking	>50 ft spacing	25 ft to 50 ft	< 25 ft	
Fatigue Cracking	1 to 9% of wheelpath	10 to 24% of wheelpath	25 to 49% of wheelpath	≥ 50% of wheelpath
Patching and Patch Deterioration	1 to 9% of area	10 to 24% of area	25 to 49% of area	≥ 50% of area
Block Cracking	1 to 9% of area	10 to 49% of area	≥ 50% of area	

DISTRESS SEVERITY LEVELS

DISTRESS TYPE	LOW	MEDIUM	HIGH
Transverse Cracking	< ¼ inch wide	> ¼ inch width & < ½ inch depressions	> ¼ inch width & > ½ inch depressions
Fatigue Cracking	Fine parallel hairline cracks	Alligator pattern clearly developed	Alligator pattern clearly developed with spalling and distortion
Patching and Patch Deterioration	Little or no defects with smooth ride	Clear signs of cracking on notable roughness	Heavy cracking or other distress with distinct roughness
Block Cracking	6 ft to 10 ft block sizes	3 ft to 6 ft block sizes	< 3 ft block sizes

Figure 18. Example of a survey crew's survey of the control sections.

ROADWAY DATA QUESTIONNAIRE

As part of our study of the field collected roadway data in South Dakota (SD96-03), we interviewed many people who either collect or use the data. In order to supplement the results of those interviews, we would appreciate your responses to the following questions. To complete the questionnaire, for each data type please place a check mark in the column that you feel best answers the question that is asked. Your answers will help us to better quantify the relative importance of different data throughout the Department. Thank you for your time.

Jim Morrow
David Peshkin

	How important is the accuracy of this data type to you in the performance of your job?					What do you think about the accuracy of the data that you receive?				
Data Type	Essential	Very Important	Average Importance	Not Very Important	Not Needed	Error Free	Very Accurate	Accurate Enough	Not Very Accurate	Very Inaccurate
Traffic Volume										
Vehicle Weights (e.g., ESALs)										
Pavement Roughness										
Pavement Rutting										
Friction										
Falling Weight Deflections										
Videolog Images										
Pavement Distress Survey (cracking)										
Transverse Joint Faulting										
Geometrics										

	How important to your job is the timing of when you receive this data?					Are these data received in a timely manner?				
Data Type	Must be Timely	Very Important	Average Importance	Not Very Important	Doesn't Matter	Always	Usually	Often Enough	Not Usually	Never
Traffic Volume										
Vehicle Weights (e.g., ESALs)										
Pavement Roughness										
Pavement Rutting										
Friction										
Falling Weight Deflections										
Videolog Images										
Pavement Distress Survey (cracking)										
Transverse Joint Faulting										
Geometrics										

	What is the overall value of this data to you in the performance of your job?				
Data Type	Essential	Very Valuable	Average Value	Limited Value	Isn't Needed
Traffic Volume					
Vehicle Weights (e.g., ESALs)					
Pavement Roughness					
Pavement Rutting					
Friction					
Falling Weight Deflections					
Videolog Images					
Pavement Distress Survey (cracking)					
Transverse Joint Faulting					
Geometrics					

Comments (optional):

____

____

____

____

Name of Respondent ____________

Office ____________

Please return to the Office Of Research by 12/20/96. Thank you.

Figure B.2. Questionnaire on roadway data value, accuracy, and timeliness.

Table B.1. Overall results of questionnaire.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of receipt		Overall Value of Data	
	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating
Traffic Volume	47	4.0	43	3.1	47	3.6	44	3.9	48	3.8
Vehicle Classification	45	3.4	39	3.1	44	3.0	37	3.8	48	3.3
Vehicle Weights	47	3.3	34	3.0	42	3.0	33	3.5	45	3.3
Pavement Roughness	46	3.4	36	3.1	42	3.1	37	3.7	46	3.3
Pavement Rutting	45	3.4	35	3.2	43	3.1	36	3.7	45	3.4
Friction	45	3.2	36	3.2	41	2.7	34	3.4	47	3.0
Falling Weight Deflections	46	3.5	35	3.4	43	3.2	39	3.6	46	3.4
Videolog Images	44	3.1	38	3.3	44	2.8	40	3.6	46	3.0
Pavement Distress Survey	44	3.3	32	3.2	41	3.0	34	3.8	41	3.1
Transverse Joint Faulting	44	3.3	43	3.1	40	3.1	34	3.6	39	3.2
Geometrics	45	3.4	38	3.1	44	3.0	38	3.5	45	3.2

Table B.2. Questionnaire results, Regions only.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of receipt		Overall Value of Data	
	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating
Traffic Volume	19	3.9	17	3.2	19	3.2	18	3.8	19	3.7
Vehicle Classification	19	3.4	16	3.1	19	2.8	16	3.7	20	3.3
Vehicle Weights	19	3.3	15	3.1	18	2.6	16	3.6	19	3.4
Pavement Roughness	19	3.6	15	3.1	17	2.8	17	3.7	19	3.3
Pavement Rutting	19	3.6	15	3.1	19	3.0	17	3.7	19	3.6
Friction	18	3.8	17	3.4	17	2.9	17	3.7	19	3.6
Falling Weight Deflections	19	3.7	14	3.2	19	3.3	18	3.7	19	3.6
Videolog Images	18	3.0	15	3.2	19	2.8	17	3.6	19	3.2
Pavement Distress Survey	19	3.4	15	3.1	18	3.0	17	3.6	18	3.3
Transverse Joint Faulting	19	3.4	16	3.2	18	3.0	17	3.6	16	3.4
Geometrics	19	3.5	16	3.2	19	2.8	18	3.6	19	3.1

Table B.3. Questionnaire results, all respondents except Regions.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of receipt		Overall Value of Data	
	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating
Traffic Volume	28	4.1	25	3.1	26	4.0	26	4.0	29	3.9
Vehicle Classification	26	3.3	24	3.0	24	3.2	21	3.8	28	3.2
Vehicle Weights	28	3.3	19	2.9	23	3.3	17	3.5	26	3.2
Pavement Roughness	27	3.3	21	3.1	24	3.3	19	3.8	27	3.3
Pavement Rutting	26	3.3	20	3.3	23	3.3	18	3.7	26	3.2
Friction	27	2.8	19	3.0	22	2.5	18	3.2	28	2.5
Falling Weight Deflections	28	3.2	21	3.5	23	3.2	26	3.5	27	3.2
Videolog Images	25	3.3	23	3.3	24	3.0	22	3.5	27	2.9
Pavement Distress Survey	25	3.3	17	3.2	21	3.3	17	3.9	23	3.0
Transverse Joint Faulting	25	3.2	17	3.0	21	3.3	17	3.6	24	3.1
Geometrics	26	3.3	22	3.1	24	3.3	21	3.5	26	3.3

Table B.4. Comments Added to Questionnaires.

Name	Comment
Ben Orsbon	These are difficult issues related to quality and continuous improvement in data because it must be used immediately after it is loaded to meet the time frames desired for delivery of the construction program. Another good question to the highest levels of management might be: How important is the _____ data to the mission of the department and to the mission of your division?
Dean Hyde	We depend on data totally! It needs to be reliable.
Steve Gramm	Accident & Maintenance Cost Data? Videolog would be more valuable if it was pavement oriented. Faulting data not collected independently yet. Geometric data would be very accurate if not for the horizontal curve data.
Dennis Winters	BIT facilitates the use of data by DOT users and collectors. I don't feel I should comment on this survey without being a user or collector of the data.
Roger Lehmkuhl	My office is neither a user or collector of this data, therefore I am unable to provide any further ratings for this survey.
Terry Jorgensen	County-projects involve an on-site inspection prior to design - We receive only traffic volumes from outside sources.
Vernon Bump	We do not use any of this information
Terry Varilek	I use the data very infrequently to research information on various projects, and to answer questions about the roadway that may come up. If I didn't have the information I could get it from someone else.
Monte Schneider	No comment-not really users
Daris Ormesher	Importance is dependent on the project assigned to the research office.
Steve Ulvestad	I have no involvement in any of these type of data.
John Adler	I do not use this data in my current position.
Todd Goldsmith	I would like to see a Pavement Management Report.
Dennis Landguth	This value is important to the field offices when it helps us program future projects.
Larry Afdahl	No way of knowing accuracy on most items. Timeliness importance is for programming and design. We use most current data at the time. We use what is in the NEEDS book and don't know when done.
Sharon Johnson	Assumed geometrics to be survey data.

SD96-03-F

SD Department of Transportation
Office of Research

Review of SDDOT's Field Collected Roadway Data

Study SD96-03
Final Report

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June 1997

DISCLAIMER

ACKNOWLEDGMENTS

This work was performed under the supervision of the SD96-03 Technical Panel:

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David Huft .... Research
Pat Kappenman .... Mitchell Region
Kenneth Marks .... Data Inventory
Mark Leiferman ....Planning and Programming
Dennis Winters ....Information Services

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16. Abstract

The South Dakota Department of Transportation (SDDOT) collects and processes a vast amount of roadway data to support internal and external analysis and design systems. These data are collected by different offices within the SDDOT, are collected by a variety of techniques, and are used for many different purposes.

This report presents findings from an evaluation of the SDDOT's roadway data collection procedures and processes. The following roadway data elements are considered: traffic, roughness, rutting, friction, falling weight deflections, videolog images, distresses, faulting, and geometrics. Current practices within the Department are evaluated, as are practices within other agencies and Federal initiatives. Within the Department, issues such as data accuracy, timeliness, and value are assessed by soliciting input from a broad range of data users through a series of interviews and a widely distributed questionnaire.

The data collection *process* is examined, with the objective of identifying procedural means of improvement. Each data element is tracked, including steps such as data collection, reduction from raw data into summary data, data entry, data use, and feedback. Components of the process that can benefit from streamlining are identified, and areas where improvements can be effected are also indicated. Process improvements include additional training for data collectors and modifications to the quality control efforts that are currently in place. Automation of the distress survey data collection is an alternative that should be considered if the Department wishes to implement a comprehensive pavement data collection plan.

Specific recommendations regarding improving the SDDOT's data collection procedures are also presented. These include the development of a manual for each data collection effort that either includes or references protocols for the data item.

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INTRODUCTION

Over the years, as a result of both internal needs and as a response to external forces, the South Dakota Department of Transportation (SDDOT) has developed analysis and design systems for which a vast amount of roadway data is collected. These data are collected by different offices within the Department, are collected by a variety of techniques ranging from manual to automated, and are used for many different purposes.

The specific data types of interest in this project are:

- pavement distress
- traffic
- pavement friction
- roughness from profile
- rutting
- sufficiency rating
- videolog images
- falling weight deflections
- verification of vertical and horizontal curves and other geometric data

Ultimately, the collected data are an integral part of the decision-making process within the Department. And, inevitably, these data have an enormous impact on the fiscal decisions made by the SDDOT. The value of accurate and timely data to facilitate making these decisions is incontrovertible.

The various data collection processes developed to meet the Department's needs have tended to evolve independently, and not as part of an effort to achieve explicitly stated Department objectives. At the same time, because of the nature of the data or, in some cases, the methods of data collection, the accuracy of the collected data and the uses to which the data are put have not necessarily evolved together. As an example, profile data are collected by automated means but distress data are manually collected. Is this a reflection of the most cost-effective means of collecting these data, the most accurate means, or the state of the art? As another example, profile and deflection data are both collected with automated equipment, but different procedures are followed in the calibration of this equipment. Are the procedures for each the best, or is one set of data inherently more accurate than the other? If there is variability, how does it affect the decisions that are based on the output?

Effective decision making is most likely to take place when the information upon which decisions are based is accurate, useful, and timely. However, not only must this information be all of these things, but users of the data must also recognize and acknowledge that the data have these attributes. Within the SDDOT there are implied concerns about roadway data. Some Divisions are collecting their own pavement data. Some data users have complained about either the timeliness or the accuracy of the data that they receive. There has been a change in the way several types of data are collected, without an evaluation of whether or not the changes are desirable.

In May 1996, the SDDOT initiated a project to assess the status of their roadway data collection processes, considering them both individually and as a system. The Department's objectives are summarized below:

1. Determine the Department's need for field-collected roadway data and its value and cost.
2. Review present methods for acquiring and ensuring the quality of roadway data.
3. Assess the accuracy of field-collected roadway data, excluding traffic data.
4. Coordinate the Department's data collection program with the FHWA's project to develop data collection protocols.
5. Recommend a comprehensive policy and procedures for roadway data collection.

Each of these objectives was achieved during the course of this project. The primary sources of information included interviews in person and over the telephone with data users and questionnaires. These sources provided information on the need for data, present methods of acquiring that data, and the data's accuracy. In addition, a literature review and interviews with representatives of other State Highway Agencies provided valuable information for use in this project.

SOUTH DAKOTA'S ROAD DATA COLLECTION PRACTICES

Roadway data collection efforts within the SDDOT were evaluated as both a coordinated process and as a series of discrete activities. The process review highlighted several opportunities to improve the flow of information within the Department. In most instances data are collected and processed by the same staff. Therefore data processing (and the subsequent availability of the results) are not available until late in the fall. Another observation is that seasonal employees or interns, who are not available for hire until May, collect the data. The use of full-time employees in this role would permit the data collection efforts to begin in April and continue until October. In turn, this could lead to more processed data being available sooner in the year. Another potential benefit is that full-time employees are more likely to be responsive to the Department's needs for accurate data.

Each of the collection practices was also studied and the individual procedures were outlined. This information is presented along with the feedback received from users of the data. Considering the data types one by one it was concluded that most data collection procedures are sound, carried out correctly, and provide accurate data for use throughout the Department. Exceptions to this general conclusion include the skid data, which are not being collected, and the sufficiency rating, which is no longer being calculated. Where there were concerns with data accuracy, delving further into the causes of the concerns usually revealed that it was the users' lack of familiarity with how the data are collected or summarized that resulted in the perception of inaccuracy rather than bad data that were being collected.

ROADWAY DATA USERS' NEEDS

The conclusion that the data were sufficiently accurate for most Department uses was verified by a questionnaire on data accuracy, value, and timeliness that was distributed throughout the

Department. The results failed to distinguish any single data type as inaccurate, without value, or untimely. Furthermore, the value of the collected data appeared to be in line with the costs expended to collect the data. This was especially the case when the impacts of the various decisions made from the data were considered.

OVERALL RECOMMENDATIONS

There are a number of recommendations that emerged from this project. Data collection procedures and protocols were found to be acceptable in most cases, although in almost every instance they lacked documentation. Developing documented procedures for each data type that cover collection, measurement, reporting, and quality control procedures would benefit both the data collectors and the data users. With the exception of pavement distress, this entails documenting and implementing existing procedures. For pavement distress, a detailed quality control procedure was developed and proposed to the Department. The FHWA's Draft Data Collection Protocols were found to be useful for rutting and roughness, but of limited applicability for pavement distress.

Considering existing practices, it was recommended that the Department discontinue the use of the Sufficiency Rating and recommence collection of skid data. Roughness, rutting, and pavement distress should all be collected at the same frequency. The videolog survey results would be more useful throughout the Department if they could be made more accessible. This is feasible if the equipment is converted to digital format and some additional image processing and handling capabilities is added. The costs of this were estimated to be around \$450,000, with an additional expense of \$2,000 for each viewing station that is needed.

One of the project tasks was to propose a comprehensive data collection policy. A policy is described that addresses principles which should guide the data collection practices of the Department. In includes an approach to prioritizing among the different data collection efforts, (based on subjective valuations of the data), and makes recommendations regarding data accuracy and the efficiency of the data collection effort. Implicit in this policy is the need to perform data validation (QA/QC) so that data are of the highest possible quality. As part of the comprehensive policy, it is argued that data be collected in a <u>consistent</u> manner from type to type, that the different data types be of similar <u>quality</u>, and that data be collected in a more <u>timely</u> manner. These objectives can be achieved by documenting procedures, developing or adopting data collection protocols, and moving to permanent rather than seasonal employees to collect roadway data. To implement this comprehensive policy, existing resources can be used, modified by the specific recommendations that are summarized below. As an alternative, the Department could acquire a single vehicle that collects distress, roughness, rutting, and faulting. This equipment could also be used to replace the videolog survey if properly configured. The costs of adding distress survey capabilities to existing equipment was about \$110,000; no estimate was made of what it would cost to add the videolog capabilities as well. If new equipment were considered, costs of equipment acquisition alone would be over \$300,000.

The move to automated distress surveys is not recommended at this time. Until the Department is sure how the needs of their pavement management system are to be met, it is more cost-effective to improve the existing procedures as recommended below.

SUMMARY OF SPECIFIC RECOMMENDATIONS

The following are the specific recommendations that are made to the Department regarding their current data collection practices. Implementing these changes would meet the objectives of a comprehensive data collection policy within existing fiscal constraints.

Recommendation 1: Data collection should be considered as a comprehensive process, governed by the principles stated in chapter 7. These can serve as a guide in making decisions about each data collection activity, as well as in determining how to allocate resources among the various data collection activities.

Recommendation 2: The Department of Transportation should perform annual surveys of pavement roughness, reporting an International Roughness Index in both wheel paths. The survey should be performed in the outer lane in both directions on divided highways and in one direction on undivided highways. Both static and dynamic calibration procedures should be adopted to ensure data quality.

Overall, no problems were found with the roughness data collection. The recommendations are intended to standardize the data collection procedure and to ensure its quality.

Recommendation 3: Rutting data should continue to be collected with the three-point rut bar mounted on the ARAN van. Rutting should be measured annually in the outer lane in one direction on undivided highways and in both directions on divided highways. Improvements in the quality of the data will be obtained from operating the equipment over test sections with known rut depth statistics and by performing an on-board comparison of rutting measurements with previously collected data. This on-board check can be manual, does not need to be run on all sections, and can be completed with minimal additional effort.

The current procedures are satisfactory, but there is an opportunity to standardize practices and raise the level of quality by performing quality control checks on a regular basis.

Recommendation 4: There are several opportunities to enhance the FWD data collection practice. It is recommended that the Department start by developing a comprehensive data collection manual that covers the FWD equipment use in all of its applications, including an annual calibration. The Department should stop performing network-level surveys, perform project-level surveys for rehabilitation projects, and continue special FWD studies. Road where it is known that there is minimal change in deflections need not be tested on a regular basis (e.g., high quality PCC pavements).

Overall, the development and use of documented standardized procedures for the FWD that include regular calibration will improve the quality of the data and the use of the equipment. The recommendations regarding which pavements to test are based on how the data are used. The FWD is most effective as a project-level tool and it should be used where the data can have an effect on the decision-making process.

Recommendation 5: The South Dakota Department of Transportation should resume the use of its skid-testing equipment by investing the estimated $40,000 needed to return the equipment to operation. The equipment should be maintained in working order and follow a regular calibration schedule, such as every other year. No network level use of the equipment is needed. There are several project-level applications for the equipment, including new material performance, evaluation of the effectiveness of construction or rehabilitation methods (e.g., diamond grinding, tining patterns), and accident investigation.

There is enough demand for friction data that the Department needs to have some means of providing these data. The Department already has equipment that can be restored to operable condition for approximately one-quarter of the cost of new equipment and that should be sufficient to meet the Department's needs.

Recommendation 6: Currently videologs are compiled over a third of the network annually. No changes are recommended to the current practice of videolog surveys. The videolog survey should be updated to a digital system and the video images made available over the Department's network when technology permits. This is expected in approximately 2 years.

If the technology is not used for distress data collection, there are several enhancements that should be considered and are discussed in the body of this report. These include increasing the frequency of the surveys and acquiring more than on image every 8 m (25 ft). The concept of using automated methods to obtain images of the pavement from which the distress survey can be performed is addressed as part of the comprehensive data collection policy.

Recommendation 7: The calculation and use of the Sufficiency Rating is no longer needed and should be discontinued.

The Department's list of upcoming projects is now developed from other indices and the Sufficiency Rating no longer serves any purpose.

Recommendation 8: Traffic data collection is performed in accordance with widely accepted practices. No changes are needed other than publicizing the existence of the reports that document the traffic monitoring process.

The Department has already prepared documentation that describes the traffic data collection procedure. The Department has also implemented a traffic data acquisition system that performs numerous quality checks as the data are collected. This documentation should be made available to those interested in acquiring a better understanding of the process. Any dissatisfaction with this process appears to stem more from a lack of understanding of current procedures than from any shortcomings in the procedures themselves.

Recommendation 9: Reporting of geometrics data in the *Needs* book should be altered so that the minimum roadway shoulder width and the predominant width are available to users. If there is also variation in the reported width for the driving lane and left shoulder these should be added as well.

What initially appeared to be a question of data accuracy turned out to be unfamiliarity with what was actually being reported. The predominant width that is reported is a value of some interest to users, but the minimum width (such as of a roadway or shoulder) may actually control more decisions. Reporting both values should address the needs of more users.

Recommendation 10: The distress survey should be performed over the entire network on an annual basis. This report proposes a Quality Control procedure for distress data collection. This procedure should be implemented and validated using actual survey results. Based on the outcome of field trials of the procedure, the Department should make revisions to either the QC procedure, the data collection procedure, or both.

The distress survey has the greatest potential for inaccurate results because it is essentially a manual process, while all users use data collection or measuring instruments. Furthermore, the survey is performed by seasonal employees who receive minimal follow up on their work after their training is completed. A QC procedure that checks the survey results against those of experienced raters is proposed. This can be used to verify data accuracy and identify areas of weakness that can be corrected with additional training.

Recommendation 11: The Department should require that all data collection procedures be documented so that they are thoroughly understood by anyone involved in their data collection, processing, or application. The documentation should be in the form of manuals of practice that address how data are to be measured, collected, manipulated, and stored. These manuals should also cover QC procedures as described above.

Many of these data collection practices are very individualized practices, dependent upon the knowledge and skill of either one or a small group of people. If the individual(s) involved in these data collection efforts were to become unavailable suddenly, the Department would be highly susceptible to a total loss of the skills required to collect or analyze certain data types. The availability of documented procedures not only helps to protect the Department against this loss, but it also helps to improve the standardization of the procedures and the repeatability of the results.

Recommendation 12: Hire a full-time employee to be in charge of the annual distress surveys. This employee's responsibilities would include updating the RES file.

Adding a full-time employee addresses several issues, including data quality, the timing of data entry, and the timing of data availability. The minimal costs associated with this are well worth the returns.

2. Project Objectives

The objectives of the project were defined in the Request for Proposals and are summarized below:

1. Determine the Department's need for field-collected roadway data and its value and cost.
2. Review present methods for acquiring and ensuring the quality of roadway data.
3. Assess the accuracy of field-collected roadway data, excluding traffic data.
4. Coordinate the Department's data collection program with the FHWA's project to develop data collection protocols.
5. Recommend a comprehensive policy and procedures for roadway data collection.

Each of these objectives was addressed during the course of this project. A brief description of how the objectives were met follows.

Determine Data Collection Needs

The Department's need for roadway collected data was evaluated in several different ways. Interviews were conducted with data users identified both by the Office of Research and by the data providers. Data users were asked what data they use and what data they would like to have. These interviews were followed up with questionnaires and, in some cases, with additional questions over the phone or in person. Value was measured through a questionnaire that solicited feedback on the value of different data elements to job performance. A subjective assessment of the data value was also made by considering all of the different decisions that are based on the field-collected roadway data. Data collection costs for 1995, 1996, and 1997 were supplied by the Department.

Review Present Methods of Acquiring and Ensuring the Quality of Data

To learn how roadway data are presently collected, interviews were conducted with roadway data collectors. Where available, any manuals or other instructional or reference material on the data collection activity were provided by the office responsible for the data collection. A literature review provided some initial information about data collection practices outside South Dakota. Telephone interviews were also held with Department staff involved in roadway data collection at a number of other agencies. This provided a basis for reviewing the Department's approach and for learning about the steps that others are taking to ensure data quality.

Assess Data Accuracy

This project did not include collecting roadway data and comparing it to some "ground truth" or baseline data for accuracy. Data accuracy was evaluated through several subjective measures, however. Both data users and data collectors were asked for their opinions about data accuracy. These questions were then repeated in the questionnaire mentioned earlier. During the interviews, some data users commented about the amount of corrections that were needed for different data types and this feedback provided another subjective evaluation of data accuracy. A draft quality control plan was developed for the pavement distress survey, but it was not verified in the field.

Coordinate with the FHWA's Data Collection Protocols

There is no specific project task that addresses this objective. However, the protocols themselves have the potential to address at least two of the project's objectives: ensuring quality of roadway data and being part of a comprehensive procedure for roadway data collection. The latest available draft versions of the protocols were supplied by the Department and reviewed for their applicability in South Dakota.

Recommend a Comprehensive Policy and Procedures

Several recommendations regarding data collection are found in the conclusion to this report. Only one of the data collection efforts—distress data—was found to be lacking procedures for quality control. A quality control procedure is recommended to the Department, but it requires field testing and refinement. For other data collection efforts, a number of recommendations are made that should, if implemented, improve the overall quality of the effort with minimal additional expense or effort. Most recommendations are in the form of incremental improvements to the existing procedures. These are fiscally conservative and acknowledge the existing trend toward reducing expenses. As an alternative, recommendations are also made to acquire a single survey vehicle that can collect distress, roughness, rutting, and faulting, while also providing video images. Acquisition and use of such a vehicle would help to further consolidate the data collection activities in a single location.

Summary

This project is a comprehensive evaluation of the roadway data collection practices within the SDDOT. The project objectives were largely met by examining and analyzing practices in South Dakota, as well as around the country.

3. Project Tasks

The technical panel established ten tasks which, when successfully completed, would meet the project's objectives. The project tasks are repeated here, and are followed by a brief explanation of the accomplishments that were made for each task and where in this report additional information is found.

Task 1. Meet with project's technical panel to review project scope and work plan.

A meeting between the technical panel and the Principal and Co-Principal Investigators took place in Pierre, South Dakota on May 13, 1996. During the meeting members of the technical panel shared their concerns about roadway data collection practices in South Dakota and discussed what they hoped this project would accomplish. The meeting itself did not result in any major changes to the work plan because feedback from the panel had already been incorporated into a revised work plan prior to the meeting. During the course of the project, the researchers met several more times with the technical panel to fine tune the direction of the project.

Task 2. Identify, describe, and prioritize the SDDOT's needs (including measurement definition, frequency, required accuracy, and value) for field-collected roadway data, including traffic data, by interviewing data users and reviewing regulatory requirements.

The data collection process included interviews, questionnaires, a literature search, and interviews with other agencies. The approach used to collect the information to complete this task is summarized below. The results of that data collection effort are found in chapters 4 and 5. Rankings of the Department's needs and the prioritization of those needs are found in chapter 6.

Interviews

The focus of this project is the field-collected roadway data that is used in the Department. The most important sources of information about these data are those individuals and Divisions who collect, process, and use the data. Therefore, an interview process was initiated to solicit feedback from this group.

Interviews were conducted over a 4-day period from May 13 to May 16, 1996. All but one of the interviews were conducted in person at the DOT in Pierre; one of the interviews was held at the Pierre Region office and one was held by telephone.

Sixteen different interview sessions were held over this period and at least 40 different Department employees were included in those interviews. The list of interviewees was selected with the intention of obtaining input from as many people as possible who have an interest in field-collected roadway data. While it was originally intended that everyone would be interviewed individually, once the list of people to interview was drawn up it became clear that many of the meetings would be held in groups. Even so, some of the people that might have been able to contribute were not available and others were interviewed instead. A list of those who participated in the interviews is presented in Appendix A.

There was no formal interview procedure although, within reason, each group of interviewees was asked similar questions. Those who collected data were asked questions such as the following:

- What data do you collect?
- How do you collect it?
- How often?
- What procedures are followed?
- Are there calibration or QC procedures?
- Are there any problems associated with the data?

There wasn't really any office that was solely responsible for "processing" data, so this did not constitute a distinct group. Data processing is usually done by the data collectors, and is occasionally done by data users.

Data users were asked about the data that they receive and how they use it. The types of questions they were asked included the following:

- What roadway data do you use?
- How accurate is it?
- How timely is it?
- Do you manipulate the processed data in any manner, including verification or quality assurance?
- Do you collect any of the data available elsewhere on your own?

Several of the interviews were followed up with additional questions, either in person or by telephone.

Questionnaires

Shortly after the interviews were completed, the research team distributed a questionnaire to several of the interview participants. Their responses indicated that a broader distribution of a follow-up questionnaire would be beneficial to the interpretation of the responses. Consequently, while not originally a part of the proposed approach to this problem, a questionnaire was added to address the lack of quantitative feedback. The questionnaire was especially helpful in addressing issues of relative cost and benefit of data elements. The results of the questionnaire are discussed in chapter 6, and the individual responses are provided in Appendix B.

Literature Search

A literature search was performed as part of the proposal preparation process. This search helped to identify recent activities in this area, but it was noted that the topics covered in this project span the pavement field, and it proved difficult to focus in on the specific interests of this project through the literature search. The research team was made aware of several key studies of interest to this project, including an ongoing study by the Federal Highway Administration (FHWA) and a recently completed National Cooperative Highway Research Program (NCHRP) Synthesis. Key elements of the literature search are summarized in chapter 4.

External Interviews

Representatives from several other State Highway Agencies were contacted for input on their data collection activities. The purpose of these interviews was to benchmark South Dakota practices against agencies in the region and agencies elsewhere in the United States who have long been active in data collection. For this report, representatives from seven other State highway agencies were contacted and interviewed either by telephone or in person. Summaries of these interviews are provided in chapter 4.

Task 3. Review literature, other States' practices, and federal initiatives to establish common data collection protocols to identify best practices for collection of roadway data, excluding traffic.

Key sources in the literature were reviewed for the project team's proposal submittal. The review of States' practices is described in this chapter and detailed results are described in chapter 4, as are the Federal data collection protocols. The applicability of the Federal protocols is discussed in chapter 7.

Task 4. Conduct a process review of SDDOT's roadway data collection program (including traffic) to assess its effectiveness, efficiency, resource requirements, and cost. Include interviews of data collection personnel.

The review of data collection processes is described in chapter 5 and the interview results are presented throughout the report, but concentrated in that chapter. The most comprehensive interview summaries are found in chapter 4. Some conclusions from the process review are found in chapter 7.

Task 5. Propose measurement and quality control procedures needed to satisfy the Department's need for roadway data (excluding traffic), preferably avoiding large capital investments.

The review of the existing data collection practices showed that quality control procedures were, for most data collection activities, already developed. What was lacking in some cases was the adherence to a strict policy of implementing the already existent quality control procedures.

Proposals for improvements to data collection procedures and processes are discussed in chapter 7.

Task 6. Provide an interim report and presentation to the project's technical panel describing the recommended measurement and quality control procedures and a plan for their evaluation.

An interim report was submitted to the technical panel in October 1996, and it was followed by a meeting between the project team and the panel. This report summarized the research findings up to that point. It did not include a recommended measurement and quality control procedure, but did provide recommendations for improving the data collection process. Following that meeting, an evaluation of the data collection procedures was completed, leading to the recommendations for a quality control procedure that are described in chapter 7.

Task 7. Upon the technical panel's approval of the recommended procedures and evaluation plan, validate the quality control procedures using measurements collected by Department staff.

Because of the nature of the recommendations emerging from this project (specifically, to change the distress survey), it was not possible to validate the quality control procedures. The 1997 survey did not start until May, when the quality control procedure was being completed. However, recommendations for validation of the procedure are made in chapter 7.

Task 8. Develop recommendations for a comprehensive data collection policy for setting data priorities and coordinating collection of roadway data, including traffic. Apply the policy to propose one data collection program that fully addresses the SDDOT's roadway data needs. If present resources are insufficient to support the complete collection program, propose another program that best addresses the needs within current research constraints.

The Department currently has good practices, but some of the data collection procedures could be improved by minor changes. Such changes are described in chapter 7. A more substantial change is also described, which would result in increased costs but could also lead to more efficient data collection and lower annual collection costs. This is also described in chapter 7.

Task 9. Prepare a final report and executive summary of the literature review, research methodology, findings, conclusions, and recommendations.

This report constitutes the completion of this task.

Task 10. Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.

A presentation to the Research Review Board was made on June 12, 1997.

4. Review of Data Collection Practices Outside South Dakota

INTRODUCTION

This chapter provides an in-depth evaluation of the data collection practices outside the State of South Dakota. This evaluation includes the results of an extensive literature review, interviews with selected State highway personnel, and a review of Federal protocols. The literature review provides insights from the experiences and research conducted by others in this area. The review of the practices in other States provides a means of comparison to South Dakota's practices, as does the examination of data collection protocols.

The findings from each of these efforts are summarized in the respective sections within this chapter. The information in this chapter, in conjunction with the evaluation of data collection practices in South Dakota, provides the framework for making recommendations to improve data collection practices.

LITERATURE REVIEW

An extensive literature review uncovered many studies that are relevant to this research effort; however, it should be cautioned that this is a very dynamic field. Developments in roadway data collection, particularly in automation and computerized systems, have heralded many changes over a short period of time. As an example, the automated pavement distress equipment addressed as part of a 1987 report bears little resemblance to what is available today (Hudson 1987). That report considered devices produced by four companies: Gerpho, PASCO, ARAN, and Laser RST. However, just a few years later at a seminar on automated pavement distress data collection equipment, the following manufacturers presented information on devices (Cable and Marks 1990):

- ARAN (Highway Products International)
- AREV (Pavement Management Services)
- ARIA (MHM Associates)
- KJ LAW 8300A (KJ Law Engineers, Inc.)
- Laser RST (Infrastructure Management Services, Inc.)
- PAS-1 (Pavedex, Inc.)
- Pavetech (Pavetech, Inc.)
- PDI-1 (Roadman-PCES Inc.)
- Road Profiler (South Dakota DOT)
- Roadrecon (PASCO USA Inc.)
- Videocomp (Videocomp)

Today, some of these devices are no longer available, are not marketed in this country, or have undergone significant modifications in their capabilities since the 1990 report. Still other devices not on this list have been introduced and are being widely promoted. And although a recent survey of State practices showed that only a handful of highway agencies use automated distress collection technologies, this situation is changing rapidly (Gramling 1994).

Distress Data Collection

Throughout the years, many standards have been developed to provide a consistent means of collecting and reporting pavement distress data. The latest and likely the most comprehensive method was developed as part of the Strategic Highway Research Program (SHRP) and is currently being employed in the Long-Term Pavement Performance (LTPP) study (SHRP 1993). The *LTPP Distress Identification Manual* describes each distress, severity level, and measuring technique and is divided into asphalt concrete pavements, jointed concrete pavements, and continuously reinforced concrete pavements.

As part of a comprehensive NCHRP synthesis, a questionnaire regarding pavement data collection practices was completed by all 50 States, the District of Columbia, and 9 Canadian provinces (Gramling 1993). One of the questions dealt with the type of manual used to collect the distress data. Of the 60 agencies responding, 49 agencies indicated that they use some sort of manual. A large majority of those agencies (41) use manuals that were developed specifically for their agency. Figure 1 provides a summary of the type of manuals being used.

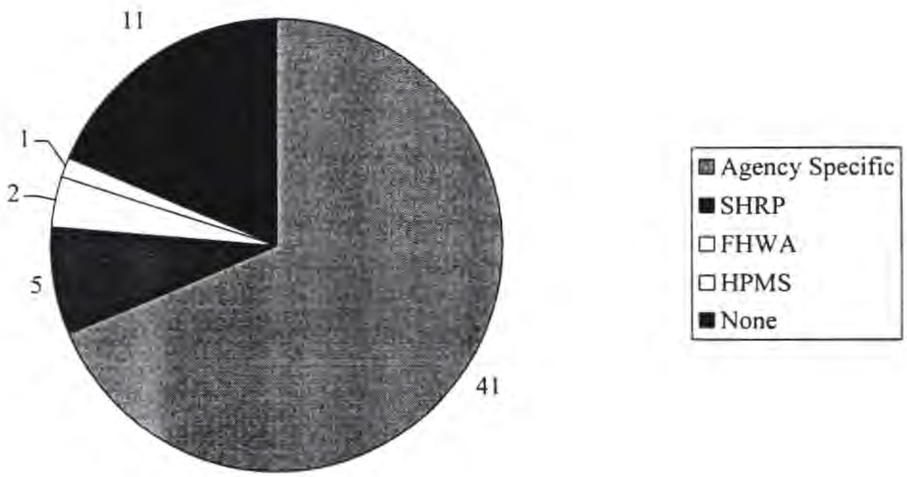

Figure 1. Distress manuals used by agencies (Gramling 1994).

In terms of the method used to collect the data, there is little consensus among the agencies. Windshield surveys, shoulder surveys, walking surveys, and automated surveys are all widely conducted. Table 1 summarizes the findings from a recent questionnaire survey. At the time of the survey, eight States were using automated data collection techniques, although it is believed that more States have now switched to an automated method. The use of automated techniques is much more widespread for the collection of rut depth measurements, with nearly half the agencies using automated methods. A comparative study of three collection methods recommended the South Dakota Profiler for collecting rut depth data at the network level (DuBose 1991). Automated methods for collecting faulting data are used by less than 30 percent of the States (TRDF 1994).

Table 1. Summary of distress data collection methods (Gramling 1994).

Data Collection Method	Number of States	Number of Provinces
Windshield	14	4
Shoulder	9	0
Walking	9	1
Combination	8	4
Automated	8	0

For the most part, the cost of the equipment bears a direct relationship with the accuracy of the equipment. At least one study reports that automated methods tend to rate the severity of some distress types lower than ratings obtained by manual methods (Smith et al. 1996).

Some agencies survey 100 percent of the pavement, while others designate a predetermined representative sample (Gramling 1994). Most of the agencies survey the pavements annually, whereas some conduct surveys biannually. Less than 10 percent of the agencies conduct surveys less frequently than every other year. The agencies record the data either on paper forms or on computers. The few remaining agencies record the data on video or film (likely those using automated techniques).

Distress data collection is viewed as the most costly part of the data collection effort. Some agencies find it easier to contract for distress data collection, so they do not have to devote agency personnel to the effort (Smith et al. 1996). Contracting out this activity also allows data collection using automated methods without the agency having to purchase expensive equipment. When contracting out this activity, the FHWA (1993) recommends that the agency define the required data and let the market forces define the methods for collecting the data.

Two other issues that require consideration in any distress data collection program are training of the survey crew and quality assurance. Training helps ensure that the data are collected accurately and consistently. Quality assurance, on the other hand, provides validation of the data collection and input process. Figure 2 illustrates the degree of training provided by the various agencies. Over 80 percent of the agencies provide some degree of training to the survey crews. However, the amount of training varies significantly from less than a day to several months. About one-third of the agencies indicated that they do not provide any quality assurance. The other agencies either perform random resurveys, compare the results to previous years, or perform checks in the office.

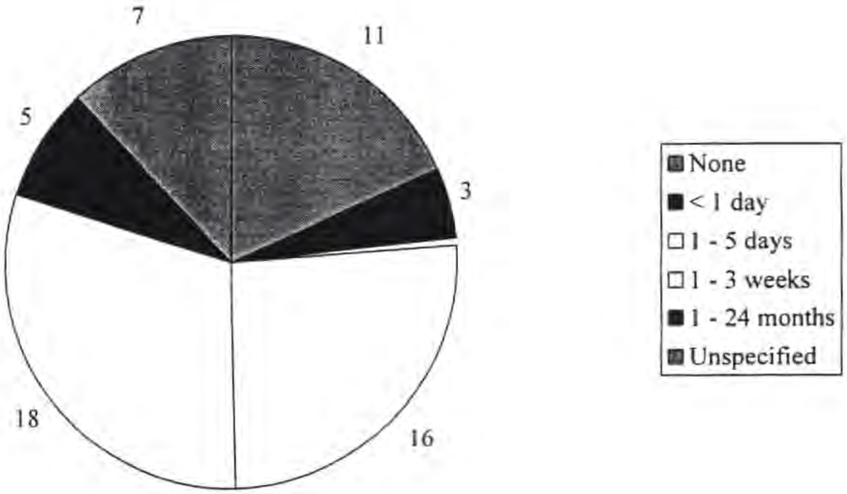

Figure 2. Amount of training provided to survey crews (Gramling 1994).

Roughness Data Collection

Although the collection of other forms of data are important, the collection of roughness data should be viewed as one of the more critical elements of a roadway data collection program, as it is roughness that ultimately affects highway users. The equipment for measuring roughness can be categorized into two general types: response type road roughness measuring systems (RTRRMS) and profilers. RTRRMS determine the pavement roughness by measuring the effect of roughness on the movement of a vehicle or wheel. Profilers, on the other hand, produce a continuous signal or trace related to the true profile of the pavement surface.

Comparison of surveys conducted in 1986 and 1991 (see table 2) indicate that more States are moving toward the use of noncontact (acoustic or laser) road sensors (Sayers et al. 1986; Gramling 1994). Of 18 States indicating that they planned on purchasing new equipment, none planned to obtain RTRRMS (Smith et al. 1996). Automated equipment is capable of surveying at speeds of 72 to 80 km/hr (45 to 50 mph). The accuracy of profiling equipment has been mixed (Perera et al. 1996).

Table 2. Comparison of the use of roughness measuring equipment (Gramling 1994).

Equipment Type	Agencies Using in 1986	Agencies Using in 1991
GMR Profilometer (K.J. Law)	4	3
South Dakota Road Profiler	1	25
K. J. Law 8300	0	3
Cox CS800 Ultrasonic	0	8
Mays/PCA/Cox Ride Meters	32	22
ARAN	0	10
BPR Roughometer	4	0
Others	0	2

As with distress data collection, most agencies collect roughness data over the entire system either annually or biannually. Gramling (1994) indicates that the current trend is to survey the higher systems, such as Interstates, annually and to survey the rest of the network either annually or biannually. On two-lane roads, the common practice is to survey only one direction, whereas on four-lane roads, the outside lane in both directions is typically surveyed.

Several quality assurance measures are being used by the States to ensure the accuracy of the collected data. These measures include the following (TRDF 1994):

- Replicate testing of calibration sections.
- Manufacturer's daily equipment check procedures.
- Review by supervisor.
- Certified training of equipment operators.

These measures are used both alone and in combination.

The International Roughness Index (IRI) is the most common means of reporting roughness. From a recent survey, nearly 70 percent of the agencies reported the use of IRI, with either the Ridescore or Root Mean Square Vertical Acceleration noted as other means of reporting the data (Gramling 1994). The data are typically collected in both wheelpaths, with the average of the two values being reported. Of the agencies collecting data in only one wheelpath, the left wheelpath is used twice as frequently as the right wheelpath. One study reported that roughness measurements are more stable for the left wheelpath than for the right wheelpath (Hadley and Roper 1991).

Friction Data Collection

Friction between the tire and the pavement (commonly referred to as skid resistance) must be maintained at adequate levels to provide safe operating conditions for vehicles. Many pieces of equipment are available to measure pavement friction. A survey of 60 agencies in the United

States and Canada found over 80 different pieces of equipment being used (Gramling 1994). The locked-wheel trailer is the predominant type of equipment, reportedly used by 85 percent of the agencies. However, a wide range of manufacturers of locked-wheel trailers is represented in this 85 percent, as illustrated in figure 3. The use of a ribbed tire is much more widespread than a bald tire.

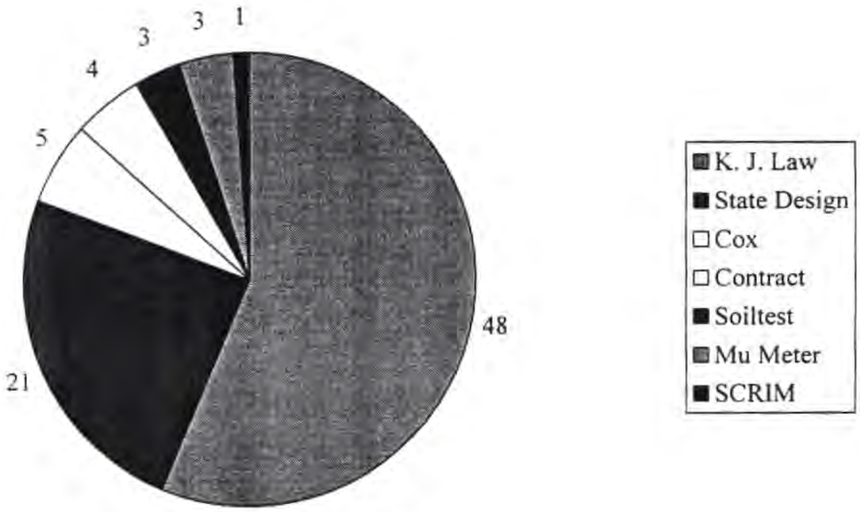

Figure 3. Manufacturers of friction testers being used (Gramling 1994).

The left wheelpath is generally considered the most critical because it receives more passes due to vehicles switching lanes. As a result, the left wheelpath is preferred when measuring pavement friction. As with other types of collected data, friction testing is typically conducted only in the outside lane on four-lane roadways. On two-lane roadways, however, it is more common to test both directions (in contrast to the collection of distress or roughness data, which is collected in only one direction).

Calibration and correlation of friction testing equipment is required to ensure accurate and consistent results. Most agencies reported the use of calibration methods with force plates employing air bearings, ball bearings, or other devices (Gramling 1994). Other means of calibration include the use of torque devices and selected test surfaces. Regional test centers are available for correcting equipment, and an ASTM/ARML program provides similar service at the agency's site. Such corrective actions are usually conducted every 1 to 3 years.

Deflection Data Collection

Deflection data are collected to measure the structural or load-carrying capacity of the pavement. Three types of equipment are available to measure pavement surface deflections (with examples of each provided in parentheses):

- Benkelman beam (California Deflectometer and La Croix Deflectograph).
- Falling weight deflectometer (Dynatest, KUAB, and Phoenix FWD).
- Vibratory load (Road Rater and Dynaflect).

Table 3 presents a summary of the type of equipment being used, as reported from a survey of 60 highway agencies in the United States and Canada (Gramling 1994). The most common type of equipment being used is the falling weight deflectometer (FWD). A strong shift toward the use of the FWD is observed in comparison to a previous survey conducted in 1986 (Epps and Monismith 1986). The FWD equipment contains rather complex instrumentation, which requires a well-trained operator and periodic calibration. Many of the devices contain built-in calibration procedures and external sensor-check procedures.

Table 3. Types of deflection data equipment being used (Gramling 1994).

Type of Equipment	No. of Agencies*	No. of Units
Dynatest	20	39
KUAB	4	4
Phoenix	1	1
FWD (type not specified)	9	10
Dynaflect	18	30
Lane Wells – Geolog	2	5
Road Rater	5	7
Benkelman Beam	7	26

* Some agencies own more than one type of equipment.

The collection of deflection data is not as widespread as other data collection efforts. Only 15 agencies reported that deflection testing is conducted at the network level, whereas 48 agencies conduct testing at the project level (the reported data include 13 agencies that do both) (Gramling 1994). Testing is typically conducted at uniform intervals throughout the project or network; a practice employed in 90 percent of the agencies.

Agencies reported a variety of uses of the deflection data (Gramling 1994). Of 60 agencies reporting, 42 agencies use the data for design purposes, and 2 other agencies are planning to do the same. Nine agencies use the data to assist in establishing seasonal loads, and the same number use the data to set load limits. Joint load transfer data are used by eight agencies for rehabilitation planning.

Strategic Highway Research Program

Another area of research that has application to this study is the work initiated as part of the Strategic Highway Research Program's Long-Term Pavement Performance (SHRP LTPP) study (and continuing as part of the FHWA's LTPP efforts). The LTPP program has considered standardization issues for FWD, roughness, distress, and videologging using the PASCO equipment. Both published and unpublished reports document the falling weight deflectometer, profilometers, distress interpretation from film logs, and calibration procedures. Some of the relevant reports include the following:

- *Comparison of the SHRP Profilometers* (SHRP-P-639) compares pavement profile data collected by four profilometers used by SHRP's LTPP. The purpose of the comparison is to determine if the profilometers can collect repeatable data with respect to each other as well as individually at a given site, and whether they are collecting accurate data (determined by comparing the IRI computed from profilometer data with that computed from Dipstick data).

- *Manual for Profile Measurement: Operational Field Guidelines* (SHRP-P-378) describes procedures to be followed when measuring pavement profiles for the LTPP program using the K.J. Law Profilometer, Face Technologies Dipstick, and the rod and level. Field testing procedures, data collection procedures, calibration of equipment, record keeping, and maintenance of equipment for each of the profiling methods are described.

- *Falling Weight Deflectometer Relative Calibration Analysis* (SHRP-P-652) describes the SHRP FWD testing procedures. These procedures require that FWDs be calibrated on a regular basis. One aspect of this requirement is monthly relative calibration of the FWD deflection measuring system. The FWDCAL software documented in this report was developed to perform these analyses.

- *Manual for FWD Testing in the Long-Term Pavement Performance Program* (SHRP-P-661) documents the procedures to be followed in the conduct of the LTPP deflection testing. It provides detailed testing programs for tests within each of the LTPP experiments developed to date, as well as field quality assurance and data handling guidelines. In addition, the SHRP FWD Calibration Protocol provides the first generally applicable, independent procedure for verifying and refining calibration of FWDs.

SURVEY OF STATE PRACTICES

As part of the effort to identify the best practices in roadway data collection, knowledgeable engineers from other highway agencies were interviewed about their Department's activities. The interviews were conducted informally, both in person and over the telephone, following no set form.

The individuals contacted for information are shown in table 4. It should be noted that these individuals are not necessarily the person in charge of the data collection effort or the pavement management activities of their respective agencies. However, they are acknowledged to be very familiar with the issues associated with roadway data collection in general, and the processes as conducted within their agency in particular.

Table 4. Contacts for survey of other agencies' practices.

Contact	Agency	Position	Telephone No.
G. Norman Clark	Kansas Department of Transportation	Geotechnical Engineer (including PMS)	(913) 296-3008
Larry Scofield	Arizona Department of Transportation	Director—Arizona Transportation Research Center	(602) 407-2620
Tim Horner, Brad Wentz, and others	North Dakota Department of Transportation	Pavement Management Engineer	(701) 328-4406
Newt Jackson	Washington State Department of Transportation (retired)	Former State Pavement and Soils Engineer	(360) 923-9359
Gaylord Cumberledge	Pennsylvania Department of Transportation	Chief, Roadway Management	(717) 787-1199
Steve Sissel	Nebraska Department of Roads	Staff Engineer	(402) 479-4317
Matt Turo	Massachusetts Highway Department	Director of Technical Services	(617) 973-7266

For selected roadway data collection activities, questions such as the following were asked of the interviewees.

- What equipment is used?
- What types of crews (e.g., full-time, part-time)?
- How often are the data collected?
- Describe the data validation and verification procedures.

The results of these interviews are summarized by agency and by distress type.

Arizona Department of Transportation (ADOT)

Distress Survey

The distress survey is done manually by a full-time crew. The survey is conducted over 30 m (100 ft) of one lane, at the milepost marker of every mile. This survey is performed annually over their pavement network. The survey is done using their own survey procedure, which includes a rating scale for the pavements of 1 - 3 - 5 - 7 - 9.

Deflection Testing

The Dynatest 8000 Falling Weight Deflectometer is used for design and rehabilitation projects; no deflection testing takes place at the network level. Larry wasn't sure about the testing, but believes that there are about 3 tests/km (5 tests/mi) unless circumstances require more intensive testing.

Friction

Skid resistance data are collected with a Mu Meter. Tests are run either over 42 or 150 m (140 or 500 ft). The Department's goal is to collect data annually over the entire network, but this probably doesn't happen.

Roughness

ADOT uses a K.J. Law 690, and annually tests 100 percent of the network. The resulting value is appended to the starting milepost. An IRI is calculated by planners, but Larry wasn't sure how they came up with it. Arizona is also using the K.J. Law equipment to report a Mays number, because there already exists a substantial amount of historical Mays data.

Rutting

Rutting used to be measured every mile as part of the distress survey. It should be part of the K.J. Law data collection effort, but is not.

Regarding the accuracy of roadway data within ADOT, no special steps appear to be taken. The PMS database has an as-built inventory, but no one checks it. There is very little data validation or verification; what does occur is usually done by those who are collecting the data. There will be a study of the effect of ADOT's new smoothness specifications on the IRI.

Nebraska Department of Roads

Responses were provided by Steven Sissel, who had been on the job for 3 months. He was very knowledgeable about the Department's activities, however, and where he was not sure of an answer he was able to solicit input from others in his group.

Nebraska has five full-time equivalents (FTEs) that are involved in roadway data collection. They go through many of the same processes as South Dakota, as they are involved in data collection and putting together the inventory, the 1-year plan, and the 5-year plan. There is a Needs group that takes care of the real PMS.

Roughness

Nebraska uses a laser profiler bar mounted on a van. This equipment is 1 year old; before that they used the South Dakota profiler. They survey their interstate pavements, bituminous pavements, and AC pavements annually, collecting readings every tenth of a mile. The data are processed on board, but verified upon data entry. There is an informal calibration of the data daily and a thorough calibration annually.

Distress

Distress data are collected in a visual survey. They run their bituminous pavements and the interstate system annually, and the PCC pavements every other year. This same crew of FTEs does the survey. They are assigned to different Districts, but try to get back on the same pavements every other year. Their survey procedure is a modified SHRP procedure. For each distress they identify its presence, severity (light, moderate, high, and X), and extent (occasional, frequent, and continuous). Some of the distresses they count are:

- Alligator cracking.
- Transverse cracking.
- D-cracking.
- Edge cracking.
- Wheelpath distress.
- Between wheelpath distress.
- Faulting.
- Popouts.
- Patching.

The shoulder is given a rating from 1 to 10. Drainage problems are rated as Yes or No.

AC pavement is rated by driving over the entire mile and giving it a rating; for PCC, ten panels at the start of the MP are examined, faulting is measured, and the entire mile is driven to see if the initial section is representative of the entire section.

The raters receive some training and do some internal informal calibration. Everyone else has been on the group for over 10 years, and they tend to look at pavement conditions the same way. For verification, they'll go out and check their findings perhaps a month later.

Rutting

Rutting measures are obtained by the profiler.

Photolog

Nebraska has photolog equipment, but it is not used by the data collection staff. This equipment is under Dan Bruegman, and Dennis Baumfalk provided information on its characteristics and use. Nebraska uses the Mandli analog system, collecting data on disks that can then be read at monitors. It is used for the following purposes: accident records, intersections, design, legal, bridge maintenance, and so on. Each District has a monitor, and there are four workstations in the central complex.

Friction

There is one person who operates this equipment. Steven thought that this data is collected every 3 years over the network.

Deflections

Deflection data are not collected or stored by this group, as the use of the FWD is not considered a part of pavement management. It is part of Materials and Testing, under George Woolstrum (479-4791).

Pennsylvania Department of Transportation (PennDOT)

Pennsylvania is changing its practices as of 1997. The information presented here reflects both past practice and the new procedures that will be implemented.

Distress

Through 1996, the pavement distress survey was performed manually. PennDOT employed 200 students every summer and they surveyed 100 percent of the NHS and 50 percent of the non-NHS every year. Some of the students held the job for more than 1 year, but it was not an explicit goal of the Department.

Prior to starting the surveys, all survey staff went through a centrally run training program. This was followed by field training, which was performed by the Districts. Surveys are run by each of the Districts; the surveyors are on their own, but there is a supervisor on the District's staff.

The survey is similar to an LTPP distress survey, although it is somewhat modified to meet the constraints of a large-scale data collection effort. The surveyors collect their data either walking or driving along the shoulder. Two calls are made on severity (low and high) and the extent is rated 0 to 5 percent, 5 to 30 percent, and above 30 percent.

There are two quality assurance programs in this system. The first is a 5 percent random sample that is surveyed by staff from the central office. This survey helps the Department to verify accuracy, to identify the need for any changes in the procedure, and to coordinate the calls made by the different Districts. The second program is a comparison of all of the data with last year's data. With the exception of overlaid sections, this check examines whether or not the data trends are headed in the right direction (i.e., pavement conditions should worsen over time/trafic). This type of verification is possible because distress data are entered in the mainframe computer no later than 2 weeks after the pavement is surveyed.

In 1997 PennDOT is switching to a video distress survey using the ARAN. They intend to maintain the same level and frequency of data collection, but will change the distress definitions slightly to accommodate the equipment's capabilities. Specifically for AC surfaces, they have defined as edge deterioration any cracking within 0.3 m (1 ft) of the pavement edge, fatigue cracking is any cracking in the wheelpath, and miscellaneous cracking is any cracking between the wheelpaths. For quality assurance of the ARAN data, Roadware has been asked to submit their own QA plan. PennDOT will also perform its own checks.

Deflection

Deflection data are collected at a project level. PennDOT uses full-time staff to operate their KUAB, and typical functions include obtaining data for overlay design, void detection, and measuring joint efficiency. PennDOT has a SHRP calibration site and it is believed that the equipment is calibrated no more than two or three times a year.

Faulting

Faulting data have been collected manually in the past. They will not be collected with the ARAN.

Roughness

The collection of roughness data, like distress, is undergoing a change. In the past PennDOT used the SD Profiler. They owned four such vans; two equipped with ultrasonic sensors and two with lasers. The roughness survey was performed with the same frequency and over the same range of pavements as the distress survey. PennDOT maintained eight sites that were controlled with a dipstick in order to calibrate the profilers. The equipment ran over a control site weekly. They are now switching to using the ARAN to collect roughness data.

Rutting

Rutting data have been collected with both a visual assessment and using the 3-point sensors. However, the database only had a means of including the visual assessment and most of the data was collected with the sensors, so the database has not been kept up to date. Rutting will now be collected with the ARAN.

Friction

PennDOT has three ICC skid trailers. They run a wet weather accident program, test on the NHS, and perform skid testing by special request. They now rate the skid resistance level for all of their aggregates based on petrography and other lab evaluations and don't feel there is as much need to do extensive field testing.

Geometrics

Some geometric data (grade, curvature, and cross-slope) will be collected with the ARAN vehicle. The ARAN is also providing GPS data. Guardrail status is being obtained with two extra cameras, and PennDOT is especially interested in looking at the end treatments.

Massachusetts Highway Department (MHD)

Distress, Roughness, and Rutting are all collected with their ARAN vehicle.

Distress

The ARAN operator keys in distresses based on the MHD's own distress manual. Distresses have three extents and three severities. Most of their pavements (all except for about 16 centerline kilometers [10 mi]) are AC surfaced. MHD looks at longitudinal and transverse cracking and alligator cracking, primarily. Longitudinal cracking in the wheelpath is rated as low alligator cracking. The Department has moved away from looking at block cracking because it's hard to transition from the other types into block.

PCC pavements are actually not rated except for rideability. The limited number of miles of PCC pavement are ridden over often enough that the MHD knows their condition.

MHD's system consists of about 17,700 centerline kilometers (11,000 mi). Of these, 2,900 kilometers (1,800 mi) are in the NHS and about 2,400 km (1,500 mi) more are State-maintained. The Department surveys about one-third of their network each year. They could rate the entire system annually but their experience is that they shouldn't see much change that quickly. They end up surveying about 9,600 to 12,800 lane km/year (6,000 to 8,000 lane mi) with a dedicated staff of 4 to 5 people.

For validation of the survey, they print out the results and manually resurvey about 10 to 15 percent of the network as a check. The District Office also provides feedback when they find a discrepancy between what the report says and what they think are the actual conditions.

Rutting

Rutting is measured from the ARAN, using a 42-sensor rut bar. They are not measuring true rutting but reporting the deepest rut.

Roughness

Roughness is measured with the ARAN. The equipment generates an IRI, pavement condition index (PCI), and rideability index (RI) from the results. The Department also has a Present Serviceability Index (PSI), which is a function of both the PCI and the RI. If the PCI < RI, then PSI = PCI. Otherwise, if PCI > RI, PSI = RI.

The MHD is in the process of establishing a Correlation Center for road roughness, which will have 9 or 10 sites with different degrees of roughness. This will be used by different states in Region 1 to calibrate their roughness output. Currently, calibration of the ARAN roughness output is done over up to 10 sections that are checked with a FACE dipstick.

Friction

They have a K.J. Law locked wheel skid trailer and perform skid testing according to ASTM 274. However, it is not currently working. Their best means of identifying poor skid resistance is to find areas of surface flushing.

The skid testing program used to be active. All pavements with a posted speed limit greater than 40 mph were evaluated, along with the 25 highest accident areas, all experimental pavements, and some new pavements (for which they would expect to find values of high 40s to low 50s). They then moved to an as-needed or on call testing program and will go back to that when their equipment is operational again.

Calibration has been performed at the Ohio calibration center. After calibration they rerun some sections near headquarters and check the results. They do one major calibration of their equipment at the beginning of the season and a few minor ones throughout the season.

Washington State Department of Transportation (WSDOT)

Distress

Washington actually first set up the survey procedure that they use in 1965, and all other condition surveys have evolved from it. The condition survey is based on distress extent and severity. In the past, the Department just used a guide that they put together themselves; now they print a real distress guide that is used not only by the DOT, but also by cities and counties in the State. Both the distresses and the processes for collecting them are well defined.

The distress survey is conducted during March, April, and sometimes part of May by four two-person teams. These crews will always include one person who has done the survey at least the year before. In the past the crews typically included people with 5 to 8 years of experience.

A survey section is defined as a pavement with uniform characteristics (e.g., cross section, traffic, and performance). The survey of the section is conducted from the shoulder at 8 km/hr (5 mph), with values reported for that section (they used to do 61 m (200 ft)/section, getting out of the vehicle, but found this was not really working in practice). The entire network of 12,800 directional km (8000 mi) is surveyed annually. The cost is somewhere between $5 and $5.60 per km per year ($8 and $9 per mile). The output is a paper system, and they can carry last year's survey with them for the purpose of comparison.

Washington spends about 1 week of training to "normalize" the trainers. As part of this process, the trainees go out and rate, calibrate, and re-rate until the crews are all doing it right. For additional validation, a sample of about 2 to 5 percent is pulled for survey and comparison with the typical surveys. There is a secondary type of validation provided by the Districts. Districts are encouraged to ride with the survey team when in their area. Districts also review the data and can provide feedback for corrections. This keeps the Districts from doing their own surveys. It was noted that when the network was surveyed every 2 years the Districts did go out and collect their own condition data, but with the survey performed annually they have been satisfied with the results. With this approach, there is no hand measurement of rutting or faulting.

Roughness

WSDOT uses a South Dakota Profiler to measure roughness. The network is surveyed on a 2-year cycle. Ride is checked against panels of known roughness. The equipment is operated by full-time staff.

Rutting

Rut data are also collected by the SD Profiler's three-point rut bar.

Friction

WSDOT uses a locked wheel skid trailer and ribbed tires. The pavement network is surveyed on a 2-year cycle, and the equipment is calibrated in Texas every 3 years. While the equipment operator is a full-time Department employee, the survey only takes about 2 to 3 months per year. This allows the crew to work on other things.

Deflections

A Dynatest 8000 is used to collect deflection data. It is part of Pavement Design and not Pavement Management. The FWD is used exclusively for project-level activities.

Geometric Data

There is no formal process of verifying geometric data. This information is carried by Planning and is available to the staff collecting field data. The field staff try to catch anomalies in the field.

Kansas Department of Transportation

Distress Data

Kansas performs a 100 percent survey of approximately 16,000 2-lane km (10,000 mi). Full-time staff perform this survey, but the staff are borrowed from Materials and Research. On divided highways they do both directions, but on two-lane highways they will survey only one direction. The survey is performed on 57 m/km (300 ft/mi): they look at 3 30-m (100 ft) sections per 1.6 km (1 mi). The survey is done from their profiler, with which they gather rutting, faulting, and profile data. A manual survey is performed for transverse and fatigue cracking. The Department also currently gathers block cracking information, but do not look at it. For PCC pavements, they do a manual survey to look at joint distress and especially D-cracking. The Department tries to check up on the survey, but this effort is variable. They still go out at random and check. The raters go through a training every year, even when they are doing the survey year after year.

Summary statistics are published and the appropriate data are also entered into their PMS. The Department puts out a performance level of 1, 2, and 3, for their pavement sections that combines the performance measures. Roughness controls the rating.

Norman did not believe that data are collected by others, with the possible exception that at the maintenance level some distress information may be collected for crack sealing. However, even in this case the need for crack sealing comes from PMS data.

As a result of the survey, about 1,900 to 2,400 km/year (1,200 to 1,500 mi) are scheduled for rehabilitation; the rest receive maintenance.

There is a manual that describes how to rate distresses and how to operate the equipment.

Friction

Skid information is collected by research but it is sensitive data. The equipment is likely a KJ Law device, and it is operated by a dedicated staff. They are on a 2-year cycle, and they try to do some percentage of each project. The skid data are not used in PMS.

Roughness

Kansas has an International Cybernetics Profilometer. They started with a Mays meter, progressed to the International Cybernetics with acoustic sensors, and now have laser sensors replacing the acoustic ones (they had problems with moisture and the results were not repeatable).

The survey is performed from March to June and 100 percent of their network is surveyed. Two people run the profile equipment and another pair does the distress survey. They have four vans, two of which are assigned to profile and two of which do the distress survey.

North Dakota Department of Transportation

Distress Data

North Dakota performs an annual distress survey, but whereas in the past they surveyed 13,500 km (8,400 mi); now it's over about 4,700 km (2,900 mi). Their focus is over the National Highway System (NHS) and heavily loaded pavements. They use the Pathways Road Profiler van, which has four cameras to film the pavement and also reads the profile. The video is viewed to rate the pavement and the rating is done by three full-time staff and some part-time employees.

Distresses are scored on the first 150 m (500 ft) of each 1.6 km (1 mi). The extent and severity of each distress are rated. The distress starts at 99 and is downgraded from there. The product of this evaluation is an overall index for the pavement.

The distress surveys start after construction and run through May or April. Sometimes work stops in January or February due to weather.

The van is also used to measure faulting, using laser sensors. HPMS data are pulled out of the distress survey.

For quality control, test sections are run every week to check the sensors. The users of the data also check the output and will provide feedback.

The information gathered in the distress survey is summarized in an annual report. The distresses are also used in their PMS.

Others are involved in distress data collection. For example, the Districts collect their own distress data, and Materials and Research also performs their own more detailed surveys for specialized purposes.

Friction

The friction survey is contracted out to a private company. Every 2 years a portion of the network is surveyed. However, this information is not released. With their profiler they do get something called a texture report. This is an area where they would like to work with South Dakota.

Roughness

Roughness is collected with their Pathways vehicle. It produces an IRI in English and metric units. The output is converted to a Ride Index using Minnesota's value. A weekly check is run on standard sections.

Rutting

Rutting is measured with the profilometer, using a three-point laser bar. The measurement is taken over the entire mile. The report can be broken down into smaller sections if desired.

Video

Their video equipment collects distress data. The tapes are also reviewed for safety, signs, right of way, and so on. They believed that they are the first users of a Pathways vehicle. It is developed by Rudy Blanco, who can be reached at (405) 366-7135.

FWD

Materials and Research collects deflection data for design. The data are collected on a project by project basis. The FWD goes out on upcoming projects to determine special details. The type of equipment used was not specified.

Geometrics

The Department can check geometric data with their video equipment. Geometrics are usually verified as part of a site visit, however. Districts are responsible for entering geometric data upon completion of the project. The Districts spend a lot of the winter making as-builts; they feel that the data are now accurate because of this.

Traffic

Traffic comes from the data collection section and from the data analysis section. They have two portable WIM and 24 sites that they do statewide per year. They have one or two piezos and one bending plate that works very well. They are making a big push statewide for classification.

The Districts used to collect data so that they would know what was going on, but do not anymore. Recently, State auditors did a survey of users of pavement data. Most said that the data were reliable. The most questionable were rutting and faulting. This group came up with their own action plan to improve data collection efforts.

Summary of State Surveys

The information obtained from the interviews with State highway personnel is summarized by data type in tables 5 through 9. These tables summarize the States' practices for collection of distress data, rutting data, roughness data, friction data, and deflection data, respectively.

Table 5. Summary of State practices for collection of distress data.

State	Method	Comments
Arizona	Visual	Developed their own rating system 100 ft surveyed at every milepost Surveyed annually
Nebraska	Visual	Use a modified SHRP procedure AC pavements surveyed every year PCC pavements surveyed every 2 years
Pennsylvania	Visual (switching to ARAN in 1997)	Surveyed annually or biannually Similar to LTPP distress survey Severity rated as low or high Extent broken into three categories Have training and quality assurance programs
Massachusetts	ARAN	Survey 1/3 each year Measure extent and severity for AC pavements Only measure rideability on PCC pavements Manually survey for validation
Washington	Visual	Surveyed annually Have developed a distress guide Have training and validation programs
Kansas	Visual	Survey three 100-ft sections per mile Have a yearly training program Have distress manual
North Dakota	Pathways Road Profiler	Surveyed annually Survey 500 ft within each mile Rate extent and severity

Table 6. Summary of State practices for collection of rutting data.

State	Method	Comments
Arizona	Manual	Measured every mile
Nebraska	Laser profiler	Surveyed annually Collect readings every tenth mile Thorough calibration collected annually
Pennsylvania	Manual and 3-point sensors (switching to ARAN)	Surveyed annually or biannually
Massachusetts	ARAN	Uses 42-sensor rut bar
Washington	South Dakota Profiler	Uses 3-point rut bar Surveyed every 2 years
Kansas	Profiler	Surveyed annually
North Dakota	Pathways Road Profiler	Uses a 3-point laser bar Surveyed annually

Table 7. Summary of State practices for collection of roughness data.

State	Method	Comments
Arizona	K. J. Law 690	Survey 100 percent annually Determine IRI and Mays number
Nebraska	Laser profiler on van (previously used South Dakota Profiler)	Surveyed annually Collect readings every tenth mile Thorough calibration collected annually
Pennsylvania	South Dakota Profiler (switching to ARAN)	Surveyed annually or biannually Equipment validated weekly (8 sites)
Massachusetts	ARAN	Determine IRI, PCI, and RI Establishing a Correlation Center (10 sites)
Washington	South Dakota Profiler	Surveyed every two years
Kansas	International Cyber-netics Profilometer	Survey 100 percent annually
North Dakota	Pathways Road Profiler	Determine IRI and RI Equipment validated weekly

Table 8. Summary of State practices for collection of friction data.

State	Method	Comments
Arizona	Mu Meter	Collected annually over entire network Tests run over 140 or 500 ft
Nebraska	Not specified	Collected every 3 years
Pennsylvania	ICC skid trailer Petrography	Specialized testing only Rate skid level based on petrography
Massachusetts	K. J. Law locked wheel skid trailer	Test sections with speed limits greater than 40 mph Also test accident areas and experimental sites Perform calibration annually
Washington	Locked wheel skid trailer and ribbed tires	Surveyed every 2 years Equipment calibrated every 3 years
Kansas	K. J. Law	Surveyed every 2 years Not used for pavement management
North Dakota	Not specified	Survey is contracted out Information is not released

Table 9. Summary of State practices for collection of deflection data.

State	Method	Comments
Arizona	Dynatest 8000	No network level testing 5 tests per mile
Nebraska	None	Not used for pavement management
Pennsylvania	KUAB	Collected at project level Equipment calibrated 2 to 3 times a year
Washington	Dynatest 8000	Collected at project level
North Dakota	Not specified	Collected at project level

SUMMARY OF CURRENT PROTOCOLS

The following sections describe current protocols used in the collection of the specified roadway characteristics. This is not a complete examination of the practices of highway agencies, but rather a summary of prevalent measurement standards and protocols currently available.

Roughness from Profile

Table 10 provides a summary of current protocols for obtaining roughness from profile. Two protocols are summarized — the SHRP/FHWA protocol and the ASTM E950 protocol. A new protocol is currently being developed by the FHWA. The items of interest in these protocols include the following:

1. Equipment Type—the type of equipment specified or used in the protocol.
2. Calibration Procedures—the type of procedures used to calibrate the equipment.
3. Extent of Network Surveyed—extent of network surveyed using the roughness-measuring equipment.
4. Frequency of Surveys—time frequency in which the roughness measurements are conducted.
5. Lanes Surveyed—lanes in which roughness measurements are obtained.
6. Measurement Location—location on the road in which measurements are obtained (e.g., right wheelpath, left wheelpath, or both wheelpaths).
7. Section Survey Length—length of evaluation section.
8. Survey Speed—speed at which roughness measurements obtained.
9. Longitudinal Sampling Rate—frequency with which profile measurement is taken in the longitudinal direction.
10. Vertical Resolution—accuracy of the vertical profile measurements (static).
11. Roughness Unit—roughness unit in which surface profile expressed.
12. Filtering—filtering requirements to reduce profile attenuations/amplifications.
13. Data Storage—how the roughness data are stored.
14. Uses of Data—how the data are used or specified for use.

Table 10. Summary of protocols for pavement profile measurements.

Element	SHRP/FHWA	ASTM E 950
Equipment Type	K. J. Law 6600	Not Specified
Calibration Procedures	Acceleration: Bounce Test Displacement: 1 in block	Acceleration: internal Displacement: 1 in block Distance: compare to premeasured distance
Extent of Network Surveyed	Not Applicable	Not Specified
Frequency of Surveys	Annual	Not Specified
Lane(s) Surveyed	Test Lane (generally right lane)	Not Specified
Measurement Location	Both wheelpaths	One or both wheelpaths
Section Survey Length	500 ft	Not Specified
Survey Speed	55 mi/hr	Generally higher speeds: avoid speeds less than 15 mi/hr
Longitudinal Sampling Interval	1 in	Class 1: ≤ 1 in Class 2: $1 < x \leq 6$ in Class 3: $6 < x \leq 12$ in Class 4: > 12 in
Vertical Resolution	0.1 mm	Class 1: ≤ 0.1 mm Class 2: $0.1 < x \leq 0.2$ mm Class 3: $0.2 < x \leq 0.5$ mm Class 4: > 0.5 mm
Roughness Unit	IRI	Not Specified
Filtering	Internal	Must be provided to permit computation of measured profile with no amplification or attenuation of wavelengths at least 200 ft long at test speeds of 15 to 60 mi/hr
Data Storage	Personal Computer	Personal Computer
Use of Data	Monitor roughness of pavement section	1. Provide profile data. 2. Used to simulate outputs of other devices

FHWA has recently developed a "Roughness Protocol," which defines standard procedures for measuring longitudinal profile and calculating IRI. The purpose of such a protocol is to help produce consistent estimations of IRI for network level pavement management. The protocol was developed specifically for use on the National Highway System and should thus be used with caution on other roadways.

The FHWA protocol recommends measuring the roughness in both wheelpaths and calculating an IRI. The roughness is reported as the average of the two IRI values. The following additional guidance is also provided:

- Surveys should be conducted in the outside (travel) lane.
- Surveys should be conducted in one direction on undivided highways but in both directions on divided highways.
- The same direction of travel and the same lane should be surveyed for each survey cycle.
- The length of the data collection section should be between 100 and 1,000 m (330 and 3,300 ft).

The protocol also recommends an extensive quality assurance plan. The plan should include a certification and training program, maintenance and calibration of equipment, and periodic quality control.

Three-Point Rut Depth

There is an ASTM protocol for the measurement of rut depth in asphalt concrete pavements for manual measurements only. This protocol is summarized in table 11. Items of interest for the measurement of rut depth include:

1. Equipment Type and Technology—type of equipment and technology used for measuring rut depth.
2. Calibration—calibration procedures for ensuring accuracy of the rut depth measurements.
3. Frequency of Surveys—time frequency over which rut depth measurements are recorded.
4. Frequency of Measurements—spatial frequency of measurements along a project.
5. Measurement Location—transverse location across the pavement where rut depth measurements are obtained.
6. Section Survey Length—length of section over which rut depth measurements are recorded.
7. Production Rate—rate at which rut depth measurements are obtained.
8. Data Storage—method in which rut depth measurements are stored.
9. Uses of Data—how the data are used or specified for use.

Table 11. Summary of protocols for three-point rut depth measurements.

Element	ASTM E 1703
Equipment Type and Technology	Straightedge
Calibration	Trueness of Straightedge $\pm$0.005 in/ft
Frequency of Surveys	Not Specified
Frequency of Measurements	Not Specified
Measurement Location	Each wheelpath
Section Survey Length	Not Specified
Production Rate	Not Specified
Data Storage	Manual Recording
Uses of Data	Indication of pavement performance

A "Rut Depth Protocol" is currently being developed by the FHWA under an ongoing research contract. The protocol is being developed for the National Highway System but may be applicable to other roadways. As with the ASTM protocol, the FHWA method recommends a three-point method for estimating the rut depth.

The reported value is the average rut depth in both wheelpaths in relation to the height at the center of the lane. The overall average is computed and used to rate the rutting into one of four severity levels. Measurements should be taken at maximum intervals of 15 m (50 ft). The recommended guidelines with respect to testing locations (lanes and directions) are the same as the "Roughness Protocol." A quality assurance plan should be developed which includes a certification and training program, maintenance and calibration of equipment, and periodic quality control.

Pavement Distress Surveys

Table 12 provides a summary of current protocols for performing pavement distress surveys. Only two protocols were identified: the SHRP/FHWA protocol and the Corps of Engineers (COE)/American Public Works Association (APWA) protocol. The items of interest include the following:

1. Distress Manual—distress identification manual used in the protocol.
2. Distress Survey Method—whether the distress survey is conducted using automated means or manual methods.
3. Frequency of Survey—time frequency with which the distress surveys are conducted.
4. Section Length—length of section for conducting the distress survey.
5. Sampling Rate—proportion of the section length over which a distress survey is conducted.
6. Production Rate—rate at which distress surveys are conducted.
7. Data Storage—method in which distress survey results are stored.
8. Uses of Data—how the results of the distress surveys are used or specified for use.

Table 12. Summary of protocols for pavement distress surveys.

Element	SHRP/FHWA	COE/APWA
Distress Manual	SHRP/FHWA 1993	COE 1979
Survey Method	Automated/Manual	Manual
Frequency of Surveys	Annual	Not Specified
Section Length	500 ft	AC: 2500 $ft^2 \pm$ 1000 ft^2 PCC: 20 $\pm$ 8 slabs
Sampling Rate	100 percent	Network: 10% Project: 85-100%
Production Rate	Automated: 50-55 mi/hr Manual: 500-1000 ft/hr	Not Specified
Data Storage	Regional/National PC Databases	MicroPaver Database
Uses of Data	Distress Modeling	Pavement Modeling and Forecasting

Although the FHWA does not specifically have a protocol for distress surveys, four protocols incorporating distress measurements are under development:

- Cracking Protocol for Asphalt-Surfaced Pavements

- Cracking Protocol for Jointed Concrete Pavements
- Cracking Protocol for Continuously Reinforced Concrete Pavements
- Faulting Protocol

The cracking protocols are not restricted to transverse and longitudinal cracking. Other forms of cracking, such as fatigue cracking on AC pavements and spalling, durability cracking, and punchouts on PCC pavements, are also measured. For AC pavements, the length of distress for each severity level is recorded. For PCC pavements, distresses are defined by the number of slabs or joints for each severity level. Either automated or manual data collection surveys can be used with the cracking and faulting protocols. A quality assurance plan should be developed and should include a certification and training program, maintenance and calibration of equipment, and periodic quality control.

Falling Weight Deflection Testing

Table 13 summarizes two protocols for conducting falling weight deflectometer (FWD) deflection testing: SHRP/FHWA and ASTM D 4694/4695. Items of interest for this topic include:

1. Type of Equipment—type of equipment specified by the protocol.
2. Calibration—calibration procedures to ensure accuracy of measurements.
3. Intensity of Testing—spatial frequency of FWD testing within test section.
4. Test Section Length—length of test section over which FWD testing conducted.
5. AC and CRCP Testing Location—FWD testing locations on asphalt concrete and continuously reinforced concrete pavements.
6. JCP Testing Locations—FWD testing locations on jointed concrete pavements.
7. AC Sensor Configuration—horizontal distance from the load plate of the deflection-measuring sensors on an AC pavement.
8. PCC Sensor Configuration—horizontal distance from the load plate of the deflection-measuring sensors on a PCC pavement.
9. Load Sequence—target weights and sequences for FWD testing.
10. Data Storage—method in which the FWD data are stored.
11. Uses of Data—how the FWD data are used or specified for use.

Table 13. Summary of protocols for FWD deflection testing.

Element	SHRP/FHWA	ASTM D 4694/4695
Type of Equipment	Dynatest	Not Specified
Calibration	Absolute: Regional Calibration Centers Relative: Stacking Sensors	Load Device Sensor Relative Calibration Sensor Absolute Calibration
Intensity of Surveys		Level 1: 500–1500 ft (5–10 tests/section) Level 2: 100–500 ft (10–20 tests/section) Level 3: 10–100 ft (10–20 tests/section)
Test Section Length	500 ft	Not Specified
AC and CRCP Testing Locations	Outer wheelpath	Level 1: Outer wheelpath Level 2: Outer wheelpath Level 3: Outer or both wheelpaths
JCP Testing Locations	Slab centers and transverse joints	Level 1: Slab centers and joints at 5% of slabs tested Level 2: Slab centers and joints at 25% of slabs tested Level 3: Every slab and joint
AC Sensor Configuration	0, 8, 12,18, 24,36, 60 in	Not Specified
PCC Sensor Configuration	0, 8, 12, 18, 24, 36, 60 in	Not Specified
Load Sequence	12 kip, 9 kip, 12 kip, 16 kip (three drops at each level)	Not Specified
Data Storage	PC	Not Specified
Uses of Data	Backcalculation of Material Properties Load Transfer	Structural capacity of existing pavement for evaluation or overlay design

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5. South Dakota's Roadway Data Collection Practices

INTRODUCTION

Roadway data in South Dakota is used for many purposes. For example, selected data are used as inputs to pavement design and rehabilitation, to comply with Federal reporting requirements, and to identify sections of pavement that should have posted spring load limits. One very important use of roadway data is to generate the information that is used to develop the Statewide Transportation Improvement Plan (STIP), a list of highway projects for each year that is used to program projects and to plan construction for the upcoming year.

While roadway data collection within the Department is a very centralized effort, it is best characterized as a series of discrete data collection tasks that are organized and summarized in one location. This interpretation is appropriate because data collection is handled by different equipment and different staff, and each specific activity is, by definition, independent. However, viewing each element of roadway data independently ignores the interrelationships between the data collection efforts and the common needs of a disparate group of users.

In this project, while each component of the roadway data collection effort is evaluated independently, it is also considered as a complete process. This approach recognizes the interdependence of many of the data collection activities, as well as acknowledges the shared benefits and shortcomings of the process.

SDDOT ROADWAY DATA COLLECTION AS A PROCESS

This section looks at the data collection process. The objective of the process analysis is to assess SDDOT's overall roadway data collection program in terms of effectiveness, efficiency, resource requirements, and cost. At the present time there is no discrete data collection process that addresses all data items as a system.

Overview

The physical collection of roadway data is done within the Data Inventory office of the Division of Planning/Engineering, except for pavement distress data, which are collected by Planning and Programs. Most data collection efforts occur during the summer when the pavement surface is readily visible with the exception of traffic.

After collection, the data are input to the Roadway Environment System (RES) by the Data Inventory Office of Planning/Engineering; distress data are input by the Planning & Data Analysis office of Planning and Programs (also referred to as the Pavement Management section). Key portions of the roadway data are analyzed within the Department's pavement management system (PMS) and database (dROAD and dTIMS), from which various values, distress indices, types of work and priority numbers for each segment of the State Highway

System are computed. A comparison with historical data is part of the data processing, and values that are anomalous (such as improvements in pavement condition over time when no improvement projects have occurred) cause an error report to be issued. The Data Inventory office is responsible for resolving any identified discrepancies in the data.

The Data Analysis section produces an annual report that summarizes the condition of each roadway section and when that section is programmed for improvement. This report, formally titled *Highway Needs Analysis and Project Analysis Report for State Administered Highways*, is hereafter referred to as the *Needs* book. The *Needs* book is used by almost every office within the SDDOT, and this use is a secondary source of quality control: as users study the report's content and apply it in the performance of their jobs, additional quality control activities are initiated and updates to the RES file are made if warranted.

Timing

The start of data collection activities has largely been determined by weather conditions and the availability of seasonal labor, with the exception of traffic data collection, which takes place throughout the year. Figure 4 depicts the timing of data collection as it relates to the comprehensive Project Programming cycle. In the first step, roadway data collection generally starts in early May when weather conditions are predictable and seasonal help and interns are available following the school year. The Distress Data Collection effort is most affected by this constraint because it uses university students during their summer break and seasonal employees.

Starting in September, the collected data are keyed to the RES system from the different data collection processes. Each data type is collected by different devices and stored on a different medium. This process takes place over several months, and then during January the data from dROAD are loaded. The significant delay between when data is collected and when it is uploaded to the RES should be noted. One reason for this lag time is the manual processing that is necessary to convert the native format of the collected data items to a format that can be uploaded to the RES System. Another reason for the delay between data collection and data entry is that the data are entered and edited by the same staff that collects the data. This delay compounds the difficulties associated with performing an effective quality control check on the data at subsequent steps in the process.

Consider the three components of the data collection process shown in Figure 5. The first group is the data collectors, those who are in the field collecting data throughout the year. The second group is the data processors, those who receive data and either manually or automatically process that data for use by the end users. In the third group are the users of the data. The distinctions shown in Figure 5 suggest the existence of three distinct groups to match the distinct operations, but often data collectors and data processors are the same person. While there may be some benefit to this combination of functions, it can also contribute to delays (for example, data must be collected before they can be processed).

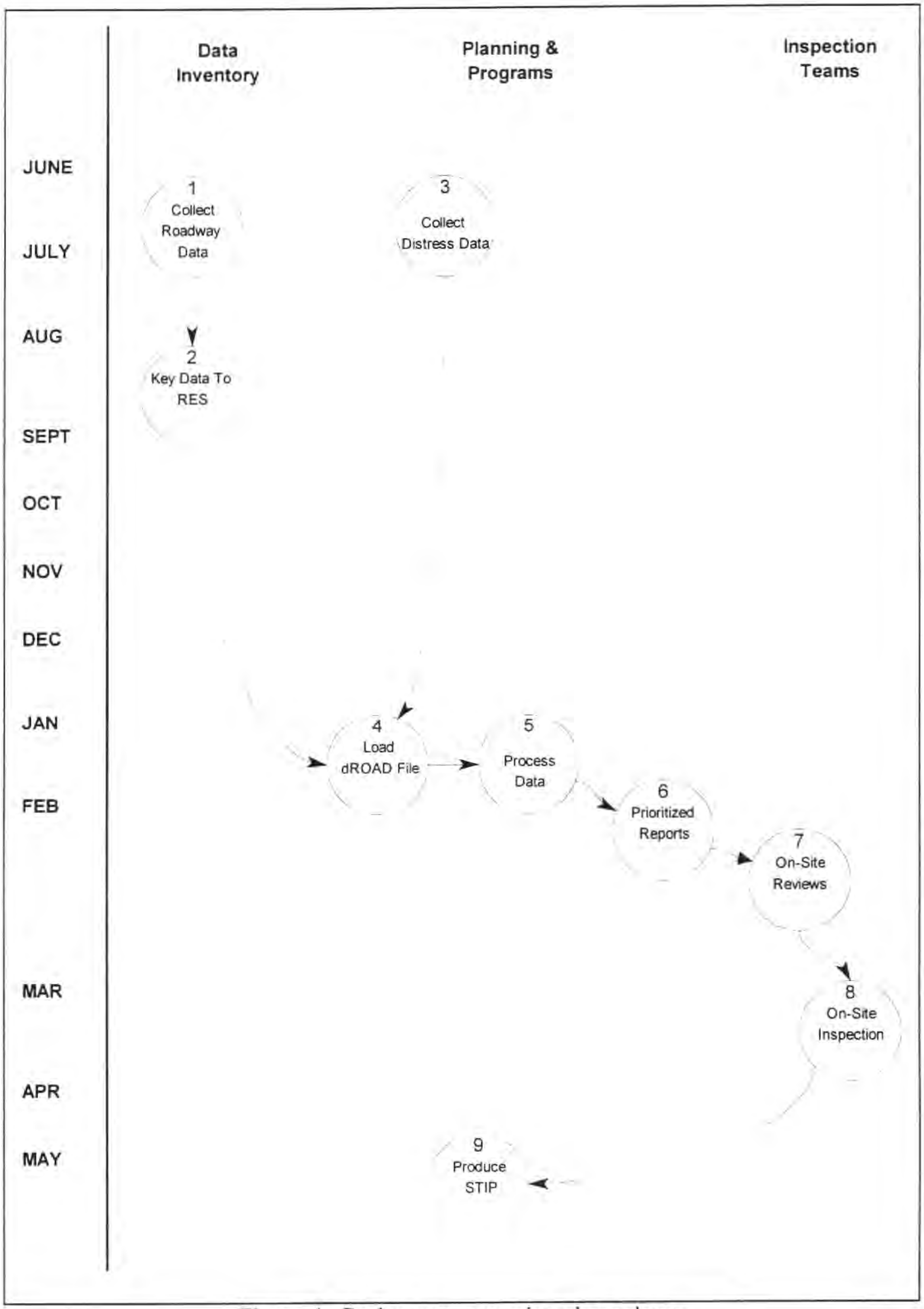

Figure 4. Project programming chronology.

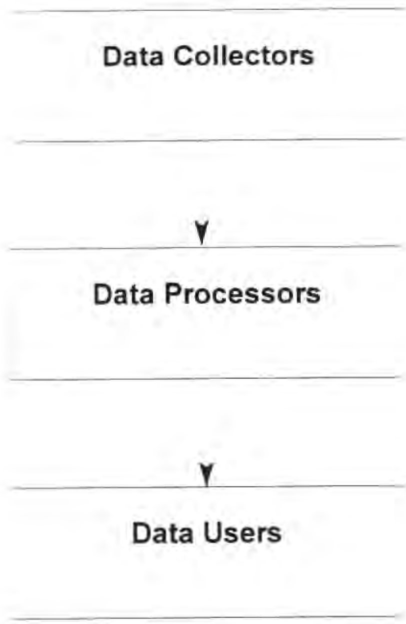

Figure 5. Components of the data collection process.

Also in January the data are analyzed to produce a hierarchy of needs for the State's highway system. Then, in early February "needs" reports are produced that help to focus Department review teams performing visual inspections of highway sites. February is also when management teams visit selected locations throughout the State to confirm needs and conditions as indicated in the computerized priority reports.

In March, management teams again inspect the physical locations to further qualify and quantify priorities for transportation construction activities. When the priorities for transportation projects have been confirmed, the State Highway Improvement Plan (STIP) is produced. This report outlines the South Dakota's proposed transportation improvement plan for the next 5 years.

Project Programming Cycle

As outlined above, the process of roadway data collection is the first step in what eventually becomes the STIP, although the data are also used in many other places. For example, HPMS and Surfacing use the roadway data, Operations uses roadway data as well as the overall condition rating, and the data are frequently accessed by the Division Director. Data Inventory and Research also have access to and use these data. Thus, the accuracy of the data is extremely important and serves as the foundation for the entire project programming process. The flowchart shown in Figure 6 depicts the project programming cycle that occurs every year.

The project programming cycle includes data collection activities, data processing, and data use. The overall interrelationship of these processes is shown in Figure 7.

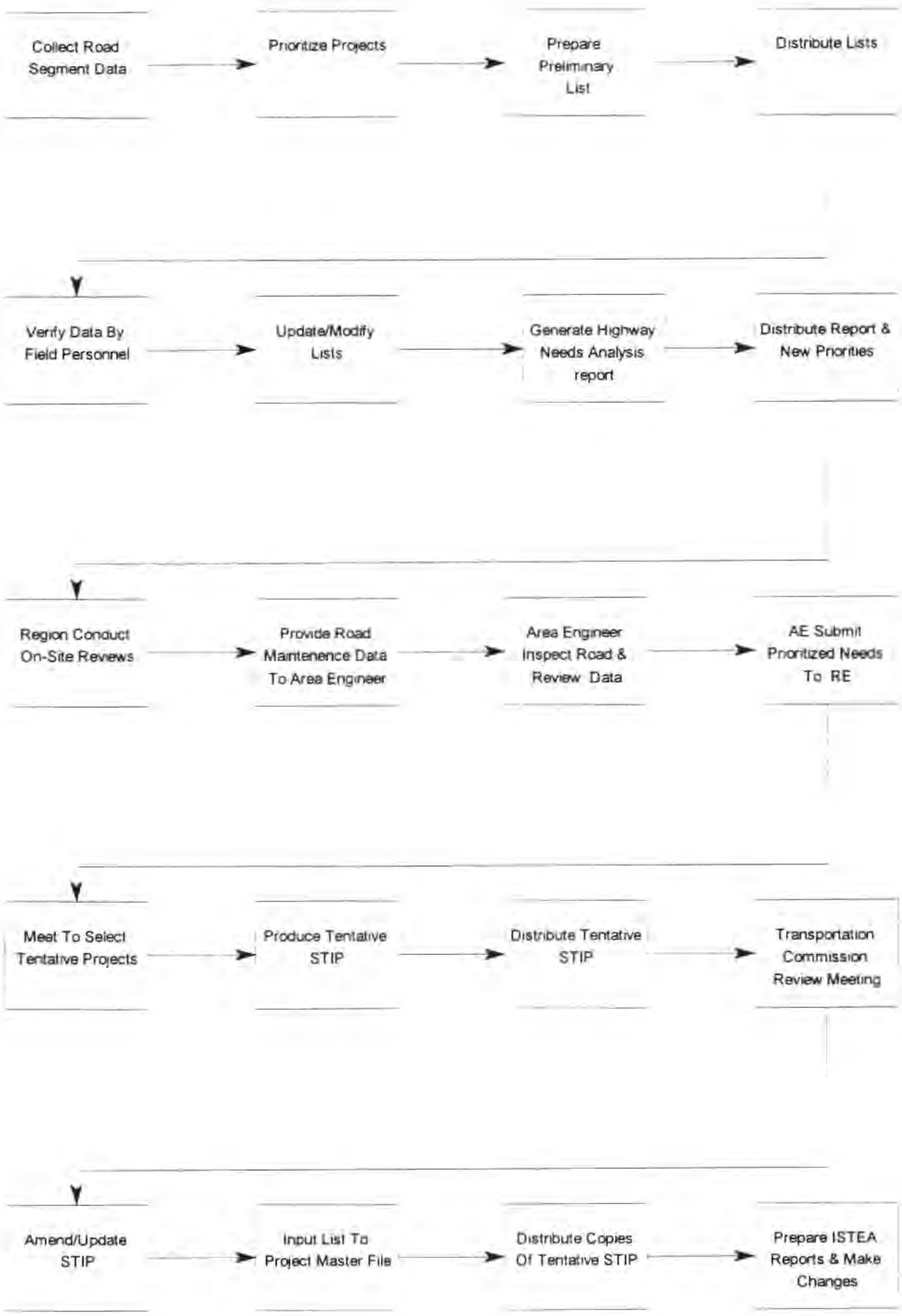

Figure 6. The project programming cycle.

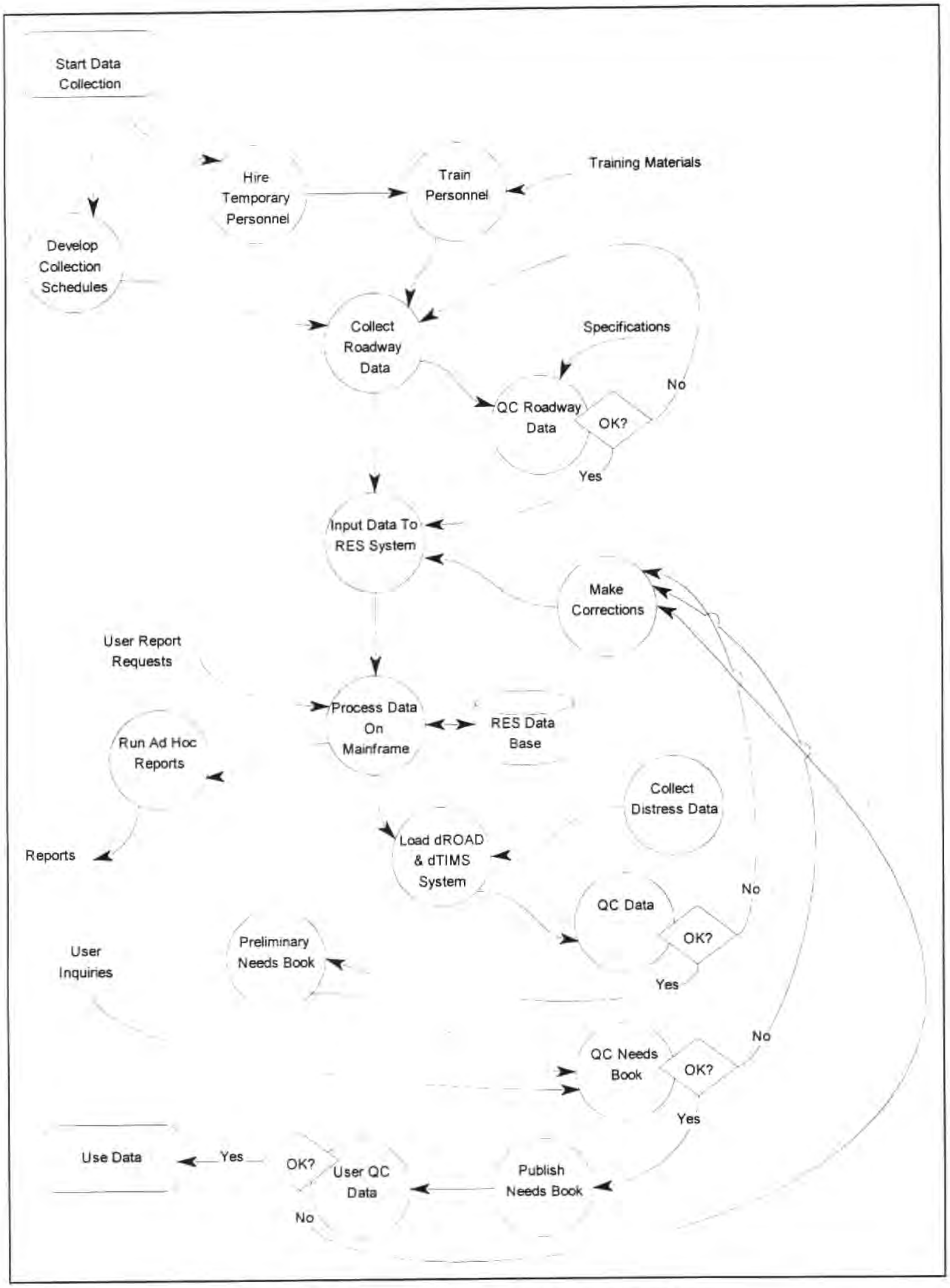

Figure 7. Current data collection process flow.

The *Needs* book is another major product of the data collection process and it is utilized throughout the Department. The process of creating and updating the *Needs* book is shown in Figure 8. Feedback about the performance of roads and perceived conflicts between actual pavement condition and the condition as reported in the *Needs* book typically come to the Pavement Management section. The Pavement Management section also maintains the Department's pavement management system (dROAD and dTIMS).

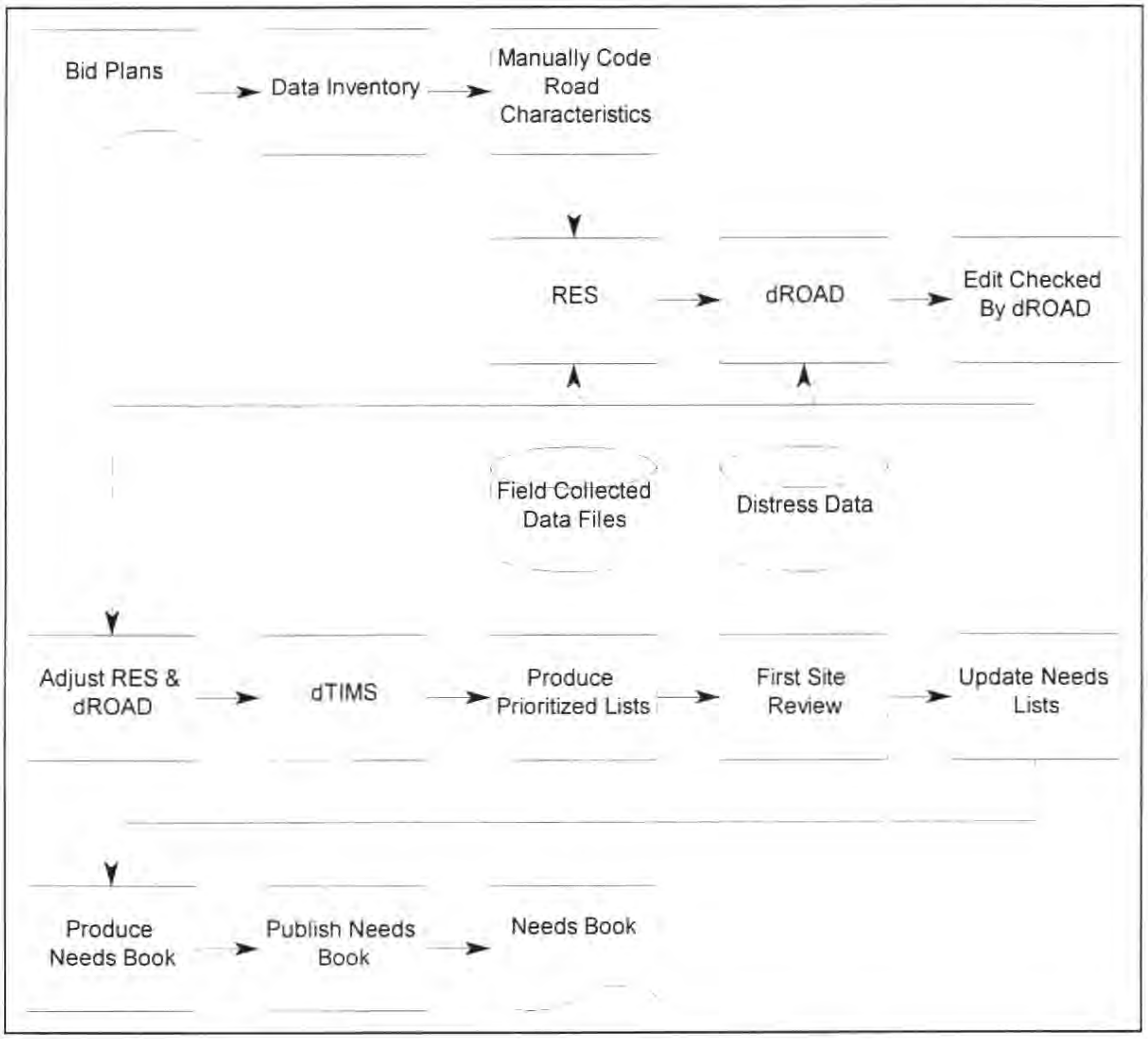

Figure 8. Processing and updating pavement data.

Roadway data are loaded into various computer programs for each type of roadway data for subsequent upload to the RES system. With many types of data this is a very long and tedious task, in which the data must be loaded floppy disk by floppy disk. RES data are passed on to the dROAD program; distress data are loaded directly into dROAD. Exception reports are kicked out of dROAD when edits are not passed. The Pavement Management section then manually researches inconsistencies and adjusts RES and dROAD systems.

Prioritized lists are generated to help schedule the first site visits by staff and management. The on-site visits provide insight that directs changes to the lists and an updated needs list is generated. The needs list is used to produce the Needs Book that is published and used throughout the Department. When projects are bid, the Office of Project Development sends plans to the Data Inventory section to adjust the RES data base. Actual updates are not done, however, until the projects are completed and signed off.

Information Services' role in this process is system development and maintenance of existing programs. One of the primary functions of this group is to get data into and out of the mainframe system. All roadway collected data types, except for Distress data, are fed into the RES system. Those data are processed by RES and are downloaded to dROAD. Distress data are loaded directly into dROAD. The data are then downloaded to an Informix data base for production of the Needs Book. The RES ALL-Data ADABAS file is a RES subfile that is used to generate ad hoc reports on request.

The goal within Information Services is to continue to expand the use of graphical information to include more data representation in the form of maps. This will continue to evolve as SDDOT moves toward Geographic Information Systems (GIS). The schematic shown in Figure 9 outlines the roadway data processing flow through the RES System.

Summary

The South Dakota roadway data collection and programming process begins in May/June with actual data collection activities, and concludes the following April/May with the development of the STIP. A variety of data are collected, and these are processed and analyzed to determine the condition and needs of the highway network. By examining the overall process, there are several opportunities to make this activity more efficient and effective. The process could begin earlier in the year if it were not dependent upon hiring summer interns after school ends in May. If data were processed while it was being collected, a long delay could be eliminated. An added benefit of this is that any errors could be identified and their cause pinpointed before a lot of effort had been expended. By the same token, earlier processing would also make it easier to improve the quality of the data. These ideas are discussed in greater detail in chapter 7.

SPECIFIC SDDOT DATA COLLECTION PRACTICES

This section describes the current data collection practice for each of the following data types:

- pavement distress
- traffic
- pavement friction
- roughness from profile
- rutting
- sufficiency rating
- videolog images
- falling weight deflections
- verification of vertical and horizontal curves and other geometric data

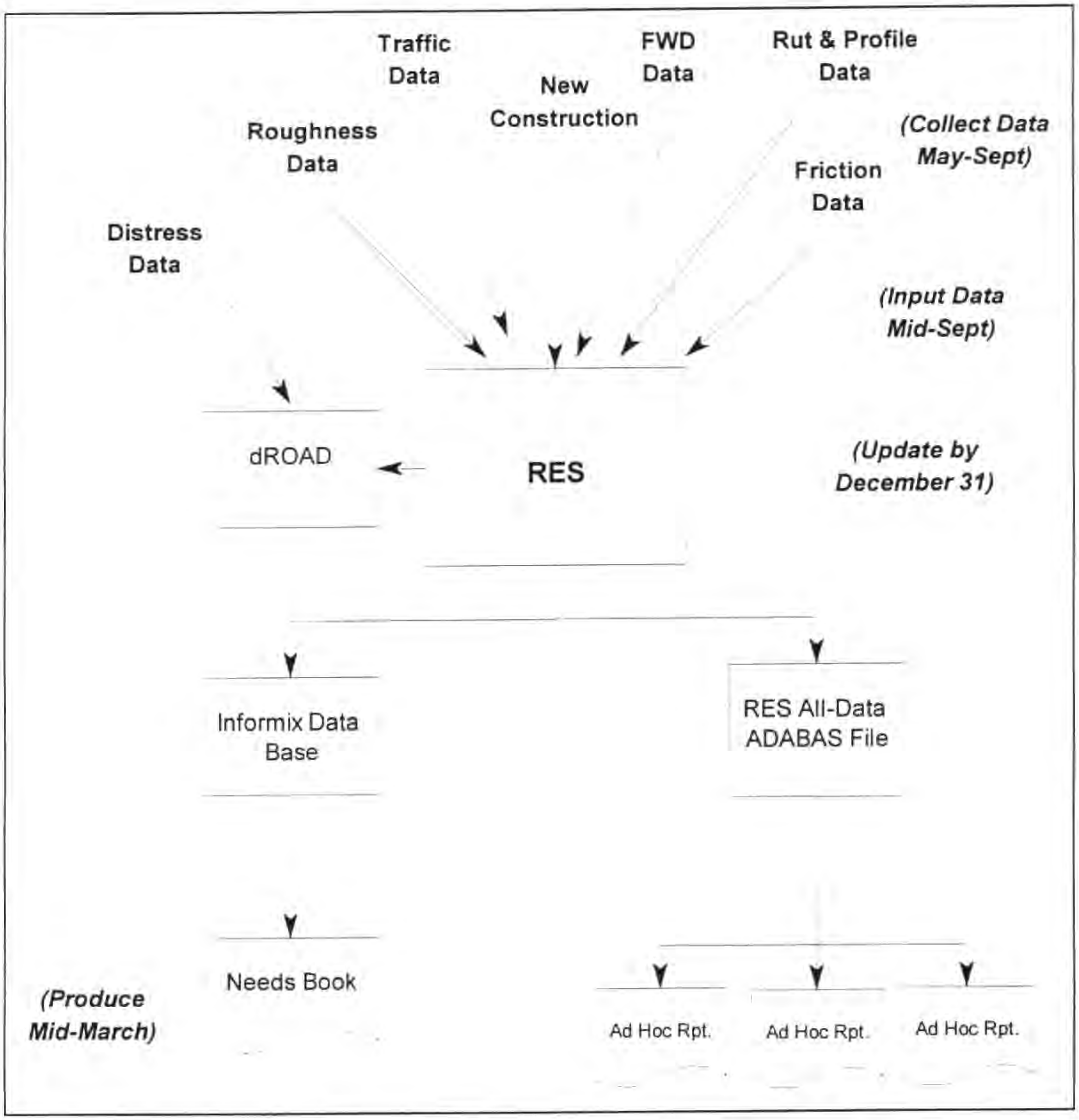

Figure 9. Flow of roadway data in and out of the RES.

Where appropriate and available, information is presented on the type of equipment, the crew size, how the data are collected, what types of data are produced, and where the data are stored. Feedback from users of the data is also provided.

Roadway Data Collection

Pavement Distress

The Pavement Management section of Planning and Programs collects, assembles, and reports pavement condition data. At the heart of the PMS is pavement distress data, so distress data collection is a primary responsibility of the Pavement Management section. Two people have full-time responsibility in this area, a third person works about 70 percent in pavement management, and a fourth is about at 30 percent. A manager spends about 10 percent of his time in this area as well.

Data Collection and Processing

Two two-person crews of seasonal employees perform the pavement distress survey. In the past 2 years these employees have been college interns, hired during the spring to travel around the State and collect pavement condition data. The interns receive 1 week of training and then do 1 week of surveys with an experienced staff member accompanying them before heading out on their own. About one day of the first week's training addresses safety issues, different distresses, and pavement types.

Permanent employees of Planning and Programs try to perform regular verifications of the quality of the collected data by going out with the survey crews, but they usually don't get out as often as they would like. Other work obligations, in conjunction with geographical constraints (it is just too far to drive to meet the survey crews easily once they leave the Pierre area), means that this quality control step does not always take place.

The distress calls are based on a modified SHRP distress identification definition; the primary modification is the elimination of distresses that don't apply in South Dakota. The distresses that are considered are shown in Table 14.

Table 14. Distresses noted in South Dakota's surveys.

Flexible Pavements	Rigid Pavements
Transverse Cracking	D-Cracking and ASR
Fatigue Cracking	Joint Spalling
Block Cracking	Corner Cracking
Rutting	Faulting
Roughness	Joint Seal Damage
Patching/ Patch Deterioration	Roughness
	Punchouts

The observed distresses are keyed into an onboard laptop. This laptop is loaded with files that actually contain the results of the previous survey, so that the pavement rater can see what distresses, severities, and extents were recorded. The procedure's genesis, distress descriptions, and issues related to distress data collection are addressed in a draft *Visual Distress Survey Manual* and in the final *Enhancement of SDDOT's Pavement Management System (SD93-4-F)*. The distress survey process is shown in Figure 10.

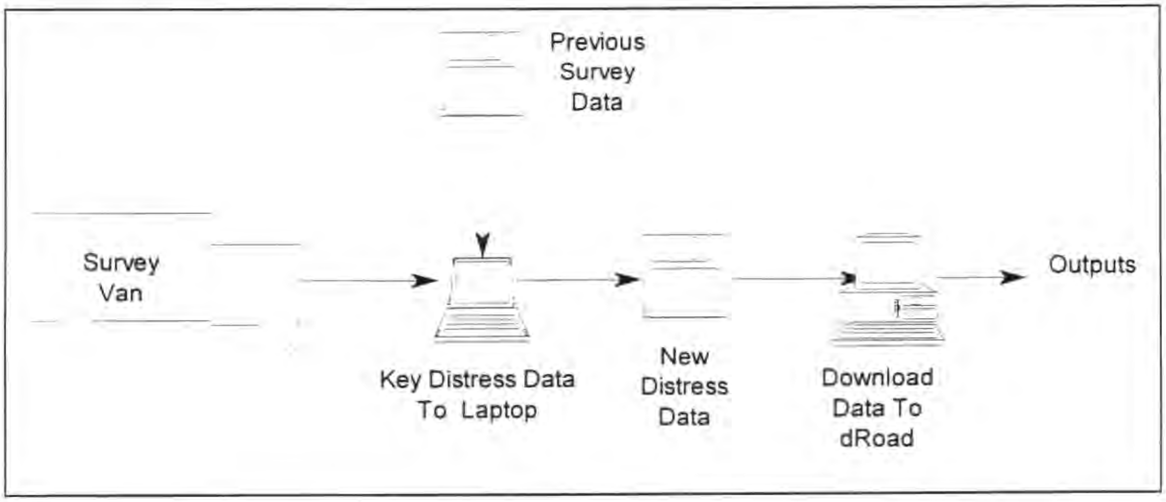

Figure 10. Distress data collection process.

The length of the survey section is about 0.4 km (0.25 mi). For PCC pavements, faulting is part of the survey and is measured on at least four joints in the right wheel path at every uniform mileage reference marker (MRM). Faulting is currently being measured with a Georgia Faultmeter, which measures faulting to a resolution of 0.03 mm (0.001 in); however, beginning in 1997 it will be measured using the ARAN® (Automatic Road Analyzer) vehicle.

The distress survey is conducted in a van that is driven along the shoulder at 13 to 25 km/h (8 to 15 mph). The van has a driver and a rater and they don't switch back and forth. However, the driver is trained to identify the distresses because occasionally there is no shoulder and the driver rates the pavement from the windshield view while driving over the section. A 100 percent visual survey is performed every year, and this level will be maintained on the interstate pavements. Roughness and rutting are reported as part of the survey, but are attached from the RES. The distress survey only loads into dROAD and does not go into the RES.

In the proposed new version of the *Needs* book, pavement distress data are all reported in the form of indexes. These indexes are on a 0 to 5 scale, with 5 being Excellent and 0 being Poor. The indexed values are computed by calculating the average measurement of interest for a particular pavement section and identifying the associated deduct (from a perfect score of 5.0). This process is described in greater detail in the new *Needs* book.

Distress Feedback

The results of the pavement distress survey are not well-suited to all potential users of this data. For most research projects, for example, specific performance information or particularly timely information is needed, which isn't available from a network-level survey. Similarly, the Regions need project-level summaries of cracking and other distresses on pavements that are scheduled for maintenance or rehabilitation. For this application the distress information should be current and the extent should be correct: if the results aren't timely they aren't of much use for their day-to-day purposes.

Another office, Local Government Assistance, raised questions about the subjectivity of temporary labor to collect certain distress data, but was not aware of any specific problems with these data.

<u>Traffic</u>

The Division of Planning/Engineering's Office of Data Inventory coordinates the traffic data collection effort, which includes vehicle volume counts, vehicle classifications, and axle loads. Traffic data are collected year-round by a full-time staff that includes six traffic technicians located in the Regions. The resultant traffic data are part of the RES, but are maintained by Data Inventory staff.

Data Collection and Processing

The State owns and operates 51 Automatic Traffic Recorder (ATR) sites from which data are fed back to Pierre by telemetry. The State also has short-term counters that are maintained by six traffic data technicians. The FHWA's *Traffic Monitoring Guide* and *HPMS Monitoring Guide* serve as the basis for the Department's traffic data collection activities. From these, the Data Inventory office has summarized its practices in its own documentation, *South Dakota Traffic Monitoring Documentation* (rev. 2/13/97).

Vehicle counts are obtained from over 6100 short-term count locations located around the State. A sampling plan for the counts is developed each year based on the functional classification of the pavement. The overall objective is to collect data at the following frequencies:

- Non-interstate HPMS sections every year.
- State trunk highway locations sampled every 2 years.
- Interstate HPMS sections every 3 years.
- Non-state trunk highways every 6 years.
- Roads in urban areas every 4 years.
- Small cities and towns every 6 years.

Classification data come from approximately 250 classification sites throughout the State. These sites are also sampled on a regular schedule, satisfying both Federal reporting requirements and State needs. The Department considers seasonal variation in vehicle counts by comparing spring, summer, and fall data. Each location is sampled three times a year: over two weekdays and one weekend.

The State uses weigh-in-motion (WIM) to collect vehicle weight data. There are currently seven active sites that consist of a combination of piezo, bridge, and bending plate data collectors.

Ultimately there will be 15 permanent sites installed. Where WIM data are collected, they are also used to provide traffic counts, which eliminates the need for separate counting sites.

The Data Inventory office processes traffic data. It collects the data, performs the quality control, analyzes the data, and prepares and distributes the data, such as in the form of traffic maps. Clients (or users) of its product include Design, Planning, Accident Records, the public, MPOs, the FHWA, and the urban areas and counties. Data Inventory also publishes summaries of some of its data. The most recent version is the *1994 Highway Traffic Report*, which includes classification and weight data among others.

Data quality is verified in several ways. The first check is with historical data. The State trunk highway data are collected every 2 years, so this serves as a useful verification process. Counties are surveyed every 6 years, so checking historical numbers is not as meaningful (the urban network is done every 4 years and Highway Performance Monitoring System [HPMS] traffic data are collected annually). All counts that come in are looked at manually. Then traffic is loaded into the RES traffic file. Again it is checked for typographical errors and again it is checked against historical data. Some data, such as that collected by WIM, also has automated validation in addition to a manual check.

In 1997, the Department acquired and implemented TRADAS, traffic data management software. This software coordinates the collection, inspection, and reporting of traffic data through its Data Collection Management System (DCMS) subsystem, while its Standard Traffic Monitoring System (STMS) performs inspection, analysis, and reporting on the collected data. Based on nationally accepted standards for monitoring traffic, TRADAS works as both an automated data collector and data processor. An integral part of this software is its extensive checks on data quality, which "filter questionable data from the analysis process."

The data collection and processing procedures for the State's HPMS sections is different from that on the State sections. HPMS has its own procedures and it has to come from specified mileage. The State uses the HPMS data to develop VMT and to find errors that come from some of their checks.

Figure 11 depicts the traffic data collection process. As is seen in this figure, traffic volume and classification data are handled separately from the weight (WIM) data. One significant difference is the manual editing that takes place with the volume and count data versus the automatic editing of the WIM data.

Traffic Data Feedback

Feedback from interviews supports the fact that traffic data are widely used throughout the Department. Almost every office reported using at least some component of traffic data, and many made widespread and frequent use of this information. To summarize traffic data feedback, the most common comment was that the counts for a specific location were sometimes not believed to be accurate, or that short or special counts were less accurate than regular counts. A second group of comments was that published data, such as in the *Needs* book, were not accurate enough for specific applications so that special requests were often made to Data Inventory. Where there existed concerns about the accuracy of traffic data, they stemmed more from a lack of familiarity with the rigorous procedures involved in extrapolating from limited counts. However, any office appears to be able to request special counts for their specific needs.

Friction

The SDDOT owns a K.J. Law Model 1270 trailer for measuring skid. The Department's equipment was acquired in 1975 and rebuilt in 1985.

Data Collection and Processing

Skid data have been collected haphazardly in recent years. While the original intention of the Department may have been to collect friction data on some subset of their pavement network annually, that has not been accomplished. In 1996 the equipment was not operational and no

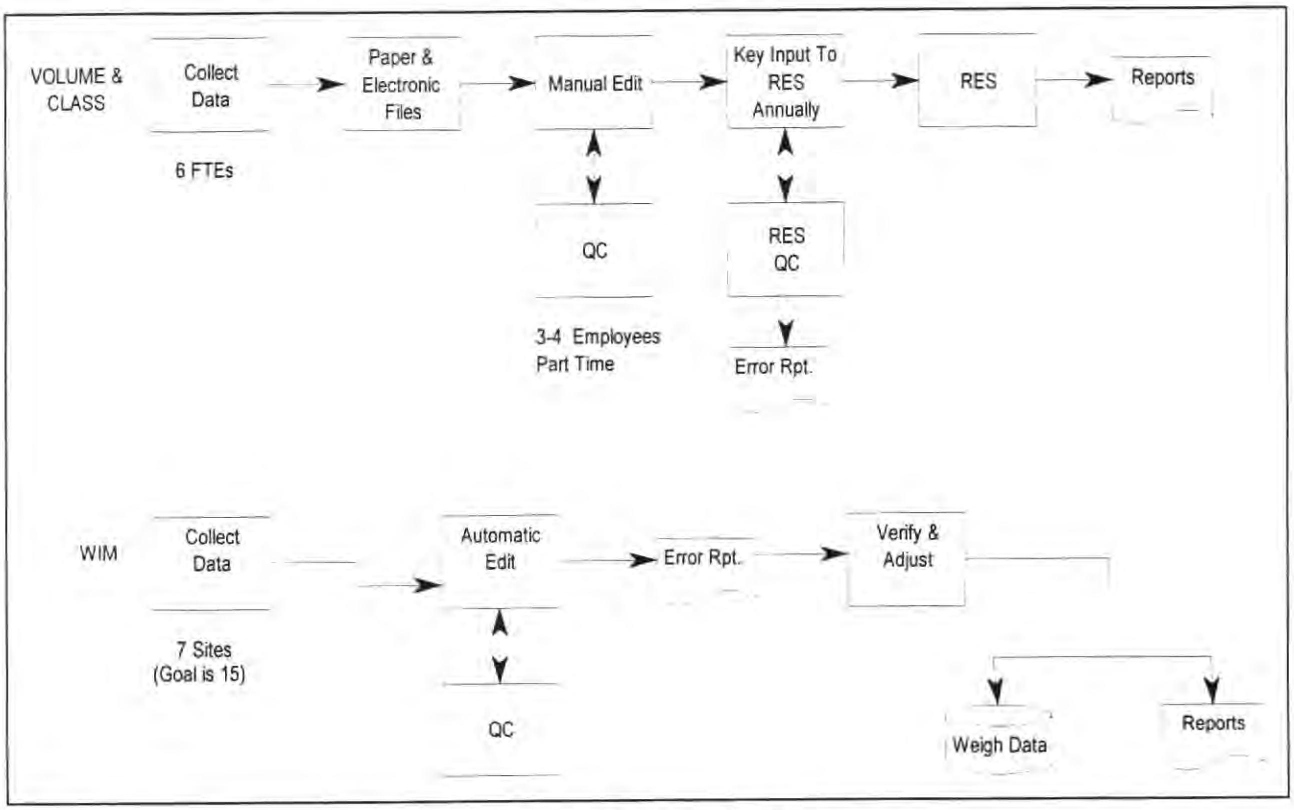

Figure 11. The traffic data collection process.

data were collected. There were plans to restore the equipment to operational condition in 1997, but it is not known if that will be accomplished.

Originally, the equipment had an operator assigned to it, but in 1991 that changed and seasonal employees have been used to collect friction data since then. The handling of the equipment also underwent a change over time. From 1981 until 1989 it was calibrated annually at a calibration center, and now it is calibrated every 4 years. The last calibration was performed in 1994. When it was in working condition, local calibration of the equipment included daily sensor and water calibration. The trailer was also tested weekly over a test strip in Pierre. Figure 12 depicts the skid testing process utilizing the K.J. Law Skid Tester.

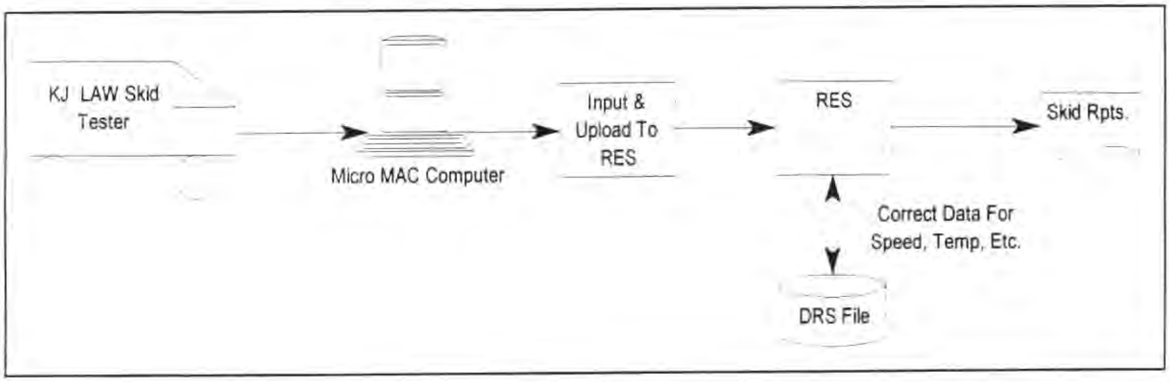

Figure 12. Skid testing data collection process.

Friction Data Feedback

Although there are many potential good uses of friction data, such as those listed below, these data are rarely used:

- Assessing the effectiveness of maintenance.
- Identifying candidates for functional overlays.
- Accident assessment.
- Evaluating effectiveness of chip seals.
- Evaluating effectiveness of experimental treatments.

In the past, Operations considered the surface friction properties to be a driving force in their resurfacing program. These data were also used to determine whether roads were being maintained properly. Several Regions noted that the data could be used to post warning signs, but they know which roads require such warnings anyway (such as from accident data or experience) and can post them without testing.

Aeronautics uses the skid testing equipment to measure skid resistance, primarily on commercial airports, where having good skid numbers is an important part of safe aircraft operation.

To obtain meaningful results with the equipment, the driver needs to operate the vehicle precisely in the wheelpath. Some users reported a potential source of error to be the inability to place the equipment in exactly the right location, exacerbated by the shift to part-time employees operating the equipment.

Roughness

At the time that information was collected for this report, the South Dakota Road Profiler was used to collect profile and rut depth data, and to develop the sufficiency rating. The equipment measures and records elevations; the data are used to calculate the South Dakota Index (SDI) and the International Roughness Index (IRI).

Data Collection and Processing

The entire network is surveyed every 2 years, and the portion that is tested is usually covered between May and September. The data are processed and analyzed between September and December, at which point they are uploaded to the RES. Once entered into the RES there are no checks on the data, but feedback is provided from the PMS group and from HPMS; this feedback is then used to make corrections.

There is one calibration section in Pierre and the equipment is calibrated weekly. If the difference in SDI readings is greater than 0.05 then a more in-depth look at the equipment is undertaken. The distance measuring instrument (DMI) is also checked against standard sections and calibrated four times a year. Tire air pressure is checked every morning. For software checks, the most current MRM is downloaded.

The current rutting and roughness data collection processes are performed with South Dakota's ARAN vehicle, as shown in Figure 13.

Roughness Data Feedback

Several groups reported using roughness data directly, including Materials and Surfacing, Research, and the Office of Local Government Assistance (responsible for Non-State Trunk Highways [NSTH]). No problems were reported with the roughness data as it is provided.

Rutting

Rutting is measured using a three-sensor rut bar mounted on the profile survey vehicle. The center sensor measures the elevation of the "hump" between wheelpaths relative to the bar, while the two outer sensors measure the distance from the bar to the pavement in the wheelpaths.

Data Collection and Processing

Rutting is reported as a displacement, by Highway, MRM, and lane. The rutting data are made available to potential users in the *Needs* book, where they are combined in approximately 0.4 km (0.25 mi) segments, averaged, and converted to an index on a 0 to 5 scale (deducts are made to a perfect 5.0 score based on the average rut depth for a pavement section).

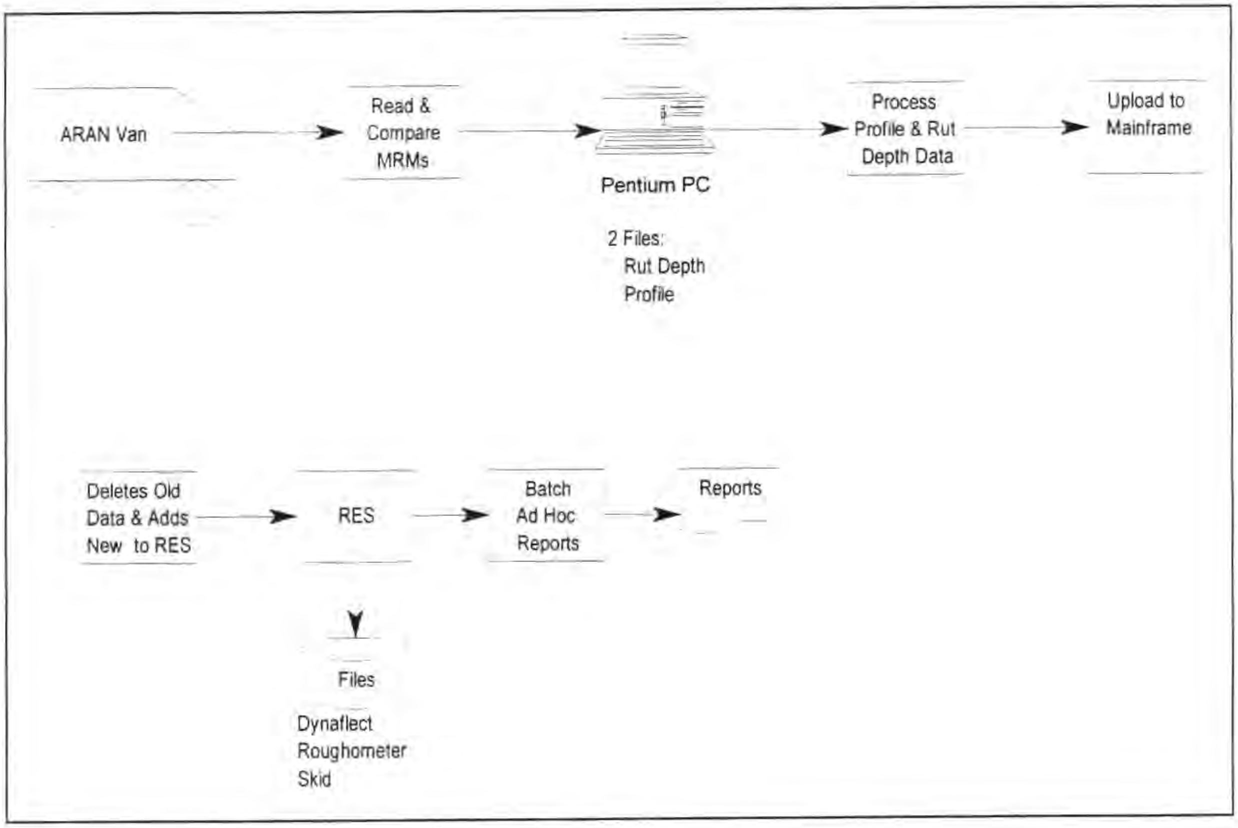

Figure 13. The rutting and roughness data collection process.

Rutting Data Feedback

Rutting data have been used to estimate quantities for rut filling, to identify the need for milling, and as a guide in determining whether to remove a surface layer. Rutting information is used by the Regions in their project planning and selection processes, and to trigger maintenance or milling. Rutting is also used by engineers in the Materials and Surfacing office to identify problem designs or mixes. Materials and Surfacing uses rut depth data for undersealing studies and for load studies. Research also examines rutting data to identify special projects where rutting is a problem. No dissatisfaction was reported with this data item.

<u>Sufficiency Rating</u>

Data Collection and Processing

The Sufficiency Rating is an indexed value that the SDDOT has used to quantify the relative or comparative adequacy of different pavements in their highway network. Based on a composite

100-point scale, the Sufficiency Rating includes components of pavement condition (40 points), safety (30 points), and service (30 points). Guidelines for calculating this index are summarized in *South Dakota Sufficiency Rating Process* (document dated 1/22/92). Over the years, attempts have been made to make the components of the rating objective. This has been partially accomplished by assigning measured values (such as those obtained with the Profiler) to certain ranges in the rating scheme.

Sufficiency Rating Feedback

In interviews conducted throughout the Department, there was some familiarity with the existence of the rating, but no one could state what was in it or how it was calculated, and few were sure what it was being used for. A likely explanation for this lack of familiarity with the rating is that as an index it does not represent a single physical property of a pavement. Decisions related to maintenance or rehabilitation are more commonly based on specific conditions with which decision-makers are more familiar. With the introduction of dROAD, the rating is not being calculated or used, and is not reported in the revised draft of the *Needs* Book.

Videolog Images

The Department uses a Mandli Video Image Capture System van to create a videolog of the pavement network. The equipment has been in use in South Dakota since 1991. Image acquisition is accomplished by a charged coupled device (CCD) camera, and the storage medium is 305 mm (12-in) optical laser disks. Each disk holds 290 km (180 mi) of records per side, for a total of 580 km (360 mi) per disk. An on-board DMI is connected to a computer that allows images to be tagged with the Region, Route number, date of the survey, and appropriate MRM and displacement.

Data Collection and Processing

The videolog survey van is operated at highway speed, generating 125 photographs per kilometer (200 per mile), and the entire pavement network is surveyed every 3 years. It is only possible to obtain a useful image when the pavement is clear and ambient lighting conditions are satisfactory, so the survey is run between late spring and fall, during daylight hours, when the weather is likely to be favorable and the pavement is likely to be dry. The camera is aimed so that an overview, or inventory, image is acquired. This image is appropriate for studying inventory location and condition information (such as bridges, guardrails, and signs) and some pavement information (e.g., number of lanes, pavement type).

One full-time Department employee is assigned to perform the videolog survey, process the data, and make the results available to the end users. There are six workstations located throughout the Department to access the videolog. These are located in Pierre in the offices of Data Inventory and Roadway Design, and in each of the four regions. Each region is given a copy of the videolog for their pavements, and a copy of the entire survey is stored at both Data Inventory and roadway design. The videolog image collection process is shown in Figure 14.

Videolog Feedback

Feedback on the videolog images was varied. Overall, the system is widely used, especially by those responsible for certain inventory tasks. For example, Road Design uses the images to look at the location and status of signs, the Office of Bridge Design uses the videolog to view guardrails for approach views, and Materials and Surfacing uses the Videolog file to see right-of-way and guardrail locations (although they reported that it was not very user-friendly, and would be more useful if it showed pavement distress and could be used to verify surface widths). The traffic engineer in the Region uses videolog for viewing guardrails and railroad crossings, and Project Development (environmental) uses the Videolog file to perform various functions, such as verifying approaches, and business and utility locations.

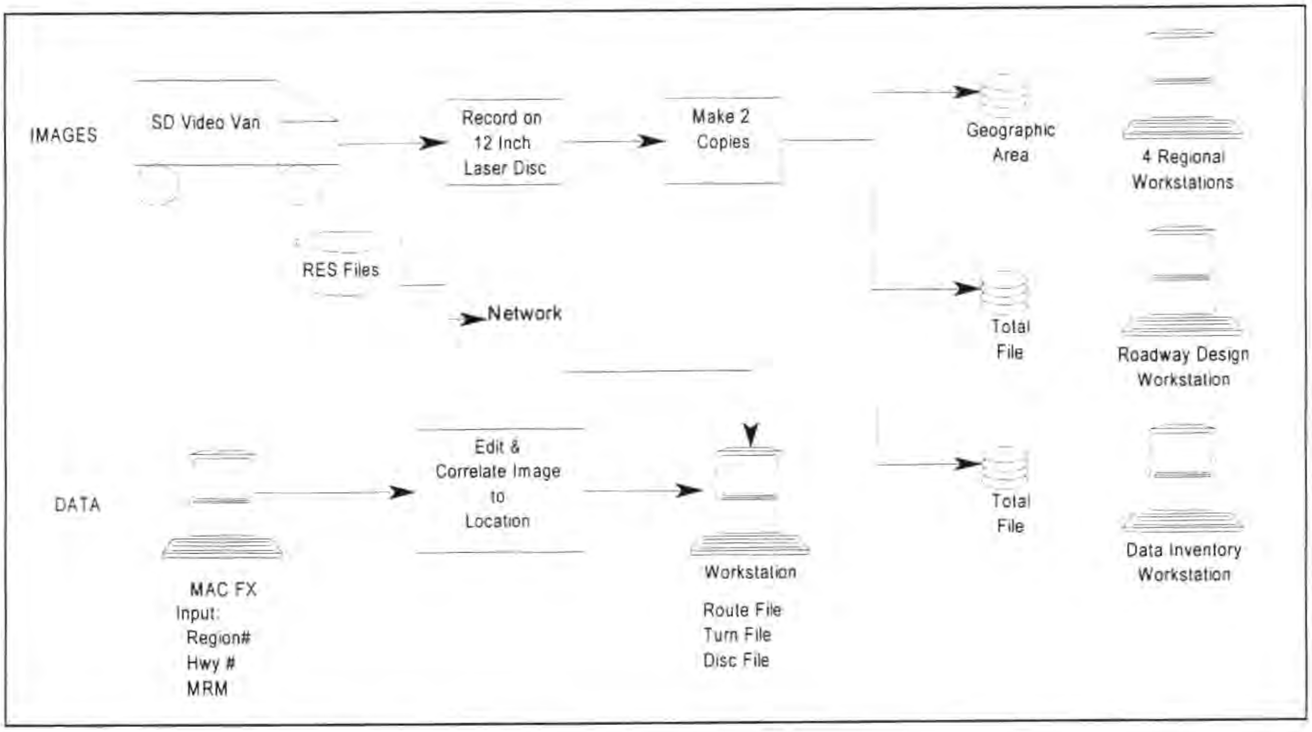

Figure 14. Videolog image acquisition process.

Each of the regions reported wide use of the videolog. Signs, billboards, delineation, and traffic signs were items that are studied on film, and if the equipment were more readily accessible it would likely be even more widely used.

Falling Weight Deflections

The Dynatest Model 8000 Falling Weight Deflectometer (FWD) is used to collect pavement deflections on roadway and airfield pavements. There is one full-time operator responsible for the equipment and all data collection activities. During the summer months, two temporary personnel are hired to assist in the data collection process.

Data Collection and Processing

The FWD is used for two types of data collection: network-level and project-level testing. Deflection data are collected for at least four types of projects. On AC-surfaced pavements, FWD data are used to identify candidates for spring load restrictions; the Regions currently make their decisions for posting load restrictions based on recommendations developed from FWD data. The restricted road information is also input into planning documents. FWD data are also used to identify candidate projects for the overlay program. Another use for deflection testing is in PCC pavement restoration projects, where the data may be used to identify the need for undersealing, load transfer restoration, and other rehabilitation needs. Finally, deflection testing is carried out on airport pavements to assess structural adequacy and design structural overlays. Use of the FWD can be summarized as follows:

- 8 weeks of PCC testing.
- 2 weeks of airport testing.
- 6 weeks of testing on materials-related work.
- 2 weeks of forensic testing for Operations.
- 8 weeks of inventory testing.

In the past, data from the FWD inventory testing process has been loaded into the RES system. There is also a location for FWD data to be stored in dROAD. Figure 15 depicts the FWD inventory data collection process:

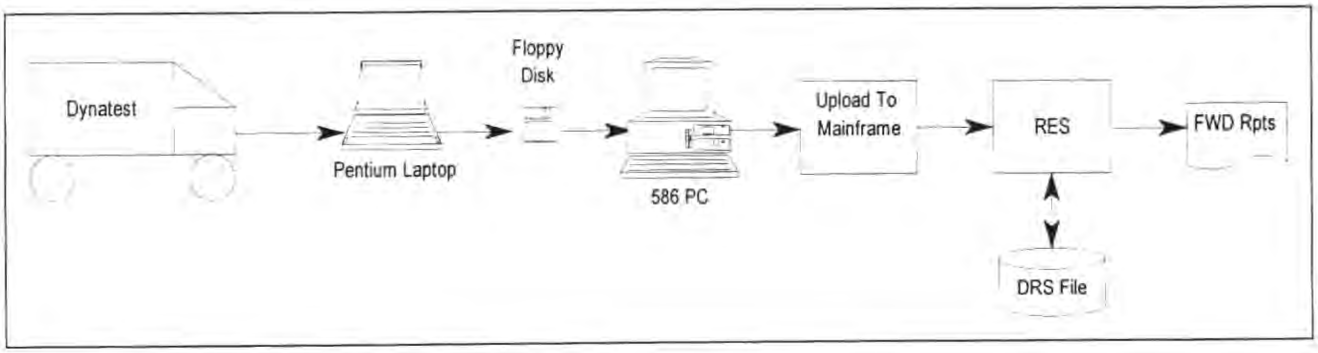

Figure 15. The FWD inventory process.

At airports, the typical testing pattern is every 150 m (500 ft) on the edges and at the pavement center. If there is a problem, the testing interval is decreased. Also, if there is a problem the testing is repeated before any rehabilitation project. The Aeronautics section would like to do an annual survey as well as spring testing to identify areas likely to weaken during spring thaw.

Testing procedures follow guidelines developed by other agencies and by the manufacturer. However, there do not appear to be documented procedures that govern the use of the equipment in South Dakota. In addition to internal data checks, the FWD is calibrated to SHRP specifications every 1 to 2 years. In between calibrations, there are online system checks of data quality.

FWD Feedback

Users of the FWD data readily acknowledged its value to their decision-making processes. Operations uses FWD data for spring load restriction postings. That same data are also used as a part of the process to consider projects for overlays in the region and to identify posted pavements that need strengthening. Occasionally, the Regions will also make special requests for FWD data to develop their maintenance programs. Aeronautics uses FWD data for assessing pavement strengths and in rehabilitation, and the data are occasionally used on the NSTH.

There was a concern expressed that that calibration of the FWD output is needed on pavements over a range of seasons to develop correction factors, which were available with the previous deflection testing equipment. However, the following corrections are already a part of the data processing:

- Test data from AC pavements are corrected to 25 °C (77 °F) using Asphalt Institute equations.
- Test data from PCC pavements uses software-specific parameter curves that are also based on temperature. Either a 5-day average or the previous 24 hour temperature is used.

Verification of Vertical Curves, Horizontal Curves, and Pavement Widths (Geometrics)

Data Collection and Processing

Vertical and horizontal alignment data are developed from the as-built drawings and summarized in a file in the RES. The width of various pavement features comes from plans, but are field-verified as possible. Field verification is performed by Data Inventory, and consists of measuring widths at a typical location. Where a different width continues for approximately 150 m (500 ft), the different width is entered.

Geometric Data Feedback

The greatest reported shortcoming of geometric data is the apparent inaccuracy of the reported pavement widths. Some *Needs* book users (particularly those in Road Design) report that pavement widths in the database do not correspond with what is seen in the field. However, the *Needs* book reports a predominant width for a section; a user may well be looking at a particularly narrow section and note a discrepancy that is not representative of prevailing conditions. Pavement cross slopes are another data item that some users desire but are generally not available. The only source of this information is from plans, and they may not be representative of what is actually found in the field. Those who need more accurate data evidently collect such data.

Summary

Data collection and processing activities for specific roadway data items are described in this section. These data items include pavement distress, traffic, pavement friction, roughness, rutting, sufficiency rating, videolog images, falling weight deflections, and geometrics. Collection and processing activities are described for each data item, and are followed by feedback from users on that data item.

There is a significant amount of variability in these data collection activities in terms of the frequency of data collection, how the equipment is operated and maintained, and how the results are perceived throughout the SDDOT. Recommendations regarding each of these activities are found in chapter 7.

OVERALL SUMMARY

An overview of South Dakota's roadway data collection activities is presented in which they are viewed as a process. The collection of the individual measurements of roadway data is also examined. This information serves as a useful backdrop to understanding current activities and developing recommendations for improvement.

Some of the data collection activities are in the process of changing, so that current practices evaluated in 1996 and early 1997 may not be representative of how the data collection is being performed. This is true at least for roughness and friction. Improvements are also being implemented in traffic data handling.

6. Roadway Data Users' Needs

INTRODUCTION

The review of data collection activities presented in chapter 5 focused on the experience of data collectors and data users. The emphasis of this chapter is on the needs of the data users, those who have a stake in the product of the data collection effort. The various concerns of this group are summarized, with the objective of identifying where in the data collection process efforts at improvements would be most worthwhile. This assessment is supported by a review of data collection costs and the results of a survey that solicited information on the relative benefits of different categories of roadway data.

PROCESS MEASUREMENTS

In analyzing the roadway data collection process, there are three major process measurements that can be considered:

- *Effectiveness* of the data collection process.
- *Efficiency* of the data collection process.
- *Adaptability* of the data collection process.

Effectiveness may be thought of as the extent to which the outputs of the roadway data collection process meet the needs and expectations of the users. A synonym for effectiveness is quality. Effectiveness also means having the right output at the right place, at the right time, and at the right cost. An ineffective process in this context is one that does not deliver the right data, or delivers the right data in a manner or at a time in which it cannot be used.

Efficiency is the extent to which the use of system resources is maximized and waste is eliminated in the pursuit of effectiveness. Productivity is a measure of efficiency. Examples of inefficiency include redundant data collection efforts and collecting data that are not used.

Adaptability is the flexibility of the data collection process to accommodate both future, changing user expectations and today's individual, special needs and future requirements. An adaptable system maintains or improves its level of effectiveness and efficiency, while a rigid system does not.

USER NEEDS AND EXPECTATIONS

From the interviews that were conducted in the Department, it was observed that user needs and expectations can be grouped into several different categories. These different categories are summarized below.

The **relevancy** or usefulness of the data must be considered. Are the data useful as collected or processed or is some other measurement more meaningful or relevant? Data users expressed a need for data that are appropriate for the user. The data collection equipment should also be capable of providing data of value.

The **form** in which the data are presented to the user is important. For example, is it raw data, a batch-processed report listing, a specific ad hoc report, or a relational data base with "what if" query capabilities? While the data may be collected and stored in a single format, users may require a range of processed forms. The following issues related to form arise:

1. The database must provide the ability to easily generate ad hoc reports and consider "what if" scenarios.
2. The data must be available in graphical form, such as in maps, figures, and graphs.
3. The data must have "hooks" that connect to other information such as supporting source documents or plans.

The **timeliness** with which the data are collected is also important. Are distress data collected in the summer after the winter damage, collected in the spring prior to any pavement rehabilitation activities, or collected 12 months previously so that the passage of time and traffic has affected data validity? A secondary issue is the timeliness with which the data are available to the user for processing. Does the time taken to collect and process the data into a usable form allow little time to use it? Users' needs regarding timeliness are summarized below.

1. The intervals for collection must be such that the data are still relevant when they become available to the users.
2. The data must be processed and available in time to meet the time constraints of the user.
3. The data must be directly available to the user without an intermediary or custodian.

The **accuracy** and **reliability** of the data are important issues to users. Are the data collected following well-defined and documented procedures and checked against quality standards? Are the data re-collected at the point of collection if they do not meet quality standards, with the collector held accountable for results? Are the data collected under the same controls and by the same personnel and equipment every time, eliminating variables and minimizing subjectivity? The data users' needs pertaining to accuracy and reliability are summarized in the following four requirements:

1. The data should not reflect the variability and subjectivity of collectors and collection equipment.
2. The data must reflect maintenance activities that change roadway characteristics.
3. The data must better reflect construction activities that change the RES database.
4. The data must be pinpointed to a specific roadway location.

The **usability** of the data is also an issue that was raised in interviews. Are the data in a form that can be readily used, or must the user undertake additional manipulating or processing of the data before it can be used? Issues relating to usability are listed below.

1. The data must be retrievable by multiple parameters such as MRM, intersection, condition, rating, and so on.
2. The data must be available at the users' desktop.
3. The data must be available from a single computer platform.
4. The data elements in the *Needs* book must be more inclusive, or the PMS reports should be made more available.

Finally, the **cost** to produce the data is a consideration. Data collection is a Department-wide function that draws on limited resources. Are the costs to collect and process the data in line with the value of the data to the end user? Users do not tend to express concern about individual costs, as costs are borne by the Department. However, overall the SDDOT is extremely interested in cost issues. The following summarizes some issues related to data collection costs:

1. The cost of data collection should reflect the value of the data to users.
2. The effort of the data user in quality checking, manipulating, or further processing of the data must be eliminated, and all such efforts and associated costs transferred to the data collection effort.
3. The costs of poor designs or inappropriate repairs to roadways because of erroneous data must be eliminated.

ROADWAY DATA USER VALUE SURVEY

In order to better quantify the value of different types of data to users, selected officials within several departments were asked to complete a survey on the collection and use of roadway data. A total of 54 department officials, representing a significant cross section of individuals with varying responsibilities, were asked to rate each data type that they use on a scale from 1 to 5, with 5 being the highest rating. The following questions were posed to the survey participants:

1. Importance of data accuracy (1 = Not Needed; 5 = Essential).
2. Actual accuracy of receipt (1 = Very Inaccurate; 5 = Error Free).
3. Importance of data timeliness (1 = Not Important; 5 = Must Be Timely).
4. Actual timeliness of receipt (1 = Never Timely; 5 = Always Timely).
5. Overall value of the data in their operation (1 = Not Needed; 5 = Essential).

A rating of 3 indicates that the data are of average importance or are generally accurate or timely enough to meet the needs of the user.

The overall results of the questionnaire survey are summarized in Table 15. This table provides the average rating for each data type in response to the above questions, as well as the number of respondents for each question. Because certain questions in the survey were not relevant to specific departments, not each question is answered by every respondent, and consequently the number of responses varies across the categories. Nevertheless, the number of responses and the cross section of individuals surveyed are believed to be more than adequate to provide meaningful insight on the value of road condition data to the SDDOT.

Table 15. Summary of overall questionnaire results.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of Receipt		Overall Value of Data	
	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating
Traffic Volume	47	4.0	43	3.1	47	3.6	44	3.9	48	3.8
Vehicle Class	45	3.4	39	3.1	44	3.0	37	3.8	48	3.3
Vehicle Weights	47	3.3	34	3.0	42	3.0	33	3.5	45	3.3
Pavement Roughness	46	3.4	36	3.1	42	3.1	37	3.7	46	3.3
Pavement Rutting	45	3.4	35	3.2	43	3.1	36	3.7	45	3.4
Friction	45	3.2	36	3.2	41	2.7	34	3.4	47	3.0
Falling Wt. Deflections	46	3.5	35	3.4	43	3.2	39	3.6	46	3.4
Videolog Images	44	3.1	38	3.3	44	2.8	40	3.6	46	3.0
Pavement Dist. Survey	44	3.3	32	3.2	41	3.0	34	3.8	41	3.1
Transverse Jt. Faulting	44	3.3	43	3.1	40	3.1	34	3.6	39	3.2
Geometrics	45	3.4	38	3.1	44	3.0	38	3.5	45	3.2

An example of the survey questionnaire, along with additional questionnaire responses, are given in Appendix B.

According to the data survey results presented in Table 15:

- The accuracy of the traffic volume data is significantly more important to end users than the other data items, presumably because of its widespread use.

- Accuracy is least important for friction and videolog, although these are not that different than some of the other items.

- The survey shows the relative accuracy of the different data items to be about the same (in the range of 3.0 to 3.4), with the accuracy of the FWD data the greatest. While this level of accuracy is generally adequate, increases in accuracy are possible for all data items.

- The importance of timeliness is also greatest for traffic volume data, with friction and videolog images again slightly less than the other items.

- The timeliness of receipt are greatest for traffic volume, vehicle class, and the pavement distress survey, followed closely by pavement roughness and pavement rutting. The timeliness for these items is generally good (ranging from 3.7 to 3.9), and are not that much different than the other data items (ranging from 3.4 to 3.6). These results indicate that the timeliness of the receipt of the data items is generally reasonable.

- Overall, traffic volume has the greatest value to the Department. From the questionnaire results, the rest of the data appear to have about equal value, with friction and videolog appearing to have the least overall value. It should be noted that the results from the distress survey as it is currently performed have only been available for the last 2 years; its true value may not be fully realized.

A separate table was constructed that reflects the value of data to the Regions. This summary is found in Table 16 below.

Table 16. Questionnaire results for regions only.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of Receipt		Overall Value of Data	
	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating	No. of Responses	Average Rating
Traffic Volume	19	3.9	17	3.2	19	3.2	18	3.8	19	3.7
Vehicle Class	19	3.4	16	3.1	19	2.8	16	3.7	20	3.3
Vehicle Weights	19	3.3	15	3.1	18	2.6	16	3.6	19	3.4
Pavement Roughness	19	3.6	15	3.1	17	2.8	17	3.7	19	3.3
Pavement Rutting	19	3.6	15	3.1	19	3.0	17	3.7	19	3.6
Friction	18	3.8	17	3.4	17	2.9	17	3.7	19	3.6
Falling Wt. Deflections	19	3.7	14	3.2	19	3.3	18	3.7	19	3.6
Videolog Images	18	3.0	15	3.2	19	2.8	17	3.6	19	3.2
Pavement Dist. Survey	19	3.4	15	3.1	18	3.0	17	3.6	18	3.3
Transverse Jt. Faulting	19	3.4	16	3.2	18	3.0	17	3.6	16	3.4
Geometrics	19	3.5	16	3.2	19	2.8	18	3.6	19	3.1

According to the results presented in Table 16:

- Accuracy is most important for traffic volume, friction, and FWD data. It is least important for videolog, and of about equal importance for the remaining data items.

- All data items show about the same level of accuracy, with the average rating for friction slightly greater than the rest. However, as with the ratings shown in Table 15, the relatively low ratings for each data item (ranging from 3.1 to 3.4) again indicate that the accuracy is generally adequate but that improvements can be made.

- The importance of timeliness is about the same for all data items, with traffic volume having the highest rating of importance. Timeliness is least important for Vehicle Weights.

- The timeliness is about the same for all data items (only ranging from 3.6 to 3.8), and the ratings indicate that the timeliness is more than adequate.

- Traffic volume again has the highest overall value rating (3.7), followed closely by rutting, friction, and FWD (3.6). Geometrics has the lowest overall rating, followed by videolog.

In comparisons between Table 15 and Table 16, traffic volume is the data item of highest value, and it is of about equal value to both the Department as a whole (Table 15) and the Regions (Table 16). On the other hand, pavement monitoring data (rutting, friction, and FWD) are of greater value to the Regions than to the Department as a whole. Geometrics and videolog consistently are of lowest value to both groups.

The sufficiency rating was not included as part of the questionnaire survey, but based on the lack of familiarity with it, it is unlikely that its overall value rating would have been greater than 3.

QUALITY CONTROL CHECKPOINTS

During the interviews, some data users indicated that the reliability of some of the data items is questionable. To compensate for this, they verify the data manually or in some other way before they use it in their respective processes. Where the end user consistently feels the need to perform a check of data quality before use, it suggests that there are insufficient quality control checkpoints. However, the purported prevalence of unreliable data was not reflected in the questionnaire results. Furthermore, a review of the data collection processes suggests that there are already more than enough quality control checkpoints. Figures 16 (a and b) highlight where in the current process data are, or could be, checked for accuracy and quality:

A close study of the data collection process shows that the problem is not a result of there being <u>too few</u> quality control checks on the data; the problem is that the majority of the problems uncovered with the data are <u>too late</u> in the process flow.

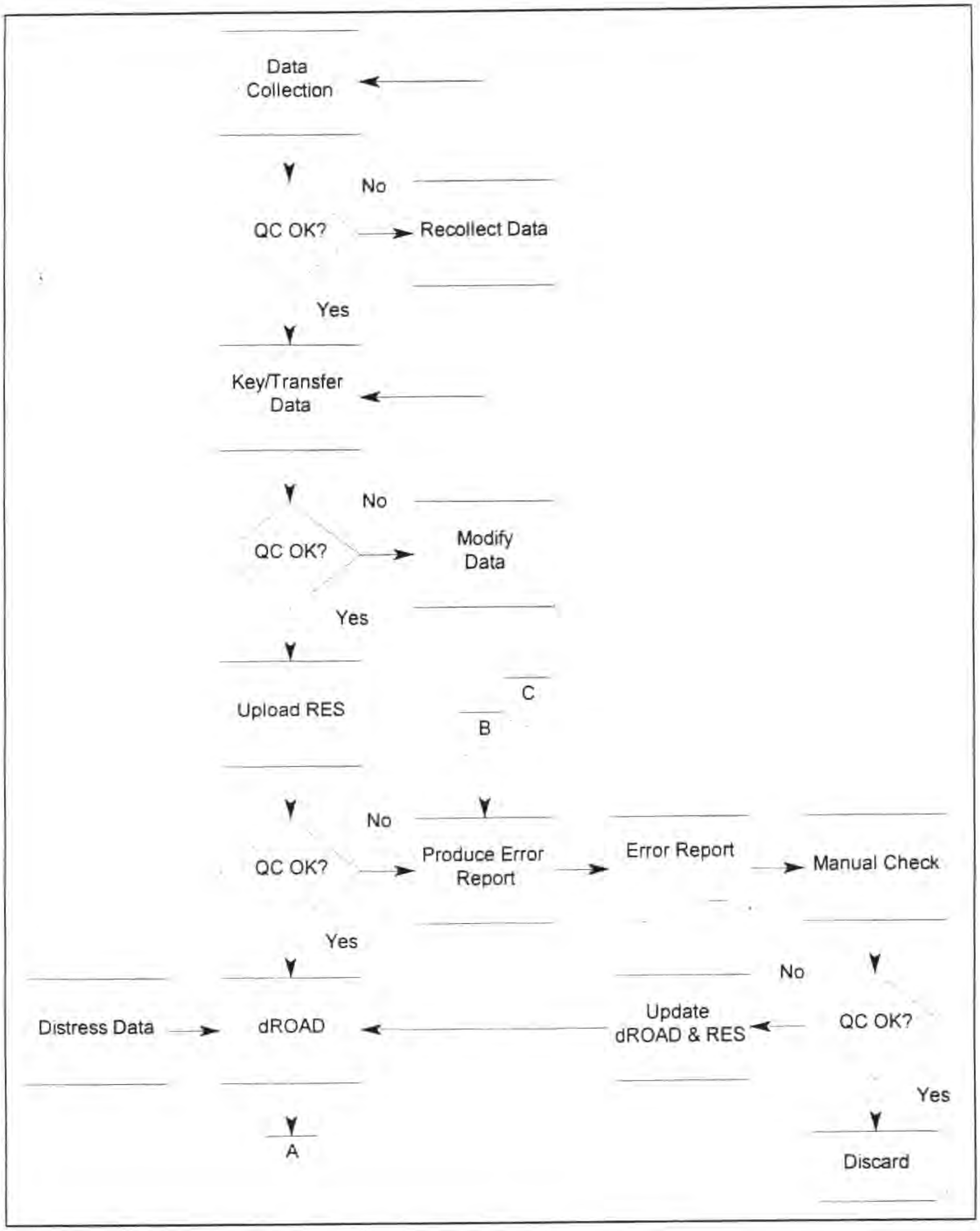

Figure 16a. Data collection quality control checkpoints.

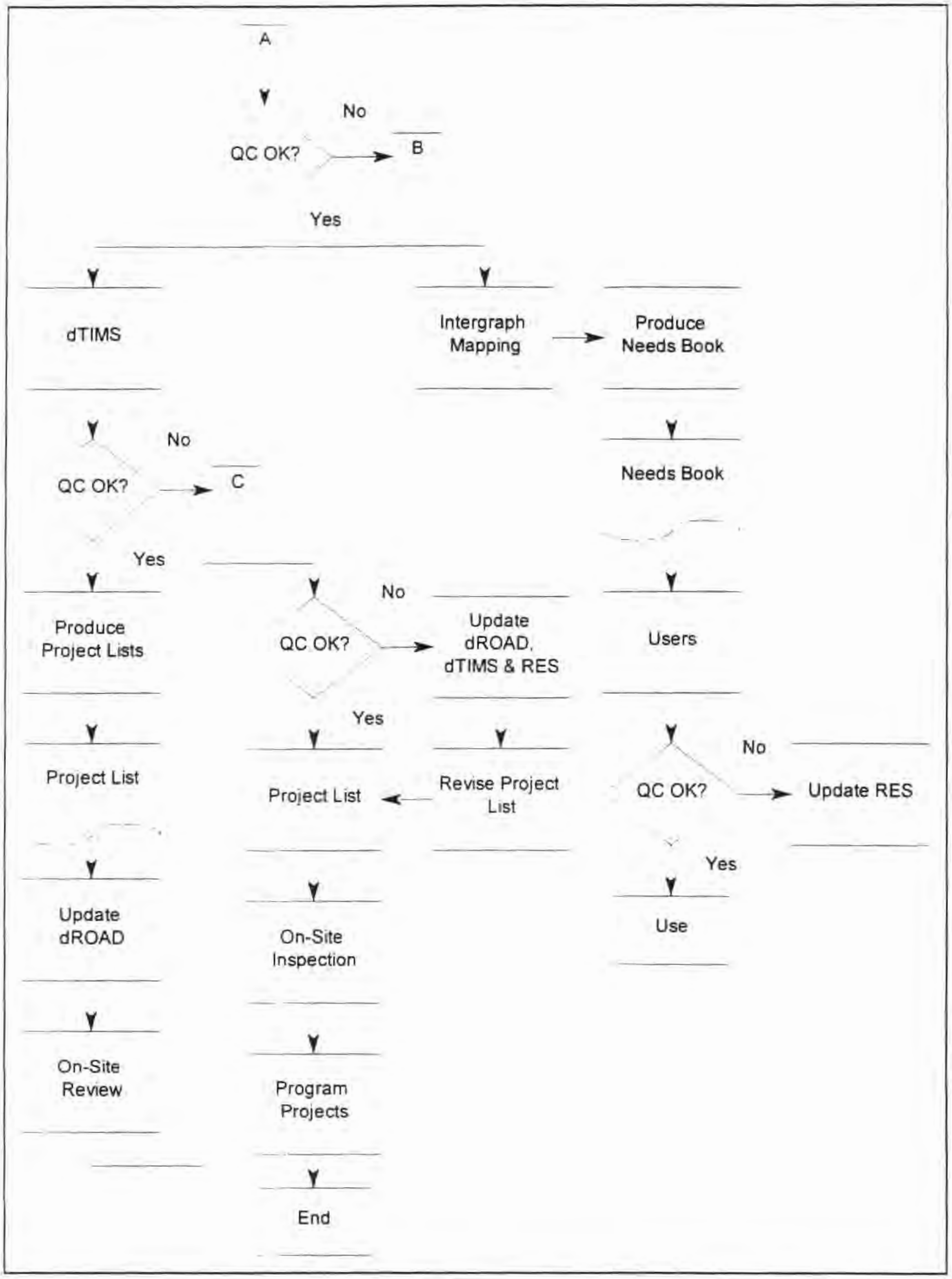

Figure 16b. Data collection quality control checkpoints.

For example, it is estimated by Data Inventory that 90 percent of the problems fed back to Data Inventory are uncovered by data users when they use the *Needs* book. However, it is also estimated that far more errors are discovered by data processors prior to the actual publication of the *Needs* book.

It is not practical to modify the *Needs* book once it is published to change the data that are found to be erroneous. At the same time, the *Needs* book is heavily used across the Department and other data users will either use the flawed data or go through the same productivity-robbing quality check routines. Either situation is very damaging to the efficiency and effectiveness of the data users and all processes that are fed by the data users.

One point to make regarding the use of the *Needs* book is that it is important that users realize what the information contained in the document represents. For example, it is possible that many of the data items that are thought to be inaccurate are actually average or representative values computed over an extended highway segment. In that case, it is important for the user to recognize what the data represent and the limitations of their applicability.

Effective Quality Control Checkpoints

For several data types virtually no quality problems are uncovered and corrected at the point of data collection. If data could be verified as accurate at point of collection, however, reliable data would flow to the users and to their processes that use the data.

Several possible reasons for not checking the quality of data at the point of collection are listed below.

1. In most cases the equipment that collects the data does not have the capability to verify data accuracy (e.g., skid, roughness, and rutting values may be collected correctly, but there is no check to verify that the measures reflect the actual pavement condition).

2. In the case of distress data collection, the collectors are seasonal employees that have no long-term accountability for quality and their classification of conditions is very subjective and inconsistent.

3. The data collection is often done under inconsistent environmental conditions.

4. Due to tight time constraints to collect the data during favorable weather conditions, the collectors are forced into a production mode. Quantity can overshadow quality as the primary goal.

If data collectors have no means to check the quality of their data, are not motivated to ensure the quality of the data as collected, are not held accountable for data quality, and know that downstream the data will be checked, the possibility of collecting reliable data is remote. The fact is that in keeping with good process design principles, the quality of a work product should be controlled at the point of production. It is almost impossible, and nearly always uneconomical, to add quality back into a product after it is created. A champion of the "quality" movement, W. E. Deming, observed that quality can not be "inspected in" to a product; rather, appropriate training and education must be a part of every production effort, whether the products are data or widgets. The producer of the work product must be held accountable for quality so it does not corrupt the processes it supplies.

DATA COLLECTION COST/VALUE ANALYSIS

The true effectiveness of each data item is evaluated by considering both data value to users and the costs to collect that data. Several tables are presented here summarizing the costs of collecting roadway data in South Dakota (as billed to data collection budget numbers by the SDDOT accounting system). Table 17 shows the FY 1995 costs to collect each data type, Table 18 shows the FY 1996 costs of collecting each data type, and Table 19 shows the FY 1997 costs of collecting each data type.

Table 17. Reported FY 1995 costs of collecting roadway data.

Data Type	COST BY CATEGORY ($)								Total Cost ($)	% of Total
	Personal Services	Travel & Subsist.	Rent & Utilities	Com. Rep. & Serv.	Other Costs	Supplies	Assets	Equip. Costs		
Vehicle Class	33,547	6,849							40,396	4.0
Weigh In Motion	5,093	169	2,354		32	141		108,571	116,360	11.5
Traffic Monitoring	286,185	45,997	21,274	5,880	1,546	58,470	10,992		430,344	42.6
Video-Logging	36,474	3,090		1,664	291	36,960	59,333	33,100	170,912	16.9
Profile and Rutting	43,732	7,159			944	534	259	12,000	64,628	6.4
Skid Test	15,776	4,865			1,426	561		8,900	31,528	3.1
Distress	34,768	16,994		32		309			52,103	5.2
Falling Wt. Deflections	65,760	17,604			1,470	1,006	2,861	15,000	103,701	10.3
TOTALS	521,335	102,727	23,628	7,576	5,709	97,981	73,445	177,571	1,009,972	

Table 18. Reported FY 1996 costs of collecting roadway data.

Data Type	COST BY CATEGORY ($)								Total Cost ($)	% of Total
	Personal Services	Travel & Subsist.	Rent & Utilities	Com. Rep. & Serv.	Other Costs	Supplies	Assets	Equip. Costs		
Vehicle Class	40,862	11,083		54		271			52,270	5.7
Weigh In Motion	14,283	159	2,417		46	475		108,571	125,951	13.7
Traffic Monitoring	282,132	42,832	22,563	1,602	1,861	71,394			422,384	46.1
Video-Logging	38,623	6,599		619	192	765	31,484	33,100	111,382	12.2
Profile and Rutting	18,170	1,725			143	130		12,000	32,168	3.5
Skid Test	10,036	1,208			352	48	278	8,900	20,822	2.3
Distress	29,236	20,086		65		200			49,587	5.4
Falling Wt. Deflections	66,483	16,897	6	1	1,488	1688		15,000	101,563	11.1
TOTALS	499,825	100,589	24,986	2,341	4,082	74,971	31,762	177,571	916,127	

Table 19. Reported FY 1997 costs of collecting roadway data.

Data Type	COST BY CATEGORY ($)								Total Cost ($)	% of Total
	Personal Services	Travel & Subsist.	Rent & Utilities	Com. Rep. & Serv.	Other Costs	Supplies	Assets	Equip. Costs		
Vehicle Class	26,754	8,055				30			34,839	8.5
Weigh in Motion	2,910	142	609					108,571	112,232	27.3
Traffic Monitoring	71,169	12,952	18,914	584	375	5,329	28,360		137,683	33.5
Video-Logging	10,986	4,665				62		33,100	48,813	11.9
Profile and Rutting	3,275	492						12,000	15,767	3.8
Skid Test	1,615	176						8,900	10,691	2.6
Distress									0	0.0
Falling Wt. Deflections	27,457	8,054		75		635		15,000	51,221	12.4
TOTALS	144,166	34,536	19,523	659	375	6,056	28,360	177,571	411,246	

An examination of these tables suggests the following:

- Traffic monitoring data are consistently the most costly data to collect, comprising 43, 46, and 34 percent of the total costs, respectively, for FY 95, FY 96, and FY 97.

- The next most costly data items to collect are weigh in motion, videologging and falling weight deflections.
- Vehicle class, skid (friction), profile and rutting, and distress consistently have the lowest costs associated with their collection.

Table 20 presents average annual collection costs for each data item for fiscal years 95 and 96 (for which the most complete data are available) and for fiscal years 95, 96, and 97. However, it should be noted that some of the information for FY 97 was unavailable, thereby making the averages reported for FY 95 and FY 96 more reliable.

Table 20 also contains the relative value of each data item (repeated from Table 15) and an estimate of the impact of the data item on resulting decisions (i.e., to what extent does a decision based on the data item impact the resulting activity?). This estimate is very subjective, but is an attempt to combine data value with a consideration of other factors. How many direct users of the data are there? What decisions does it impact? Are the data direct inputs to design with a resultant impact of tens of millions of dollars, or are the data used in a less "critical" manner? The development of these subjective ratings is shown in Table 21. It should be noted that with little exception, all of the data have an important impact.

Table 20. Summary of 3-year costs, overall value rating, and impact of data item on decision making for each data collection category.

Data Item	FY 95 and FY 96 Average Annual Cost ($)	FY 95 and FY 96 % of Total	FY 95, FY 96, FY 97 Average Annual Cost ($)	FY 95, FY 96, FY 97 % of Total	Overall Value Rating	Impact of Data Items on Resultant Decisions (1 = Little Impact, 5 = Significant Impact)
Vehicle Class	46,333	4.8	42,502	5.3	3.3	3
Weigh in Motion	121,156	12.6	118,181	14.9	3.3	5
Traffic Monitoring	426,364	44.3	330,137	41.5	3.8	5
Videologging	141,147	14.6	110,369	13.9	3.0	2
Profile and Rutting	48,398	5.0	37,521	4.7	3.35	3
Skid Test	26,175	2.7	21,014	2.6	3.0	3
Distress	50,845	5.3	50,845	6.4	3.1	5
Falling Weight Deflections	102,632	10.7	85,495	10.7	3.4	4
Grand Total	**963,050**	**100**	**796,064**	**100**		

Table 21. Assessment of use and impact of roadway data items.

Data Item	Used Directly By	Impacts Decisions	Impact Rating
Distress	Regions/Operations	Rehabilitation decisions, timing, maintenance	5
Traffic	All	Rehabilitation decisions, pavement design, planning and programming decisions	5
Roughness	Materials & Surfacing, Research	Rehabilitation decisions	3
Rutting	Regions/Operations, Materials and Surfacing, Research,	Materials selection, rehabilitation decisions	3
Friction	Regions, Aeronautics, Materials & Surfacing	Materials selection, posting, potential liability in accidents	3
Videolog	Bridge Design, Road Design, Materials & Surfacing, Regions/ Operations, Project Development	[saves trips to field to confirm inventory items]	2
Sufficiency		Project selection (not any longer)	1
FWD	Aeronautics, Research/ Operations, Regions, Materials & Surfacing	Maintenance vs. rehabilitation vs. reconstruction, overlay thickness, posting load limits, pavement design	4
Geometrics	Bridge Design, Road Design, Regions/Operations	Decision to reconstruct vs. rehabilitate	3

5 = highest impact, 1 = lowest impact

Combining data collection costs, value, and the impact of each data item is a good way of drawing overall conclusions regarding data needs. The data presented in this table suggest the following interpretations:

- While traffic monitoring has the greatest associated collection cost, it also has a high overall value to the users and has a great impact on resultant decisions. The cost appears to be balanced with user value.

- Videologging represents about 14 percent of the total cost, and has an overall value rating of 3 and an impact rating of 2.0. Respondents noted that they would use the videolog output even more often if it were more accessible and easier to use; additional investment in collecting this data seems justified. It should be noted that the low impact rating reflects that this technology saves time and money, but does not have a very large direct effect on decision-making.

- FWD data collection represents nearly 11 percent of the total cost and had a relatively high overall rating. In addition, it has a high impact rating due to the effect of the FWD information on pavement overlay designs, for example.

- Rut and Profile data represent only about 5 percent of the total data collection cost and also have value to users. The use of the ARAN vehicle to collect these data may increase the value rating even more.

- Although friction has a low collection cost, its value rating and impact rating appear to indicate that its overall worth is much greater than the current expense of collecting it.

SUMMARY

Input from roadway data users was sought through both interviews and a questionnaire. The interviews were used to develop an understanding of the needs of data users. The interview results helped to identify issues of importance to users and to solicit ideas for where improvements were needed. Overall, data collection needs can be better met by improvements to the quality of the data, the timing of data collection, and the ability of the entire process to recognize change.

Surprisingly, the questionnaire results did not provide as clear-cut a substantiation of the issues raised during the interviews as might be expected. The questionnaire results showed that all data were of at least average accuracy and timeliness, and no single data item had a "value" below an average rating. Traffic monitoring did have the highest value.

When data collection costs and a subjective assessment of the impact of the data are considered, there appears to be a high degree of congruency between costs and value. This does not mean that the process can not benefit from a greater effort to improve the quality of the data—especially when the processes are examined closely—but there is not a high degree of dissatisfaction with accuracy and timeliness reported by questionnaire respondents.

7. Procedural and Quality Control Recommendations to Improve Roadway Data Collection

INTRODUCTION

The review of data collection practices in the Department, in other agencies, and in standard practices elsewhere indicate that overall South Dakota's practices are sound. From insights gleaned during this review process, recommendations are provided to improve these practices. These recommendations are organized in the following manner:

- Presentation of a principles of a comprehensive roadway data collection policy.
- Procedural recommendations that affect each roadway data type.
- Alternatively, the implementation of a comprehensive data collection device that combines multiple data collection efforts.
- The development and implementation of quality control procedures for distress data.
- Summary of recommendations.

DATA COLLECTION POLICY PRINCIPLES

One of the objectives of this project is to propose a comprehensive data collection policy. Such a policy should help the Department to allocate existing resources to data collection. The policy should also allow the Department to prioritize data collection needs to address either a decrease in available activities or an increase in data collection needs.

There are several principles proposed for such a comprehensive policy. These are enumerated below:

1. Roadway data collection activities provide information that is used to drive decisions that have a large impact within South Dakota.

2. Each of the elements of the data collection practices of the SDDOT (e.g., roughness, friction, distress) should be collected so they are individually of the highest possible quality given the Department's resources. Similarly, different data types used to make decisions affecting South Dakota's pavements should be of similar quality.

3. Data that have no value to the Department should not be collected.

4. Data that have a "high" value and a large impact on decisions are worthy of a proportionally larger investment than data that have a "lower" value.

   An initial assessment of value is provided in Table 21, but this can and should be refined based on the Department's determination of its own values.

5. Data collection frequency for different data types should match usage. For example, if distress and roughness are used together in a performance index, they should be collected at the same frequency. If little change in roughness is noted from year to year, but a more noticeable change occurs every 2 or 3 years, than an appropriate frequency for collecting such data is every 2 or e years.

6. Needed roadway data should only be collected once. If the same data are used in different locations throughout the Department, the data should be collected and available in a timely and readily accessible manner.

   There are two approaches to accomplishing this. The first is to ensure that the data users are satisfied with data quality. The second is to ensure that users are receiving the data when they need it. This is primarily a processing and data distribution issue.

7. Both the technologies associated with roadway data collection and the uses of the collected data are changing rapidly. The SDDOT should regularly reassess its practices in the face of such changes, perhaps every 3 to 5 years

This chapter addresses each of the data elements in the roadway data collection activities of the SDDOT and suggests improvements that are possible with limited additional resources. This is an application of the first six of the preceding principles. After considering the individual data types, the applicability of automated distress data collection equipment is addressed. This addresses the seventh principle, evaluating new technologies.

PROCEDURAL RECOMMENDATIONS TO IMPROVE ROADWAY DATA COLLECTION ACTIVITIES

Recommendations for each data procedure are provided in this section. In most cases, these do not involve any substantial additional cost. For example, if the recommendation is to document the procedures, it is assumed that manuals can be assembled without significant effort and no costs are identified. If the recommendation is to use different equipment or to implement new technology, an attempt is made to identify costs.

Data Types

Roughness

Based on information provided by users and a review of technology and other practices, there is no problem with the roughness data collection procedure or the equipment used in this procedure. However, development and implementation of quality control procedures will help to ensure that the output continues to be useful. These include the development of control sections over which the equipment can be run on a weekly basis (see *Dynamic Calibration* below) and the required use of daily system checks of the equipment's hardware and software. The draft protocol on roughness that is being developed under the FHWA's sponsorship offers good guidelines for such procedures. The final version of this protocol should be integrated into a guide for South Dakota's roughness measurement program.

It is recommended that the roughness survey be performed annually over the same sections as the distress survey. An appropriate data collection segment is 0.4 km (0.25 mi) so that it corresponds with distress survey segment lengths. An annual survey of the entire network is recommended until performance model development is satisfactorily completed. The survey should be performed in the outer lane in both directions on divided highways and in one direction on undivided highways. Results should be reported as an IRI for each pavement management section. Roughness should be measured in both wheelpaths and the result reported as an average of the wheelpaths.

Static Calibration

Static calibration involves the evaluation of the accuracy of the sensors (displacement test) and an evaluation of the integrity of the accelerometers (bounce test). These tests should be conducted on a daily basis. Another test of interest is the evaluation of the DMI to ensure its accuracy, but this test does not need to be done daily.

In the displacement test, a thin block or plate of known thickness (typically 25 mm [1 in]) is placed beneath the sensor. After ensuring that the block is level, multiple readings are taken to ensure that the readings are within a specified tolerance (usually provided by the manufacturer). If they are out of tolerance, a new calibration factor must be calculated.

In the bounce test, the vehicle is rocked vertically and horizontally by the operator jumping on the bumper. During this test, the profile output should be flat and show very little variation. If it is not, the equipment is not operating properly.

Dynamic Calibration of Profiling Equipment

The dynamic calibration takes the actual profile measurements (or profile-generated roughness statistics) obtained from the equipment and compares them to those obtained from a baseline measure (usually rod and level survey or dipstick survey). The intent is to ensure that the results compare favorably to one another (again, within a specified tolerance). If significant differences exist, this may suggest an equipment error.

Two test sections, each 0.4 km (0.25 mi) long, should be established for AC and PCC pavements. Pre-measurement of the IRI should be made on these test sections, using either a rod and level or dipstick survey to establish baseline roughness measurements. Then the ARAN should be operated weekly over both sections. The costs associated with equipment calibration are minimal. It is not believed that additional staff or equipment would be required, nor should calibration require additional costs.

Rutting

Rutting is estimated from data collected with the three-point rut bar mounted on the ARAN van. A document that describes this practice, similar in format to the FHWA's *Draft Rut Depth Protocol*, needs to be prepared to describe this data collection activity. As noted in the *Draft Protocol*, specific quality control practices that are applicable include the following:

1. Establish test sections with known rut depth statistics for both pavement wheelpaths and rate these sections with the ARAN on a weekly basis. Ideally, test sections would cover a range of pavement classifications.

2. Develop and perform on-board checks that compare rutting measurements with previous values and validate measures against an allowable range. Rutting should never decrease, so even a manual examination of trends would be of value. By comparing new data with the previous survey, instances in which rutting decreased or increased by more than a specified reasonable amount would be flagged to be retested.

These validation procedures should not require a significant additional expense to perform. While creating the test sites may require several days, checking the equipment will not require a substantial effort. However, the FHWA's entire draft rutting protocol should not be implemented in its current form because the severity levels for rating rut depth are not refined enough to be useful to the SDDOT.

The rutting survey should be performed at the same frequency as the roughness and distress survey. In general, the three-point rut bar provides sufficient information about the size of a rut to model rutting, assess material performance, and identify safety hazards. No additional costs are required to adopt the recommended changes, although productivity may be slowed down slightly.

If the SDDOT is concerned about the ability of the vehicle operator to place the vehicle in the precise lateral position required to measure the deepest rut, one solution is for each operator to make a mark on the hood or windshield to assist in aligning the vehicle with edge or center markings. However, the wheelpath location does vary and in the end the mark may not be of much help. If the Department remains dissatisfied with rutting measure variability, they should consider adding sensors to the rut bar so that a more continuous transverse profile is measured.

Pavement Distress

Recommendations concerning pavement distress are discussed in the section on quality control and are not repeated here. In addition to the protocols already discussed, the FHWA has supported the development of draft protocols that address crack measurement on all pavement surfaces, and faulting on PCC pavements. The adoption of these protocols in South Dakota is not necessary at this time. They appear to have been developed to facilitate standardized automated distress surveys and perhaps even automated interpretation of the results. Adopting these would require significant changes in distress definition, which would in turn impact modeling deterioration. The current definitions used in South Dakota are more detailed and provide more complete information about the surveyed pavements.

Falling Weight Deflections

While there are no major problems identified with the FWD procedures, a review of the current practices in South Dakota suggests several opportunities for improvements.

1. There does not appear to be any documented procedure currently being followed for FWD testing. Although reference was made to the Texas DOT's procedure being used as a guide, it is not clear that these procedures are always followed. A manual should be developed that specifies how FWD testing is to be performed in South Dakota. Such a manual should describe the testing pattern, equipment settings, and testing frequency for the different pavement types encountered in the State, such as AC pavements, AC-overlaid pavements, jointed concrete pavements, continuously reinforced concrete pavements, and possibly surface treated pavements. This manual should also address what backcalculation procedures are used for the different pavement types. Limitations of the technology may be considered as well. The manual should include documentation for both highway and airport pavements.

   The graphical output in the existing FWD test reports is good. Providing explanations of the output and the different ways of presenting the data in the manual will help to educate potential users about the technology and how it may be used to their advantage.

2. Network level surveys are not needed and should not be performed. There is sufficient variability in deflections due to factors that are not well understood that the use of network-level deflection data is questionable. The estimated savings from eliminating this portion of the survey is somewhere between $19,750 and $39,500 (8/26 of the labor costs would be eliminated, but some travel time would still be needed). The testing plans for concrete and interstate asphalt pavements appear appropriate, based on SDDOT's experience.

3. Perform project-level surveys for pavements that are candidates for rehabilitation where a decision is being made between a structural and a functional rehabilitation. If it is known that a functional overlay will be constructed, no FWD testing is needed.

4. System calibration appears to be satisfactory, but there does not appear to be any standard that is being followed. Part of the State's FWD manual should address annual calibration at an approved calibration center, and the regular calibrations that can be done in the field. Field calibration sites are not needed, as it would be impossible to achieve any repeatability.

5. FWD data are ready to be stored in dROAD/dTIMS and the RES. Because these data are now being used at the project level, reconsider the need to store them with network-level data.

Special studies may also be established to continue to make the FWD a useful tool within the Department. The use of FWD data for assisting in posting spring load restrictions is one good application of such special studies. Because the regions are trying to post fewer and fewer roads each year and FWD data are only one part of the decision process, this program should be able to continue with a reduced testing effort. Other special uses of the data include assessing seasonal variability of deflections for different pavement types, field testing and calibrating AASHTO's nondestructive testing method of overlay design, and developing typical support values for different native materials.

Friction

Friction data collection, or the measurement of skid resistance, has been a problem in South Dakota for some time. Since 1991, seasonal employees have been used to collect these data, and variability in the results has been attributed to this shift to part-time employees.

The Department did not collect friction data in 1996, but has discussed restoring the equipment to operational condition and using it in 1997. While friction data collection efforts are greatly reduced, the need for these data remains. Areas where skid numbers are important include:

- Airport runway evaluation.
- Evaluation of new pavement materials and construction methods.
- Accident investigation and litigation defense.

The Regions also expressed a desire to continue to receive skid data. Because of the demand and the value of skid data, it is recommended that the Department continue to collect it. While the SDDOT could walk away from its commitment to maintain this equipment, such an approach does not serve the users of South Dakota's roadways. A well thought out program of friction testing, addressing new materials, performance of selected existing pavements, and both general and specific safety issues would benefit the State. There does not appear to be any demand for a network-level survey. Instead, the equipment can be used by Aeronautics, by the Regions and Research on an as-needed basis, and by Materials and Surfacing.

The importance of using properly maintained and calibrated equipment can not be over-emphasized, as was pointed out in discussions with the Massachusetts Highway Department. While non-calibrated equipment may be adequate for research or other in-house purposes, it can not protect the Department when lawsuits occur. Therefore, if the equipment is made operational again, the previously described daily and weekly calibrations should be retained. The equipment should also be sent to a national calibration site at least every 3 years. If the friction data are used in support of the Department in legal actions, the equipment should be calibrated at a national site every 1 to 2 years.

The cost impacts of resuming the collection of skid data are an important issue. The Department estimates that $40,000 is required to restore to working order their existing equipment;

replacement equipment wil cost approximately $170,000. Given the magnitude of this difference, it is recommended that the existing equipment be restored <u>if</u> it can be calibrated within acceptable limits. Operating costs are estimated at between $25,000 and $35,000 annually. Approximately $31,500 was spent in this area in FY 1995 and $20,800 was spent in FY 1996. No national calibration was performed in either of those years, which would have made the costs higher.

<u>Videolog Images</u>

The videolog survey is performed on State trunk highways on a 3-year cycle, with image acquisition controlled by good weather and the available light. The mission of this equipment is the collection of <u>inventory</u> data on roadway and roadway-related features. In interviews throughout the Department, it was found that there were many different users of this technology and almost as many ideas for additional uses if only the output could be enhanced in one way or another. For example, while images can be viewed they can not be "manipulated" or easily used in other applications. A move to the use of digital images would allow the images to be of greater value to the end users.

The videolog survey acquires an image approximately every 8 m (25 ft), but users expressed an interest in a more continuous survey (rather than discrete photos). A more continuous survey is possible with other equipment available on the market, but the Department has expressed an interest in identifying potential improvements to the data collection process that do not entail large capital expenditures.

For videolog output to be more useful throughout the Department, especially to those who need more detailed pavement data, the following capabilities are desirable:

- Automatic, accurate interpretation of the data.
- More frequent data collection than a 3-year cycle.
- Ability to operate under a variety of lighting conditions.
- Digital rather than analog output.

The technology for automatic interpretation of the data is not yet mature enough to be useful to the Department. Data could be collected more frequently than every 3 years and under a variety of lighting conditions, but not without some modification. This would include the addition of cameras that would allow image capture from the front and rear of the vehicle and external lighting systems. This equipment is not well suited to these changes and they are not recommended.

The manufacturer of the videolog equipment has introduced a digital upgrade system. Examining the platform, data storage and connectivity of the new system suggests that it would be completely compatible with desktop workstations that would support Electronic Document Imaging for project files. Those workstations would include 530 mm (21 in) high-resolution monitors as well as 2 to 4 Megabytes of VRAM.

The digital roadway images are stored as JPEG files on a dedicated server connected to the Department's Local Area Network (LAN). Those files are highly compressed from approximately 1 Megabyte (MB) to 70 Kilobyte (KB). The compressed image size would allow the Department to transmit the images over the Wide Area Network (WAN) as readily as 50 KB 216 x 280 mm (8.5 x 11 in) document images contained in the project files.

The manufacturer recommends that files be stored on Redundant Array Of Inexpensive Disks (RAID)-5 magnetic disk drives for rapid access. Data storage would be approximately 7 Gigabytes (GB) per 1,600 km (1,000 mi) roadway segment. The data could also be stored on optical discs in a jukebox as an option, but would offer slower retrieval time.

The approximate cost of a digital system to replace the analog system the SDDOT currently uses is $450,000. This includes a completely outfitted new van and central office processor. The price is for a complete system, including all processing equipment, hardware, and software. Casual users could view images using Adobe Photoshop at a small cost. Intensive users who need full image and associated data retrieval and manipulation capability would require workstation software at a cost of about $2,000 per seat.

By integrating the roadway images into a client-server network, every image-enabled user on the network, including field locations, could have convenient access to roadway images. The digital images could be manipulated by the user at the desktop to provide the most effective view.

Being able to view roadways from the desktop should reduce the number of trips taken to the field to verify data, eliminate costly design errors, and facilitate decision making. Predesign can be facilitated as well as the inventorying of signs, guardrails, and so on. The data collection process also supplies an attributes map as a by-product that can be incorporated into building a Global Positioning System (GPS). In addition, the system would provide the capability for interested parties to collaborate with the same roadway image displayed at the same time on multiple network computers.

Because of the high demand for the video images from many users throughout the Department, it is recommended that the Department make this transition if and when users' computer systems are updated to allow image access. However, for the present no changes from current practice are recommended. This includes modifications to the equipment and altering the frequency of the survey. Eventually, the Department should convert over to one vehicle that performs all of the automated data collection, including image acquisition, and that point is some time in the future.

Sufficiency Rating

With the introduction of dROAD the sufficiency rating is no longer being computed. It is recommended that the sufficiency rating no longer be calculated or used.

Traffic

The traffic data collection activities undertaken by the Department are the most comprehensive and costly of all the different roadway data collection efforts. However, the data generated by these efforts are an essential component of the decision-making process throughout the Department. This information impacts pavement characteristics (it is used in design and rehabilitation, and in the analysis of pavement performance) and funding (funds for many different purposes are allocated based on traffic data).

Overall, traffic data collection is being undertaken in accordance with standard accepted practices. Some of the problems with traffic data do not appear to result as much from shortcomings in the technology as they do from misconceptions related to its application. As an example, many of the procedures associated with providing traffic numbers rely on statistical principles. These include determining the required number of data collection sites and establishing the frequency of data collection. Because of the sampling techniques, there may be a perception that some traffic data are more than accurate than others. However, overall the principles are being applied correctly. The concerns seem to be related to interpolations, or estimations of traffic at one location based on measurements made elsewhere. However, without increasing the data collection effort substantially, this is the most effective means of determining traffic data where none have been collected. It is recommended that the Data Inventory office issue a final version of their traffic monitoring documentation and either distribute it to traffic data users or make them aware of its availability. Admittedly, this document may not be read by data users. But it should enable data users who are interested in becoming more familiar with how published traffic data are obtained.

Verification of Curves and Other Geometric Data

One of the greatest problems with data appeared to be with geometric data, and especially with pavement widths. The *Needs* book reports predominant widths for a section, including shoulder widths, pavement widths, and ROW widths. These do not necessarily correspond to a measure made at any given location along the section. While reporting a predominant width may be an appropriate means of presenting condition or traffic data, it is not adequate for some uses of geometric data. For example, users may be concerned about the minimum width, since it, more than a predominant width, controls safety and operations.

Two methods of improving pavement width information in the database are suggested. A "high tech" method is the addition of a camera to the videolog survey. This camera would be pointed down at the pavement and a scaled grid would permit a reasonable estimation of pavement width. An attempt is underway to determine if the current Mandli system supports such a technology. An alternative method is to consider adding a entry to the *Needs* book that reports the minimum width. This could be added to the same column by reporting "Predominant Width/Minimum," and presenting the data as "8/5" for example. No additional costs should be incurred in reporting this additional information.

COORDINATED SURVEY IMPROVEMENTS

In order to make effective decisions about pavements (for example, regarding type and timing of maintenance, rehabilitation, and reconstruction), it is imperative that data needed to make such decisions is available. The field collection of roadway data, however, is one of the most labor-intensive activities within a Department of Transportation. The ARAN vehicle is currently used to collect rutting, faulting, and roughness information, while the Mandli equipment is used to create a videolog of pavement inventory information. However, the ARAN vehicle has the capability of acquiring video images of both the pavement surface and inventory features, so that with some modification distresses could be acquired at the same time as roughness, rutting, and faulting data (as could videologs if this option were selected). These distresses would then be interpreted at a workstation operated in the office. In addition to the ARAN, there are several manufacturers that are marketing equipment that collects almost all of the roadway data used by the SDDOT, and new devices are being developed all the time. Even now, there are many states that have adopted this type of data collection and report very satisfactory results.

According to the manufacturer (Roadware), the projected costs to modify the ARAN and add a workstation so that it could collect pavement distresses are about $110,000. These include the addition of a vertical gyro system, a grade system, and survey calibration and software. The addition of another camera and associated equipment (at about $25,000) would allow the videolog to operate more frequently, and improve the efficiency of the distress survey.

There are several advantages to performing distress identification at the workstation. First, it reduces the amount of money spent on personnel in the field by eliminating the field trips currently being conducted by seasonal employees. One or two technicians or seasonal employees will still be needed to conduct the surveys at the workstation, but no costs are incurred for hotels and other travel expenses. Secondly, the workstation provides an opportunity for direct communication between the raters and experienced staff, which should improve the quality of the data being reported. The use of a workstation to examine pavement condition should not result in a loss of distress survey quality. In the current procedure, the rater seated in the van surveys 40 0.4 km (0.25 mi) segments while traveling on the shoulder. Their results are not anticipated to be significantly different from those obtained from reviewing a video taken by cameras aimed at the pavement surface.

The use of a workstation also creates an opportunity to involve other individuals in the data collection effort. The State of Illinois, for example, invites District personnel to the central office to conduct the condition surveys for the Interstates. The Interstates in each District take approximately half a day to rate, so all nine Districts are rated in approximately 4 to 5 days. Because both central office and District personnel are involved in the rating, there are no disagreements in the overall ratings. The Illinois Department of Transportation (IDOT) has purchased workstations for each of its Districts, as well as for the central office, so that the Districts conduct the non-interstate condition surveys. Approximately 10 percent of the sections for each District are reviewed in the central office for quality control purposes.

The ARAN vehicle could also easily be adapted to be used for videologging efforts through the addition of a video camera in the front of the vehicle, should the Department be interested. This approach is used by a number of states, including Pennsylvania (as discussed previously). This would further reduce the number of passes required over each pavement section. The workstation would provide an opportunity for anyone in the central office to view the video for sign inventory, striping, or any other purpose.

Using a video-based distress survey also provides SDDOT with the flexibility to incorporate new technology as it becomes available. The protocols being developed by the FHWA appear to be moving toward procedures that accommodate the collection of distress data using automated vehicles such as the ARAN. These protocols involve the classification of distress based on its location within a pavement lane. For example, distress located within the outer third of a pavement lane is classified as alligator cracking. Distress located in the middle third of the lane (between the two wheel paths) is classified as block cracking or transverse cracking depending on the crack pattern. The implications of these protocols on the condition rating approaches being used by state highway agencies is unclear since the reclassification of distress based on location rather than pattern has not been studied. However, SDDOT could modify its existing procedures to accommodate the protocols, should they be adopted. Even if the SDDOT purchased a workstation for conducting condition surveys, it could still be used for reviewing unusual pavement sections or verification of the automated survey results.

It is recommended that the SDDOT not adopt the use of automated distress surveys at this time, however. While the need for data for performance modeling is still being evaluated, it would be premature to change the distress data collection procedure. This approach should be reconsidered in 2 to 3 years, at which time initial performance models will be available, new (and perhaps less expensive) equipment will be available, and the Department's needs should be firmly defined.

MEASUREMENT AND QUALITY CONTROL PROCEDURES TO IMPROVE ROADWAY COLLECTED DATA

Introduction

One of the original objectives of this project was to identify quality control procedures that could be implemented to improve the overall quality of the collected data. When the project began, there appeared to be a widespread belief that certain elements of roadway data were frequently inaccurate or otherwise flawed. The researchers hoped that these flaws could be identified and that a system-wide solution could be identified to improve the quality (i.e., accuracy and reliability) of the roadway data.

Through interviews, the process evaluation, questionnaires, and studies of the literature and the practices of other agencies, it became clear that accuracy of South Dakota's roadway data was not the real problem. Furthermore, in almost every case there already existed good quality control procedures for the data collection process. For example:

- The equipment used to collect roughness and rutting undergoes hardware and software calibrations on a regular basis.
- The FWD is regularly calibrated and its software detects errors while the data are being collected. It is also calibrated at a SHRP/FHWA calibration center.
- The friction equipment, when used, is calibrated on control sections on a regular schedule and has been tested and calibrated at a national test site.
- The traffic data undergo numerous software and manual checks. The Chaparral system will make this process even more efficient.

The concept of quality control procedures does not really apply to South Dakota's videolog image collection or to the verification of vertical and horizontal curves, and the sufficiency rating is no longer calculated. This leaves only the pavement distress data process for consideration. This section describes current and proposed quality control procedures for the pavement distress data collection effort.

Overview of Distress Data Collection

Each year, seasonal employees are used to collect pavement distress data. Starting in the spring, these employees are hired, trained, and then travel in vans in two groups of two to collect pavement distress data around the State from May to August. The data are keyed into computer files and in November the data are downloaded into dROAD. In the newly revised version of the *Needs* book, pavement distress data are reported as indices and thus become a part of the road-related decision-making process throughout the State. The pavement distress data also drive pavement deterioration models that have an impact on many critical design and rehabilitation decisions.

Because of the importance of pavement distress data, it is critical that accurate and meaningful distress data be collected. In order for this to be accomplished, an appropriate distress data collection *process*, including proper training, effective survey techniques, and periodic checks and verification, must be in place. The following recommendations address these needs and introduce a quality control procedure that will improve the overall accuracy of the data with minimal additional effort or expense.

Recommendations

<u>Training</u>

Since seasonal employees are used to collect the distress data, it is imperative that they be properly trained in distress identification. The following are specific recommendations regarding the training of the seasonal employees. Most of these steps are already being followed.

1. Before conducting any surveys, spend a minimum of 1 week training the crews in pavement distress identification. This training should consist of both office training (reviewing pavement distress types and distress survey procedures) and field training (using nearby roads for practice). The training should be based on SDDOT's *Visual Distress Survey*

Manual (Draft), which itself should be periodically reviewed to ensure that the photographs and their descriptions remain applicable.

a. After spending about one day reviewing distress types and pavement distress survey procedures, conduct pavement surveys on nearby roads of each pavement type that is found in South Dakota. The results of the two crews will be compared to one another and to the results obtained from an experienced rater. (An experienced rater is defined as either the instructor from the above-noted training or any other individual identified by the Department as qualified to make accurate distress calls.) Any differences in the results shall be discussed to determine why those differences exist. These roadways should be resurveyed until results obtained by both crews agree. Where necessary, establish ground rules as to how to classify unique or unusual distress conditions that may be encountered.

b. Part of the training session should be devoted to safety issues in relation to conducting pavement surveys under traffic on high-speed pavement facilities.

c. To provide the seasonal employees with an idea of how the data are to be used (and consequently to emphasize the importance of accurate distress data collection), a portion of the training should include a review of the development and use of the *Needs* book and the STIP. The use of pavement data in general and distress data in particular in prioritization and actual decision-making should be emphasized.

d. The training should conclude with a test that covers the key concepts believed by the Department to be essential for pavement raters to master.

2. Survey crews should be trained to document and discuss with the experienced raters any unique or unusual distress conditions. Over the course of the data collection activities, the supervisor should share any such information with the other crew as needed to ensure consistency and accuracy in the overall collection of the data.

<u>Field Surveys</u>

After the 1-week training period, the distress crews will begin their distress surveys. The following are recommended features of the distress surveys:

1. Begin both survey crews on an initial survey trip of about 1 week in length. These trips can be to a location of the Department's choosing; the important part is that each crew is accompanied by an experienced rater. Each crew conducts surveys on their respective assigned pavements, with guidance and supervision provided by the experienced rater. The experienced rater should work with both crew members to verify their ability to correctly identify and rate pavement distresses on all the pavement types that will be encountered.

2. The driver and the rater should be encouraged to discuss distress identification issues, or even to periodically change roles to reduce some of the tedium of the surveys.

3. Raters should <u>not</u> use the results of the previous year's survey as the starting point for data entry. This is especially the case with inexperienced raters, for whom the temptation to modify last year's results might be too strong. If ASR and D-cracking are consistently miscalled, consider providing the previous survey's results.

4. A cellular phone should be made available to each crew so that they can easily contact the experienced raters in Pierre with questions on distress identification and collection procedures. A camera could also be useful (a digital camera might be even more useful) for photographing questionable calls and discussing them back in Pierre with the experienced raters.

<u>Validation Procedures</u>

Validation is needed to ensure the reliability of the data that are collected under the program. For pavement distress data collected by humans in an admittedly subjective process, this is highly problematic. The following procedure is not perfect, but does go a long way toward improving the data collection process. It is premised on the notion that the trainers and other experienced DOT staff will correctly identify pavement distresses every time they evaluate the pavement. Therefore their evaluations can be said to constitute "baseline values" or the actual condition of the pavement. While this will not always be the case, this quality control procedure requires that the collected data be compared to what is believed to be the actual measure. With this in mind, recommended validation procedures are outlined below:

1. Selected segments of the surveyed network are to be grouped together into "control" sections. A control section is made up of 40 pavement management segments; the total number of control sections shall cover approximately 2 to 5 percent (280 to 700 two-lane km [175 to 435 two-lane miles]) of the pavement network. They should include segments from each pavement type found in South Dakota and should contain a representative sample of the types and severity levels of all of the pavement distresses associated with that pavement type (based on the current version of SDDOT's *Visual Distress Survey Manual*).

2. Control sections are rated by the experienced raters. With these sections distributed throughout the State, these initial surveys by the experienced raters can be done either in one long trip or as part of several shorter trips throughout the summer (simply staying ahead of the scheduled stops of the survey crews). The shorter the delay between the experienced raters' and the survey crews' evaluation of the control, the less likely there is to be a discrepancy due to an actual change in pavement condition.

3. Control sections are spaced throughout the State so that each survey crew will pass survey control sections according to the following schedule:

   - During the first 3 weeks of the survey, each survey crew will rate one control section a day.

- For the remainder of the survey each survey crew will rate one control section a week.

4. It is imperative that the location of control sections remain unknown to survey crews, although they should have a general understanding of their existence and purpose. The schedules will be drawn up by the survey coordinator in order to include the required control sections but without revealing any information about their location to the survey crews.

There are three components of the survey to compare as part of the quality control check: the distress type, severity, and extent. The survey crews' results are evaluated by first looking at the distress type. The survey crew should have at least 90 percent of the distresses properly identified to be accepted. Consider the example survey sheets for the experienced rater, shown in Figure 17, and the survey crew, shown in Figure 18 (which only include 10 segments for simplicity's sake, rather than the 40). In the experienced rater's control section 21 distress types were identified, so the survey crew must get at least 18 correct (0.9 x 21, rounded to the nearest integer) to pass. In this example, the survey crew made 2 incorrect distress calls (shown by an "X" in the distress box) so the distresses are identified within acceptable limits.

Next look at distress severities. For each correctly identified distress, the survey crew can correctly identify the severity level, miss by one level, or miss by two levels, depending upon whether the experienced rater has scored either a L, M, or H (i.e., if the rating is M, the most the survey crew can miss is by one rating; for a L or H they could miss by two). Using the experienced rater's form, count the number of possible misses (for each experienced rater's M, the count is –1; for each L or H it is –2). In this example, the maximum number is –33. However, the –33 is corrected to –31 because of the one missed distress in segment 9 on the survey crew's sheet. An acceptable score is to rate correctly at least 70 percent of the total possible, which in this example is 22 (0.7 x 31). Count the number of actual misses by counting 1 point for each severity that is off by one level and 2 points for each severity off by 2 levels. In this example, there were a total of 8 points counted. The actual score is then 23 (31 – 8), so the severity ratings are identified within acceptable limits.

Finally, consider the distress extents. Again not counting the distress types that were mis-identified, ignore the severity rating and calculate the sum of missed points by the survey crew. For example, if the survey crew rated an extent of 4 and the experienced rater had a 2, then a –2 is added to the missed points. Calculate the missed points for each segment and total them. Then add up the maximum amount that the survey crew could miss, using the scheme shown below:

- If survey crew extent is 1 or 4, maximum miss is 3
- If survey crew extent is 2 or 3, maximum miss is 2

If the survey crew has at least 60 percent correct then the results are acceptable. In Figure 17 the maximum amount missed could be –50 (again, the transverse cracking extent is not counted because the distress type was missed) so that the survey crew's extent rating is acceptable if it is

ASPHALT DISTRESS SURVEY FORM

DATE: 5/20/97 RATERS: EXPERIENCED RATER

HIGHWAY	TRANSVERSE CRACKING			FATIGUE CRACKING			PATCHING AND PATCH DETERIORATION			BLOCK CRACKING		
SEGMENT	L	M	H	L	M	H	L	M	H	L	M	H
1		2					1					
2	1				3							
3						4		2				
4	2											
5		2		1			1					
6		1			2					1		
7											3	
8		2							1			
9			3	1				3				
10						4			3			

INSERT DISTRESS EXTENT RATING UNDER THE PROPER SEVERITY COLUMN FOR EACH DISTRESS

DISTRESS TYPE	EXTENT RATING			
	1	2	3	4
Transverse Cracking	>50 ft spacing	25 ft to 50 ft	< 25 ft	
Fatigue Cracking	1 to 9% of wheelpath	10 to 24% of wheelpath	25 to 49% of wheelpath	≥ 50% of wheelpath
Patching and Patch Deterioration	1 to 9% of area	10 to 24% of area	25 to 49% of area	≥ 50% of area
Block Cracking	1 to 9% of area	10 to 49% of area	≥ 50% of area	

DISTRESS SEVERITY LEVELS			
DISTRESS TYPE	LOW	MEDIUM	HIGH
Transverse Cracking	< ¼ inch wide	> ¼ inch width & < ¼ inch depressions	> ¼ inch width & > ¼ inch depressions
Fatigue Cracking	Fine parallel hairline cracks	Alligator pattern clearly developed	Alligator pattern clearly developed with spalling and distortion
Patching and Patch Deterioration	Little or no defects with smooth ride	Clear signs of cracking on notable roughness	Heavy cracking or other distress with distinct roughness
Block Cracking	6 ft to 10 ft block sizes	3 ft to 6 ft block sizes	< 3 ft block sizes

Figure 17. Example of an experienced rater's survey sheet for a control section.

ASPHALT DISTRESS SURVEY FORM

DATE: 5/27/97 RATERS: SURVEY CREW

HIGHWAY	TRANSVERSE CRACKING			FATIGUE CRACKING			PATCHING AND PATCH DETERIORATION			BLOCK CRACKING		
SEGMENT	L	M	H	L	M	H	L	M	H	L	M	H
1		2						2				
2	2				3					1		
3						3		1				
4	2											
5		3		1				1				
6	2					1					2	
7										2		
8		2						1				
9				2			3					
10						4			2			

INSERT DISTRESS EXTENT RATING UNDER THE PROPER SEVERITY COLUMN FOR EACH DISTRESS

DISTRESS TYPE	EXTENT RATING			
	1	2	3	4
Transverse Cracking	>50 ft spacing	25 ft to 50 ft	< 25 ft	
Fatigue Cracking	1 to 9% of wheelpath	10 to 24% of wheelpath	25 to 49% of wheelpath	≥ 50% of wheelpath
Patching and Patch Deterioration	1 to 9% of area	10 to 24% of area	25 to 49% of area	≥ 50% of area
Block Cracking	1 to 9% of area	10 to 49% of area	≥ 50% of area	

DISTRESS SEVERITY LEVELS			
DISTRESS TYPE	LOW	MEDIUM	HIGH
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Fatigue Cracking	Fine parallel hairline cracks	Alligator pattern clearly developed	Alligator pattern clearly developed with spalling and distortion
Patching and Patch Deterioration	Little or no defects with smooth ride	Clear signs of cracking on notable roughness	Heavy cracking or other distress with distinct roughness
Block Cracking	6 ft to 10 ft block sizes	3 ft to 6 ft block sizes	< 3 ft block sizes

Figure 18. Example of a survey crew's survey of the control sections.

ROADWAY DATA QUESTIONNAIRE

As part of our study of the field collected roadway data in South Dakota (SD96-03), we interviewed many people who either collect or use the data. In order to supplement the results of those interviews, we would appreciate your responses to the following questions. To complete the questionnaire, for each data type please place a check mark in the column that you feel best answers the question that is asked. Your answers will help us to better quantify the relative importance of different data throughout the Department. Thank you for your time.

Jim Morrow
David Peshkin

Data Type	How important is the accuracy of this data type to you in the performance of your job?					What do you think about the accuracy of the data that you receive?				
	Essential	Very Important	Average Importance	Not Very Important	Not Needed	Error Free	Very Accurate	Accurate Enough	Not Very Accurate	Very Inaccurate
Traffic Volume										
Vehicle Weights (e.g., ESALs)										
Pavement Roughness										
Pavement Rutting										
Friction										
Falling Weight Deflections										
Videolog Images										
Pavement Distress Survey (cracking)										
Transverse Joint Faulting										
Geometrics										

Data Type	How important to your job is the timing of when you receive this data?					Are these data received in a timely manner?				
	Must be Timely	Very Important	Average Importance	Not Very Important	Doesn't Matter	Always	Usually	Often Enough	Not Usually	Never
Traffic Volume										
Vehicle Weights (e.g., ESALs)										
Pavement Roughness										
Pavement Rutting										
Friction										
Falling Weight Deflections										
Videolog Images										
Pavement Distress Survey (cracking)										
Transverse Joint Faulting										
Geometrics										

Data Type	What is the overall value of this data to you in the performance of your job?				
	Essential	Very Valuable	Average Value	Limited Value	Isn't Needed
Traffic Volume					
Vehicle Weights (e.g., ESALs)					
Pavement Roughness					
Pavement Rutting					
Friction					
Falling Weight Deflections					
Videolog Images					
Pavement Distress Survey (cracking)					
Transverse Joint Faulting					
Geometrics					

Comments (optional):

____

____

____

____

Name of Respondent ____________

Office ____________

Please return to the Office Of Research by 12/20/96. Thank you.

Figure B.2. Questionnaire on roadway data value, accuracy, and timeliness.

Table B.1. Overall results of questionnaire.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of receipt		Overall Value of Data	
	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating
Traffic Volume	47	4.0	43	3.1	47	3.6	44	3.9	48	3.8
Vehicle Classification	45	3.4	39	3.1	44	3.0	37	3.8	48	3.3
Vehicle Weights	47	3.3	34	3.0	42	3.0	33	3.5	45	3.3
Pavement Roughness	46	3.4	36	3.1	42	3.1	37	3.7	46	3.3
Pavement Rutting	45	3.4	35	3.2	43	3.1	36	3.7	45	3.4
Friction	45	3.2	36	3.2	41	2.7	34	3.4	47	3.0
Falling Weight Deflections	46	3.5	35	3.4	43	3.2	39	3.6	46	3.4
Videolog Images	44	3.1	38	3.3	44	2.8	40	3.6	46	3.0
Pavement Distress Survey	44	3.3	32	3.2	41	3.0	34	3.8	41	3.1
Transverse Joint Faulting	44	3.3	43	3.1	40	3.1	34	3.6	39	3.2
Geometrics	45	3.4	38	3.1	44	3.0	38	3.5	45	3.2

Table B.2. Questionnaire results, Regions only.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of receipt		Overall Value of Data	
	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating
Traffic Volume	19	3.9	17	3.2	19	3.2	18	3.8	19	3.7
Vehicle Classification	19	3.4	16	3.1	19	2.8	16	3.7	20	3.3
Vehicle Weights	19	3.3	15	3.1	18	2.6	16	3.6	19	3.4
Pavement Roughness	19	3.6	15	3.1	17	2.8	17	3.7	19	3.3
Pavement Rutting	19	3.6	15	3.1	19	3.0	17	3.7	19	3.6
Friction	18	3.8	17	3.4	17	2.9	17	3.7	19	3.6
Falling Weight Deflections	19	3.7	14	3.2	19	3.3	18	3.7	19	3.6
Videolog Images	18	3.0	15	3.2	19	2.8	17	3.6	19	3.2
Pavement Distress Survey	19	3.4	15	3.1	18	3.0	17	3.6	18	3.3
Transverse Joint Faulting	19	3.4	16	3.2	18	3.0	17	3.6	16	3.4
Geometrics	19	3.5	16	3.2	19	2.8	18	3.6	19	3.1

Table B.3. Questionnaire results, all respondents except Regions.

Data Type	Importance of Accuracy		Accuracy of Receipt		Importance of Timeliness		Timeliness of receipt		Overall Value of Data	
	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating	# Responses	Average Rating
Traffic Volume	28	4.1	25	3.1	26	4.0	26	4.0	29	3.9
Vehicle Classification	28	3.3	24	3.0	24	3.2	21	3.8	28	3.2
Vehicle Weights	28	3.3	19	2.9	23	3.3	17	3.5	26	3.2
Pavement Roughness	27	3.3	21	3.1	24	3.3	19	3.8	27	3.3
Pavement Rutting	26	3.3	20	3.3	23	3.3	18	3.7	26	3.2
Friction	27	2.8	19	3.0	22	2.5	18	3.2	28	2.5
Falling Weight Deflections	28	3.2	21	3.5	23	3.2	26	3.5	27	3.2
Videolog Images	25	3.3	23	3.3	24	3.0	22	3.5	27	2.9
Pavement Distress Survey	25	3.3	17	3.2	21	3.3	17	3.9	23	3.0
Transverse Joint Faulting	25	3.2	17	3.0	21	3.3	17	3.6	24	3.1
Geometrics	26	3.3	22	3.1	24	3.3	21	3.5	26	3.3

Table B.4. Comments Added to Questionnaires.

Name	Comment
Ben Orsbon	These are difficult issues related to quality and continuous improvement in data because it must be used immediately after it is loaded to meet the time frames desired for delivery of the construction program. Another good question to the highest levels of management might be: How important is the _____ data to the mission of the department and to the mission of your division?
Dean Hyde	We depend on data totally! It needs to be reliable.
Steve Gramm	Accident & Maintenance Cost Data? Videolog would be more valuable if it was pavement oriented. Faulting data not collected independently yet. Geometric data would be very accurate if not for the horizontal curve data.
Dennis Winters	BIT facilitates the use of data by DOT users and collectors. I don't feel I should comment on this survey without being a user or collector of the data.
Roger Lehmkuhl	My office is neither a user or collector of this data, therefore I am unable to provide any further ratings for this survey.
Terry Jorgensen	County-projects involve an on-site inspection prior to design - We receive only traffic volumes from outside sources.
Vernon Bump	We do not use any of this information
Terry Varilek	I use the data very infrequently to research information on various projects, and to answer questions about the roadway that may come up. If I didn't have the information I could get it from someone else.
Monte Schneider	No comment-not really users
Daris Ormesher	Importance is dependent on the project assigned to the research office.
Steve Ulvestad	I have no involvement in any of these type of data.
John Adler	I do not use this data in my current position.
Todd Goldsmith	I would like to see a Pavement Management Report.
Dennis Landguth	This value is important to the field offices when it helps us program future projects.
Larry Afdahl	No way of knowing accuracy on most items. Timeliness importance is for programming and design. We use most current data at the time. We use what is in the NEEDS book and don't know when done.
Sharon Johnson	Assumed geometrics to be survey data.