University of Alberta

DECISION SUPPORT SYSTEM FOR PRIORITIZING PAVEMENT MAINTENANCE ALTERNATIVES

by

AHMED MOHAMED HAMMAD ©

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Name of Author:	Ahmed Mohamed Hammad
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Ahmed M. Hammad
304, 9904-90 Ave. NW
Edmonton, AB
T6E 2T3

Dated: 8/25/99

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Decision Support System for Prioritizing Pavement Maintenance Alternatives" submitted by Ahmed Mohamed Hammad in partial fulfillment of the requirements for the degree of Master of Science in Construction Engineering and Management.

Dr. S. M. AbouRizk, P. Eng.

Dr. Ashraf El-Assaly

Dr. Dave Chan, P. Eng.

Dr. Horacio Marquez

Approved on: 8/24/99

The author wishes to dedicate this thesis to his mother, Dr. Nabilah, his sister, Dr. Enas, and his wife, Regine for their continuous love, support, and encouragement throughout all phases of his life.

ABSTRACT

One of the major problems facing transportation agencies is that of evaluating pavement maintenance alternatives and finding the optimum maintenance strategy for defected pavement segments. Applying the optimum maintenance strategy reduces the total maintenance costs over the service life of pavements, postpones the costs of major rehabilitation, and maximizes the benefits gained from limited budgets.

Pavement maintenance and rehabilitation problems present many opportunities for the application of computer-aided Decision Support Systems (DSS). The main objective of this research is to provide a prototype DSS for prioritizing pavement maintenance alternatives based on multi-criteria. The prototype DSS outlined here introduces consistency to the decision-making process, enables decision-makers to manage a highway network efficiently, and offers maximum usage of pavement Surface Condition Rating (SCR) data.

The prioritizing module is based on the application of the Analytical Hierarchy Process (AHP), which combines the knowledge of the human experts with mathematical calculations to obtain the desired priorities. The required experts' knowledge was obtained from a group of Alberta Transportation and Utilities (AT&U) pavement experts. The DSS involves a data management subsystem, a user-friendly interface, and an output module to interact with the end user. The prototype DSS was developed using MS Access along with Visual Basic (VB) programming. The main characteristics and limitations of the prototype DSS are explained in this thesis.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The history of pavement goes back to 312 BC when the Romans used stones for building the famous road, "Via Appia" (Haas, 1997). Since that time, pavement has played an essential role in improving humanity's lifestyle. The highway network in North America represents a multi-billion dollar investment that is essential for the transportation of people and goods throughout the continent. It is one of the main factors contributing to the overall economic growth of the United States and Canada. The amount of construction required for this highway network constitutes a major part of the total construction investments in the two countries and is usually called transportation-engineering construction. In Canada, the total value of transportation-engineering construction was $5.874 billion in 1996, which represented 7.3% of the total value of construction and 20% of the heavy engineering construction of that year (Statistics Canada Catalogs, 1998). These percentages reflect the importance of transportation engineering construction to the Canadian construction industry and to the national economy.

The highway network usually consists of three main components: roads, bridges, and appurtenances. The term "appurtenances" refers to the signs and road furniture required for safe driving on highways. The road part is the major asset in the network compared to the other two parts. Roads are usually comprised of pavements and small percentage of unpaved roads. Historically, paved roads have been divided into two main categories (Yoder, 1975): flexible pavements and rigid pavements. Flexible pavements consist of asphalt concrete surface built on a base course, which may or may not contain subbase course, resting upon a compacted subgrade. Rigid pavements consist of a reinforced or plain Portland cement concrete surface resting on a base course or on the subgrade directly as shown in Figure 1.1. The main difference between the two types of pavement is the way they transfer traffic loads to the subgrade. This research will focus only on flexible pavements because they represent the majority of paved roads in North America.

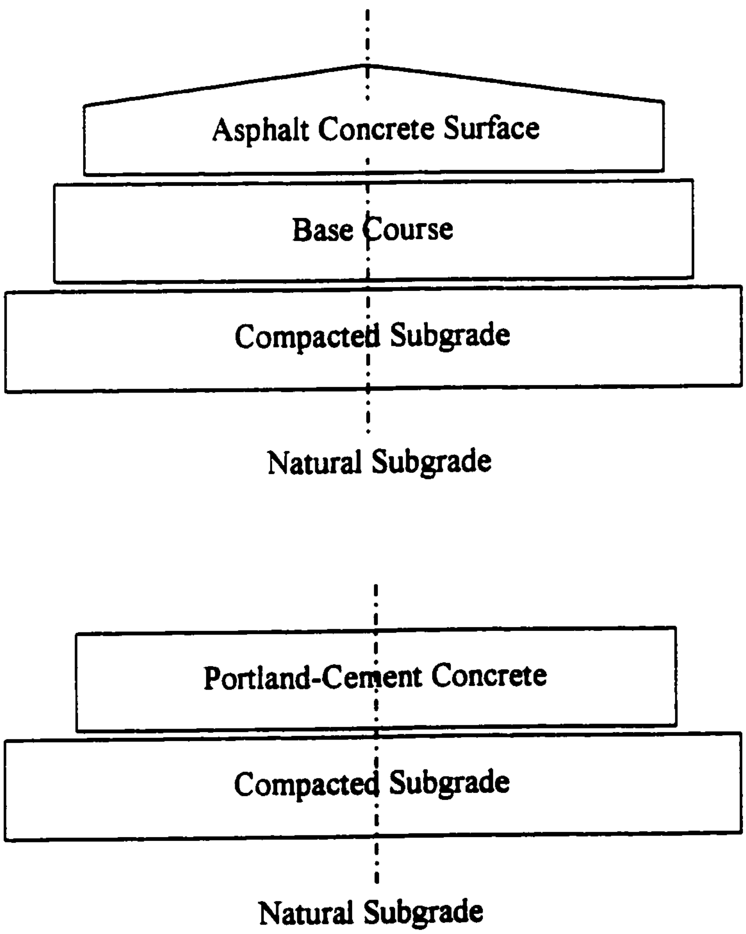


Figure 1.1 Main Components of Flexible and Rigid Pavements

The North American highway network is used to satisfy the public need for safe transportation. The ability to use the network by public in a safe manner is called serviceability. The main objective of the state and provincial transportation agencies is to provide a network with maximum serviceability at the minimum possible cost. The challenge facing most of these transportation agencies is that the public demands that they respond to increasing needs while accommodating increasing fiscal restraints on budgets (AASHTO, 1987). Optimal allocation of the available budgets helps increasing the value of the current assets and network serviceability.

1.2 HIGHWAY NETWORK OF ALBERTA

In Alberta, the highway network constitutes more than 30,000 km between primary and secondary highways as shown in Table 1.1. A map for the primary highway network of Alberta is attached in Appendix (1). In 1998, the total value of this asset was estimated to be approximately $3 billion (MSCA, 1998). Alberta Transportation and Utilities (AT&U) is the governmental department responsible for managing this valuable asset. The total operating and capital budget assigned for this purpose in 1998 was approximately $250 million. This budget is divided between the three main components of the network (roads, bridges, and appurtenances). In the road section, the budget is divided between the maintenance program, the major rehabilitation program, and new construction. New construction consumes only a small percentage of the budget; most of the funds go to maintaining and rehabilitating the existing paved roads.

Table 1.1 Distribution of the Highway Network in Alberta

Highway Surface Type	Paved Surface (Km.)	Based Surface (Km.)	Gravelled Surface (Km.)	Not Constructed (Km.)	All Surface Types (Km.)
Primary Roads	14,426.62	92.56	583.14	35.6	15,137.94
Secondary Roads	8,290.19	1,744.12	5,172.25	101.72	15,308.29
Total Kilometers	22,716.82	1,836.68	5,755.4	137.32	**30,446.23**

One of the major problems facing AT&U and all North America transportation agencies is that paved roads deteriorate with time. Paved roads are always exposed to tough weather conditions (e. g. temperature changes, continuous cycles of freeze and thaw, high precipitation rates, etc.) and heavy traffic loads, which play a major role in affecting the deterioration rate. The subgrade type on which the road is constructed as well as the base material used for paving the road are also two essential factors affecting the deterioration rate (El-Assaly, 1998).

In order to slow the deterioration rate, ensure safe and comfortable riding, and sustain or increase network value, two different strategies are being used simultaneously by transportation departments. These strategies are represented in the routine maintenance program and the major rehabilitation program. AT&U's rehabilitation and routine maintenance budget for 1998 was $88 million. This figure shows that the rehabilitation and maintenance budget represents approximately 44% of the total annual budget of AT&U. This indicates that maintaining the existing facilities has become one of the major efforts of transportation agencies.

1.3 PAVEMENT PERFORMANCE EVALUATION

In order to manage the highway networks; Pavement Management Systems (PMS) were introduced to assure maximum benefits of the available funds. PMS require having sufficient data to define the current network performance. The data should represent the network performance with an acceptable level of confidence. The level of confidence required means the data should represent statistically and physically the actual conditions of the network. Storing this data in an organized and easy-to-use form results in a powerful database, which can be used for analyzing pavement performance over time.

Most of North America's transportation agencies evaluate the current performance of the pavement by measuring three main parameters (Haas, 1997):

- Riding Comfort or Roughness, which reflects the ride quality of a pavement and is usually represented by Riding Comfort Index (RCI), Riding Comfort Rating (RCR), or International Roughness Index (IRI).
- Structural Capacity, which reflects the load carrying capacity of a pavement and is usually represented by a Structural Adequacy Index (SAI).
- Surface Condition, which reflects the visual assessment of pavement surface condition and is usually, represented by a Distress Manifestation Index (DMI) or Surface Distress Index (SDI).

Pavement surface condition is usually monitored through the Surface Condition Rating (SCR) process. This is a formalized method for assessing the surface condition of a pavement based on visual inspection. Pavement surface condition is the main factor for triggering routine maintenance activities to the highway network. Applying appropriate maintenance strategies is essential for preserving the network and minimizing pavement deterioration effects and major rehabilitation costs.

There are many types of maintenance alternatives, which vary in cost, applicability, and expected service life. With the availability of advanced technologies, new types of maintenance alternatives are frequently introduced to the pavement maintenance field. Using cold pour, a crack-filling technique instead of the traditional hot pour is an example of a recently introduced maintenance alternative.

1.4 PROBLEM STATEMENT

Selecting the most appropriate maintenance alternative for a defected pavement segment is a daily problem for AT&U and transportation agencies in general. These decisions significantly affect the service life of roads and their overall life cycle cost. This decision must be made by experienced engineers or technicians who are able to identify the problem and allocate the most appropriate treatment. Personnel responsible for this task are usually called Maintenance Inspectors. Most transportation agencies in North America are facing a lack of experienced staff due to an aging workforce and newly introduced budget constraints. There is a tremendous need to transfer the knowledge of experienced staff to new and less experienced staff.

Once the maintenance inspector has determined which treatments are applicable for a defected segment, there is still more than one feasible solution for each type of pavement distresses. These solutions must be compared and the most appropriate one must be selected based on standard criteria. The current practice is mainly subjective and depends only on the inspector's experience. Solving this problem in a consistent manner will help transportation agencies manage pavement better and estimate budgets for the future. Knowing the most appropriate treatments for the entire network will also help in allocating the available budgets to achieve optimal benefits.

Another problem facing maintenance inspectors is identifying the pavement segments that are reasonable candidates for complete surface treatment such as cold mill and inlay the whole segment. These types of treatments cost much more than regular routine maintenance, however they last much longer and fix most of the pavement distresses. The inspector must decide whether to continue fixing the segment distresses one by one separately or apply one of the general treatments. Identifying these segments based on standard criteria and suggesting the most appropriate treatments for them will help solve this problem.

Obtaining the maximum possible benefit of the available data regarding pavement performance evaluation is another challenge facing transportation agencies. Collecting this data is a costly and time-consuming process, which requires considerable amount of resources. Introduce this data to maintenance inspectors will enable them to make better decisions and enhance the usage of the available data.

1.5 RESEARCH OBJECTIVES

Computer-aided Decision Support Systems (DSS) can be of great benefit for solving the previously mentioned problems. There are different types of DSS, which can be commercially available or developed in-house for special purposes. DSS usually consist of a knowledge management module, a data storage and management module, and a model management subsystem. The model is used to compare the available alternatives, rank them, and suggest the optimum solution. The Analytical Hierarchy Process (AHP) is one of the approaches that can be used to develop computer-aided DSS. AHP basically builds a hierarchy model of the problem under investigation and develops priority weights for each possible alternative. The decision-maker can then select the alternative with the highest priority.

The main objective of this research is to develop a prototype decision support system to help allocate the most appropriate maintenance alternative to the defected flexible pavement segments. The system depends on the Analytical Hierarchy Process (AHP) for comparing the feasible treatment alternatives and prioritizes them based on pre-specified criteria. The prototype DSS also enables maintenance inspectors to preview pavement segments' attributes, SCR, and roughness data.

1.6 RESEARCH APPROACH

After identifying the problem, the research methodology started by a comprehensive review of the available literature regarding flexible pavements' surface distresses. Other state and provincial highway agencies in North America were contacted to obtain their current information regarding their SCR practices as well as defining and assessing of pavement surface distresses.

The second stage of the study involved comprehensive literature review regarding DSS and their main components and characteristics. The review also involved the previous application of DSS in construction and pavement management. Based on the findings, the conceptual design of the DSS, its main components, and their requirements were established. The AHP was selected as the model management subsystem of the DSS. The hierarchy model of the problem was built and the decision-making criteria were defined.

A committee of pavement experts from AT&U was established to capture the required human knowledge for the knowledge management component of the DSS. A series of meetings and workshops with the committee members led to the following sub-objectives:

- Unify the syntax for different pavement surface distresses and decide which of them the system should assess.
- Determine the most probable causes for pavement surface distresses and group them based on similar predominant causes.
- Determine the thresholds for different degrees of severity for each of the defined distresses.

- Identify weights for each pavement distress and develop a composite surface condition index.
- Define the technical constraints (i. e. the feasibility of applying specific treatment to fix a given problem).

The fourth stage of the study involved capturing the required data for the data management module of the DSS. This data was found in three different databases, which were merged together into the required format. This included the SCR data for the Alberta highway network for the year 1998. The second database contained network attributes including soil type, base type, climatic region, and traffic load. The third database included the network roughness data for the year 1998 represented in IRI.

The fifth stage of the study involved developing a prototype DSS in the MS Access environment using Visual Basic (VB) programming language. The system suggests the most appropriate treatments for several distress types and applies the AHP to prioritize them. The prototype DSS also includes a user-friendly interface to communicate with the end user and an output module to print the system recommendations.

The last stage of the study involved system implementation and validation by a selected group of pavement maintenance experts. Figure 1.2 summarizes the approach that was followed to achieve the research objectives.

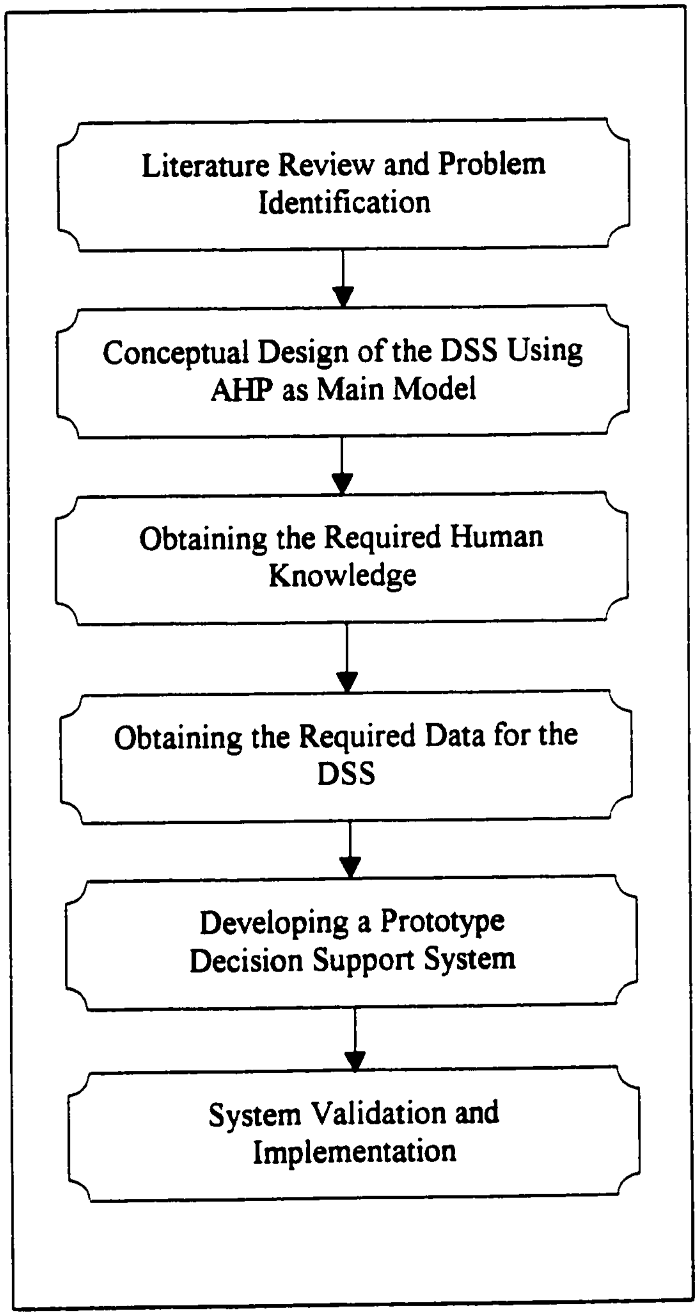


Figure 1.2 Methodology used for developing the System

1.7 EXPECTED CONTRIBUTIONS

This study is expected to contribute in both academic and industrial fields. The academic contribution is introducing the AHP to solve a multi-criteria decision-making problem, which involves technical constraints. The technical constraints are introduced to the problem because each distress type with a specific severity degree requires different treatment. It was required to structure the problem in a suitable way for applying AHP to obtain the required priorities.

The industrial contributions involve modifying the current practice of Surface Condition Rating (SCR) in Alberta. It is expected to develop new distress scores with their measurement techniques and thresholds for degrees of severity and density. Relative impact weights for these distresses are also required to be merged with the previously mentioned scores to develop a composite Surface Condition Index (SCI) for Alberta. This index represents the segment's condition in one number for network-level management purposes. AT&U spends considerable amount of money and effort to collect and update pavement performance data. This research is expected to submit an easy and comprehensive method to access and present this data in a graphical manner. It also introduces the integration of the SCR data with pavement attributes and another pavement performance measure, which is roughness. This integration will help plan for maintenance and rehabilitation programs. The last contribution is organizing and introducing consistency to the decision-making process of prioritizing and allocating the optimum maintenance alternatives. This will help optimize budget allocation based on actual needs and maximize benefits obtained from limited funds.

1.8 THESIS ORGANIZATION

Chapter two is a review of the literature regarding flexible pavement surface distresses. The chapter also introduces a brief description of the pavement surface treatments, which were used in the prototype DSS. Chapter three describes the main characteristics of decision support systems and their application in different fields with emphasis on construction management. The Analytical Hierarchy Process (AHP) theory, technique, and how it can be used for solving problems are illustrated. The chapter also covers the previous studies conducted in the field of applying computer-aided tools for allocating pavement maintenance alternatives. The last part of the chapter demonstrates the conceptual design of the DSS, its requirements, the model management subsystem, and the data management subsystem. Chapter four represents in full detail all the steps followed to capture the human knowledge required for building the knowledge base of the system. The chapter starts by describing the findings of a survey conducted among North American transportation agencies regarding their SCR practices. The chapter also summarizes the final findings regarding pavement surface distresses' definitions, causes, grouping, measuring methods, and applicable treatments.

Chapter five outlines all the steps followed to develop the prototype DSS in Access. The chapter also describes all the components of the prototype DSS including user interface and output module. The system validation process and the system limitations are illustrated at the end of the chapter. Chapter six presents concluding remarks and possible future enhancements of the prototype decision support system.

CHAPTER 2: FLEXIBLE PAVEMENT SURFACE DISTRESSES

2.1 BACKGROUND

Thomas et al define distress as "the condition of a pavement structure that reduces serviceability or leads to a reduction in serviceability" (Thomas, 1978). Serviceability is usually defined as the ability of a pavement to serve the public. However, surface distresses affect not only serviceability but also pavement deterioration. Accurate treatment of distresses at the right time can prevent or slow the deterioration rate for a pavement (Brown, 1988). Flexible pavement surface distresses are usually represented through type, severity, and density. The term "density" stands for the frequency of problem occurrence. The units for measuring density can be percentage of defected area, lineal meters or number of defects per a specific segment area. Severity reflects how extensive the damage is and is usually measured on a subjective scale (i.e. slight, moderate, extreme, etc).

Pavement surface distresses are usually measured through a Surface Condition Rating (SCR) process. It is a formalized method of assessing the pavement surface conditions based on fixed rules. SCR data can be used for the following purposes:

- Obtain an overall picture of the highway network and assure that the network service level improves or at least remains constant from year to year.
- Reflect the degree of damage to pavement caused by traffic loads or environmental factors.

- Determine the appropriate maintenance or rehabilitation treatments and the best timing for their application based on unit cost and expected life.
- Quantify and predict the cost of maintenance alternatives based on the current conditions of a pavement.
- Optimize budget allocation and prioritize rehabilitation projects to address tight fiscal restraints.
- Develop pavement deterioration models accompanied with other performance evaluation measures such as roughness or structural adequacy.

2.2 SURFACE CONDITION RATING (SCR) PROCESSES

The rating process usually takes place at the beginning of Autumn or Spring. The process starts with dividing the network into segments. These segments are generally used for the rating process. The network can be divided into constant length segments or segments with similar attributes or conditions. After segmenting the road, a test section is selected to represent the condition of the whole segment. The frequency of data collection, the percentage of the network covered on each rating process and the different methods for segmenting and selecting the test sections vary among transportation agencies. After selecting the test section, the surface condition of the segment is evaluated by examining the pavement surface distresses that exist in the section. Predefined thresholds govern the different degrees of severity and density for each type of distress. After that, scores representing the existing distresses in the segment are assigned. These scores can be used for developing a composite surface condition index that represents the segment's surface condition.

This is usually done by obtaining fixed weights for each distress type. Different methods might then be applied to combine these weights and scores in one composite index. This composite index is used with other measures for evaluating pavement performance (e.g. roughness or structural adequacy) to evaluate the entire highway network performance.

2.3 PAVEMENT SURFACE DISTRESSES

A comprehensive literature review was conducted regarding pavement surface distresses. It was found that the U. S. Army and the Ontario Ministry of Transportation introduced the leading efforts in the field of documenting pavement surface distresses. The technical report prepared by the U. S. Army Construction Engineering Laboratory in 1973 was one of the first steps towards documenting pavement maintenance knowledge (Dept. of the Army, 1973). The report identifies twenty-four types of flexible pavement distresses without classifying them under any categories. For each type of distress, the causes, probable conditions for occurrence, degree of severity are defined. It also suggests and describes one or two types of repair methods, which suit the identified type of distress.

" The "Manual for Condition Rating of Flexible Pavement" prepared by the Ontario Ministry of Transportation in 1989 classified flexible pavement distresses into three main categories (Chong, 1989). These categories are cracking, surface distortions, and surface defects. Fifteen types of distresses were identified under these three categories. The severity levels were defined as slight, moderate, and severe. For each type of distresses, different thresholds were defined to identify these degrees of severity and density. The manual also suggests several types of treatments for each level of severity and density.

The Roads and Transportation Association of Canada (RTAC) published the report, "Pavement Surface Condition Rating Systems" to provide a system which has a high degree of acceptability in Canada (Anderson, 1987). The report adopted the Ontario method for rating pavement surface conditions. The report also surveyed the Canadian transportation agencies in an effort to identify the differences between their respective surface condition rating practices. The survey covered only the distresses assessed by each province within Canada.

The Strategic Highway Research Program (SHRP) introduced another leading effort (SHRP, 1993). The program is a part of the American National Research Council (NRC) and focuses on highway and pavement management. One of the projects adopted by the program is the Long-Term Pavement Performance Project (LTPPP). The "Distress Identification Manual" for this project contains photographs and drawings describing fifteen types of pavement surface distresses. These distresses were classified under five groups: cracking, patching and potholes, surface deformation, surface defects, and miscellaneous distresses. The severity of distress is divided into three levels low, moderate, and high; thresholds are defined for most of the distresses.

Several other manuals were obtained and were found to have similar definitions and classifications with slight differences. These manuals are; "Surface Condition Rating Manual" (AT&U, 1997), "Pavement Surface Condition Rating Manual" (British Columbia Ministry of Transportation, 1997), "Flexible Pavement Condition Survey Handbook" (Florida Department of Transportation (DOT), 1994), "Road Surface Management" (Georgia DOT, 1990), "A Guide to Evaluating Pavement Distresses through the Use of Video Images" (Virginia DOT, 1998), and "Pavement Surface Condition Rating Manual" (Washington State DOT, 1992). The information obtained from these manuals helped prepare an initial set of pavement distresses' definitions to be reviewed and modified by the pavement experts committee.

The Virginia DOT introduced a leading effort towards using video images in pavement surface condition Rating (Virginia DOT, 1998). The method depends mainly on installing a video camera in a standard vehicle, which then records the conditions of the full width of the driving lane. The video images have sufficient resolution to identify cracking of one-millimeter width during the scanning process. The raters then review the video images and record all visible distress types based on pre-specified thresholds. One drawback is that the method requires excellent visibility conditions to obtain clear images. The method is still under development to minimize possible errors and increase accuracy. Computer software is developed, with user interface, to enable raters to control the tape speed and record distress types, locations and severity.

2.4 COMPUTER AIDED MAINTENANCE ALTERNATIVES ALLOCATION

Maintenance is defined as an action taken to correct deficiencies that are potentially hazardous and to repair defects that seriously affects serviceability so as to maintain or keep the pavement within a tolerable level of serviceability (Thomas, 1978). The proper maintenance of the highway network increases driving safety, slows pavement deterioration rates, and minimizes the costs of major rehabilitation. Routine maintenance alternatives are usually allocated using two main policies; "Fix Worst First" and "Use a Priority Index" (Rohde, 1997). Many transportation agencies adopt the policy of "Fix Worst First" as the guideline in pavement routine maintenance activities allocation. This policy mainly depends on the subjective decision of the maintenance inspector to allocate the available funds to the road segments with the worst surface conditions. After the available funds are exhausted, the remaining segments are left to deteriorate. Rohde et al, in their study of long-term highway network performance, proved that this policy significantly increases the percentage of the network in poor conditions over the policy of using priority index (Rohde, 1997). Figure 2.1 illustrates Rohde et al's future prediction for the network percent in poor conditions using the two policies.

Artificial Intelligence (AI) techniques were introduced in the late 1980's for allocating maintenance activities on the right time. Most existing applications use Knowledge-Based Expert Systems (KBES) as an AI technique. The purpose of these applications is to capture human knowledge in the field of allocating the right treatment for defected pavement segments. Five of these applications will be discussed and described briefly in this chapter. These applications are SCEPTRE, ROSE, PERSERVER, ERASME, and PMAS.

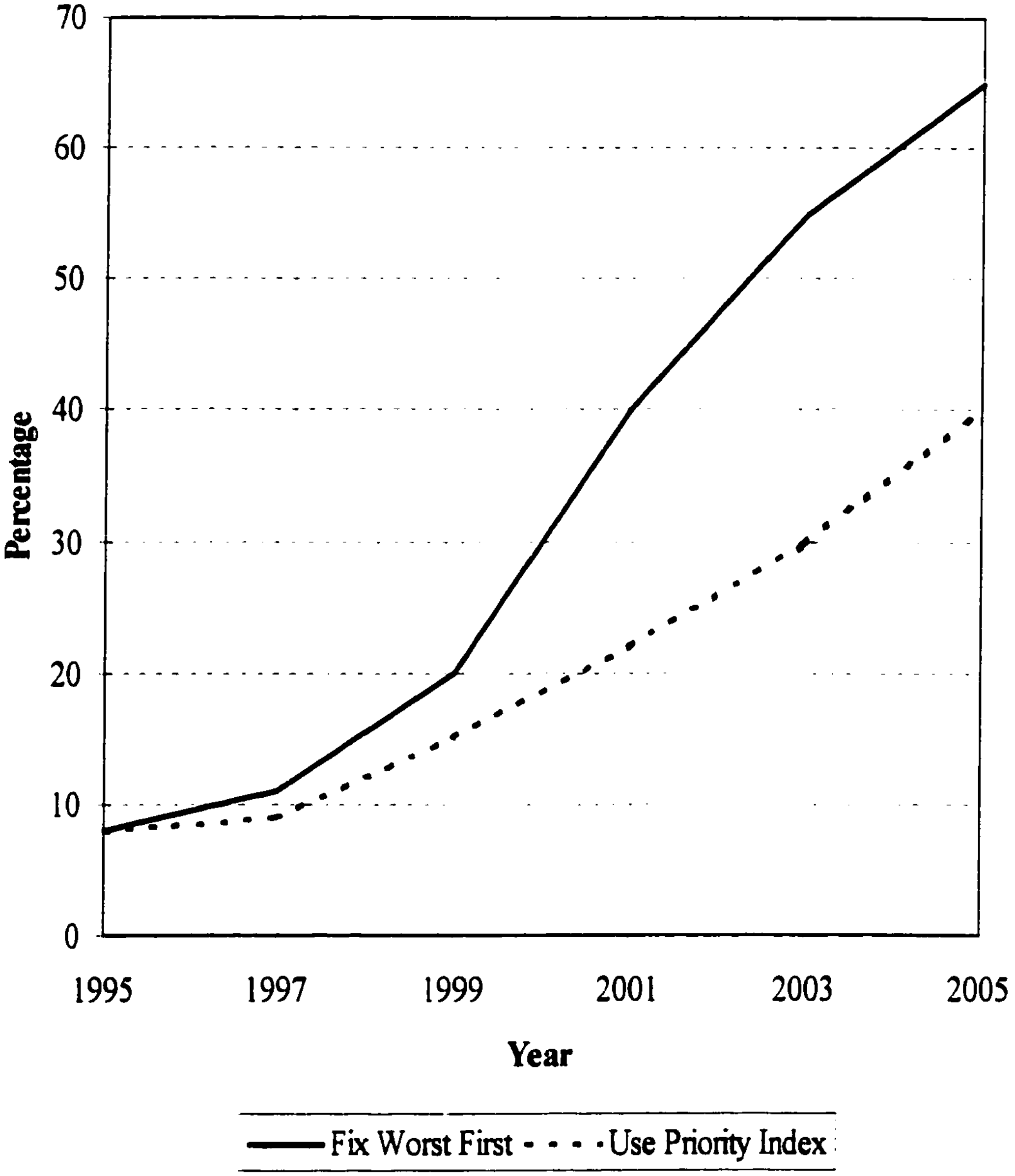


Figure 2.1 Future Prediction of Percent of Network in Poor Condition (Rohde, 1997)

SCEPTRE is one of the first KBES used in pavement management and is basically an advisory tool for evaluating flexible pavement surface conditions (Ritchie, 1986). The system also recommends rehabilitation strategies based on only four types of surface distresses. These distresses are alligator cracking, transverse cracking, longitudinal cracking, and rutting. The system uses six factors to select and recommend one of ten rehabilitation strategies. These factors are type, amount, and severity of surface distress, existing pavement performance, traffic loads, and climatic effects. The system was built on the experience of two pavement specialists from the states of Washington and Texas. Several rehabilitation and maintenance alternatives are stored in the software accompanied with their expected service life. In the final output, four treatments are suggested to fix the problem. The expected service lives of these four treatments as well as the probability that the actual service life for each treatment will be at least the expected one are also presented.

ROSE is a knowledge-based system designed specifically for selecting the appropriate treatment of cracks in cold regions (Hajek, 1986). It was built on the knowledge contained in "Ontario's Pavement Maintenance Guidelines" and on the experience of three pavement experts from the Ontario Ministry of Transportation. The system considers all crack types found in flexible pavement except alligator cracks. The selection depends on the following factors: crack type, crack severity, pavement serviceability, pavement structure, presence of pavement distresses, and availability of maintenance treatments. The system was developed using an expert development shell called "Exsys".

PERSERVER uses the cost per year of the expected service life of treatments as the only criterion for treatment allocation. It recommends the single most cost-effective maintenance treatment for each road segment (Haas, 1987). It also tries to select treatments that fix more than one distress in the segment. Before recommending a treatment, the system ensures compatibility with the major rehabilitation plan. The system accounts for three types of distresses; alligator cracking, progressive edge cracking, and distortion. The source of the treatment allocation rules is the Pavement Maintaining Guidelines of Ontario Ministry of Transportation. The rules are based on empirical associations developed by interviewing many experts. The system depends on obtaining the road segments condition from the user and determines all the possible treatments. After a set of treatments is defined, the equivalent annual cost for each treatment is calculated and is then used to select the best treatment.

ERASME is a knowledge-based expert system developed in the Directorate of Roads in France to facilitate the decision making process in the area of pavement maintenance (Allez, 1988). The system assists the user in selecting the appropriate rehabilitation technique for homogeneous pavement sections. Pavement segments are declared homogenous when all their significant parameters are the same. The significant parameters are pavement structure, nature and date of previous pavement repairs, and surface conditions. Homogenous segment lengths vary from a few hundred meters to a few kilometers. The system takes into account durability, serviceability, cost, and construction duration of the treatments.

PMAS is a knowledge-based expert system developed for selecting the appropriate maintenance strategies in the province of Newfoundland (Hanna, 1993). It fits only to cold coastal regions and counts for both flexible and rigid pavements. The system recommends the most appropriate maintenance strategy and displays its expected service life. The system counts for only three types of distresses: rutting, alligator cracking, and transverse cracking. The system variables are surface condition, riding comfort index (RCI), traffic volume, and climate. Maintenance alternatives for combined distresses were also considered.

Another two applications were found; these applications did not use the KBES technique. The two applications are RAMS and MICRO PAVER. The first application is the Rehabilitation and Maintenance System (RAMS), a decision making tree developed for the Texas department of highways and public transportation (Scullion, 1985). The system contains fourteen maintenance strategies ranging from *"Do nothing"* to *"Thin overlay"*. The decision making tree starts by identifying pavement type and distress type, then counts for three degrees of extent (density) for each distress. Four different levels of traffic loads were taken into account. For each individual distress type/ pavement type/traffic level combination, one appropriate maintenance strategy is recommended as shown in Figure 2.2. The system also recommends the maintenance strategy that is able to repair most of the distresses found in the pavement segment. A final report is presented to the user illustrating the recommended treatments and the total applicable area for each one. The final reports are then used for predicting maintenance requirements for the entire highway network.

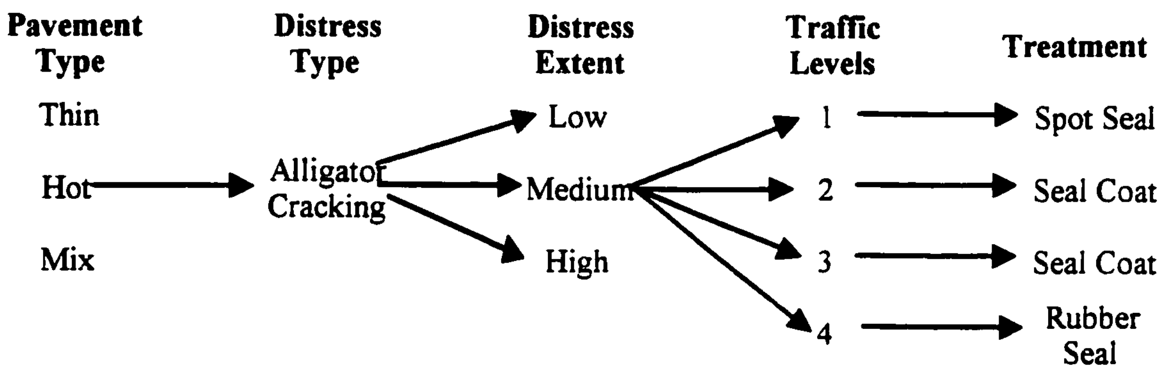


Figure 2.2 Example of one Branch of the Decision Tree

The second application is MICRO PAVER, developed by the U. S. Army Construction Engineering Research Laboratory (USA-CERL) in Champaign Illinois (Cation, 1987). The system uses an objective rating scale to prioritize maintenance strategies for flexible pavements. First, a density classification of low, medium, or high is assigned to each distress based on pre-specified thresholds. The same process is done for distress severity and a single density/severity code is assigned to each combination. The rating system starts at one for distresses with low severity and low density and runs up to nine for distresses with high severity and high density. The system contains tables showing the applicable treatments based on the distress type and the density/severity code. The system questions the user regarding the unit cost of each treatment and submits a final report regarding the suggested treatments and their expected costs.

2.5 PAVEMENT ROUTINE MAINTENANCE ALTERNATIVES

Another definition for maintenance is "well timed and executed activities to extend pavement life until the deterioration of the pavement materials is such that a minimum acceptable level of serviceability is reached and/or it is more cost-effective to rehabilitate the pavement" (Haas, 1997). Daily improvements in technology have led the number of pavement maintenance alternatives to increase rapidly. The treatments considered here are all currently in use by AT&U. Some of these treatments have been introduced recently and others have been in use for a long time. The treatment alternatives can be classified into two main classes: **Cracks filling treatments** are measured by lineal meters and **Surface treatments** are measured in square meters and are used to fix all other types of distresses. The information illustrated in this section is obtained from the following references: "Highway Maintenance Specifications" (AT&U, 1998), "Pavement Maintenance Techniques" (ITS, 1984), and "Pavement Maintenance Guidelines" (Chong, 1989). Six types of crack filling treatments and another six types of surface treatment are described below.

2.5.1 Hot Pour

This is the process of filling the pavement surface cracks (five millimeters and greater in width) with a molten bituminous asphalt compound. The cracks and surrounding area must be cleaned before sealing and the atmospheric and sealant temperatures must be within the range specified by the sealant manufacturer. The cracks must also be clear of any liquid water or loose material. The sealant is usually applied with a pressurized wand and then spread with a squeegee. There is a worker safety issue related to molten asphalt, which increases the safety hazards concerning this treatment. The sealant usually lasts until the crack opens up due to thermal contraction of pavements in the early winter.

2.5.2 Cold Pour

Cold pour is the process of sealing pavement surface cracks with a rubberized asphalt emulsion. The process is similar to hot pour except that molten bituminous asphalt is replaced with rubberized asphalt emulsion, which does not need to be melted before application. This replacement decreases the worker safety hazards during the treatment application.

2.5.3 Rout and Seal

The process consists of routing, cleaning and drying pavement surface cracks before sealing them with a molten rubberized asphalt sealant. Routing means cutting a channel into the pavement surface using a vertical rotary cutter. The rout profile varies based on crack type. For transverse cracks, a wide shallow channel with dimensions of (forty x ten) millimeters is used. A narrow and deep profile (nineteen x nineteen millimeters) is used for longitudinal cracks. These profiles gave the best long-term deformation characteristics, during thermal contraction and expansion of the pavement, based on AT&U experimental test sections' findings. This type of treatment is sensitive to the type of sealant used and to the climatic zone in which it has been applied.

2.5.4 Mill and Fill

The work consists of milling a trapezoidal-shaped notch over the crack to the level of the base, filling it with hot-mix asphalt concrete and compacting the mix. Figure 2.3 shows a typical cross section for a mill and fill profile. The advantage of the trapezoidal section is that the existing asphalt supports the new fill.

Previous experience shows that it is essential for the channel to go down to the base layer otherwise, the fill will fail within several weeks.

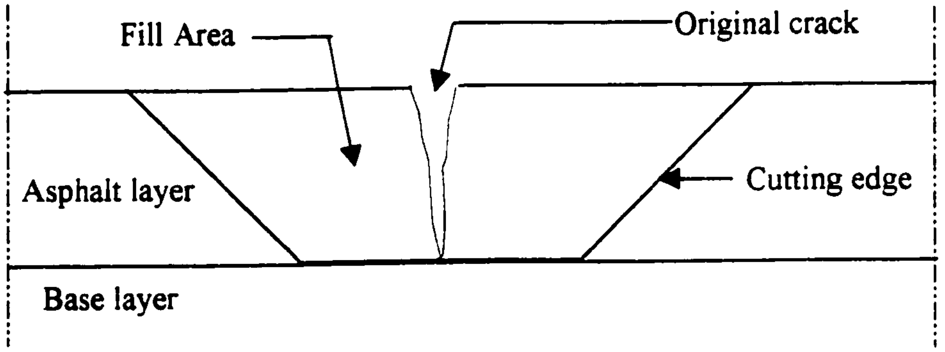


Figure 2.3 Typical Cross Section for Mill and Fill Treatment

2.5.5 Lineal Spray Patch

The process consists of cleaning the crack, applying asphalt binder as tack material, filling the crack with a mixture of washed, crushed aggregate and asphalt binder, and compacting the mix. Compressed air is usually used to shoot the mixture as with applying shot-crete to renovate concrete structures. The minimum practical depth is one and a half times the maximum aggregate diameter in order to obtain lasting patch. The process can also be applied in layers for cracks up to ten centimeters in depth.

2.5.6 Thermo Patch

The process includes applying a mixture of graded sand and molten sulphur to form a brittle patch. The process is usually applied to severely depressed transverse cracks.

2.5.7 Fog Coat

This process consists of spraying a thin layer of liquid asphalt binder onto the pavement surface. The application rate is usually between half a litre and one litre per square meter. Some pavement maintenance inspectors believe that working the fog coat into the pavement with a rubber-tired roller increases the life of the treatment, however this has not been proven yet. The process is sometimes referred to as "flushing".

2.5.8 Ship Seal

This process consists of spraying a thick coat of liquid asphalt onto the pavement surface, then laying down a layer of graded crushed aggregate. The chips are compacted by a pneumatic-tired roller and excess chips are removed off the road. The process of chip sealing protects only the pavement surface and does not add structural strength to the road section. The process can be used as a cheap, low strength paving method if applied directly on a prepared gravel base.

2.5.9 Seal Coat

The process is similar to chip seal except it uses sand or non-graded fine aggregates as chips.

2.5.10 Hot-in-place Recycling

Hot in-place recycling is an on-site, in-place method that rehabilitates deteriorated flexible pavements and minimizes the use of new materials. The equipment usually consists of three separate units and one conventional asphalt paver as shown in Figure 2.4. The first one is a heating unit, the second is a milling unit, and the third is a mixing unit. The process involves heating the surface with infrared radiation and then milling it to a desired depth (between 20 and 65 millimeters). The mix of the old asphalt layer can be changed by adding virgin asphalt and a new amount of bitumen. The working widths vary between three and half meters and four meters. The process is environmentally friendly and it enables recycling of the milled layer on site.

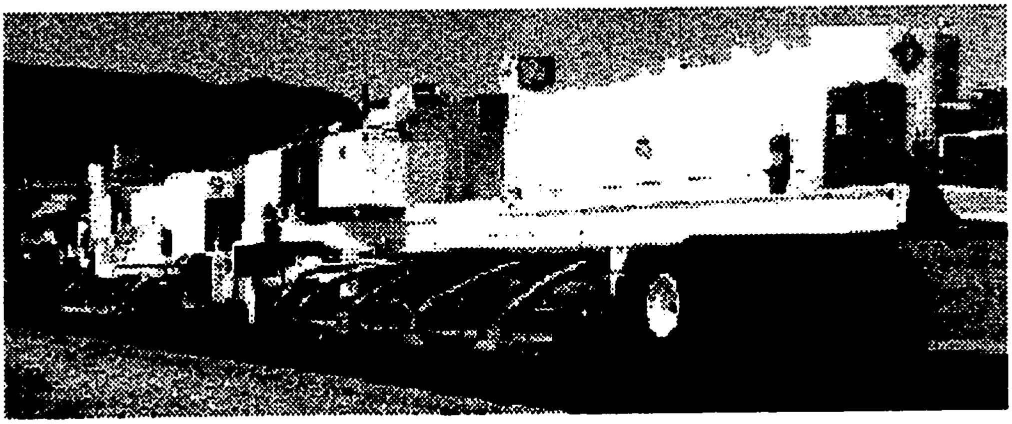


Figure 2.4 Hot in-place Recycling Equipment

2.5.11 Cold-in-place Recycling

The process involves milling approximately thirty centimeters of the existing asphalt. The road is then re-paved using virgin material. The milling product is sent to the mixing plant to be crushed and used as aggregate.

2.5.12 Cold Mill and Inlay

The process starts by removing the surface layer of asphalt (typically 25 to 50 millimeters) using a milling machine in one travel lane, usually the outer lane, as it generally gets most of the heavy traffic. A hot mix asphalt layer is then laid in the milled area using a normal paving machine to restore the pavement surface to its original profile. This type of work can be used for a wide range of projects ranging from intersection treatment to major rehabilitation.

This process has the advantage of not raising the surface of the pavement. This advantage is particularly important for urban cross sections with curb, gutter, and manholes and for under bridges where it is necessary to maintain the clearance height. Some or all of the original pavement material can be recycled. The process does not add significant strength to the pavement structure, and does not repair base or sub-base defects. The main difference between this process and the cold in-place recycling is the milling depth.

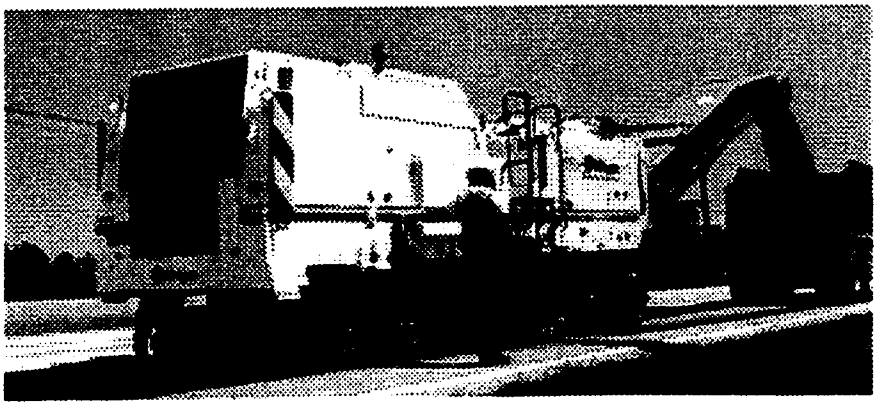


Figure 2.5 Typical Milling Machine

CHAPTER 3: COMPUTER-AIDED DECISION SUPPORT SYSTEMS

3.1 BACKGROUND

The impact of computer technology on everyday aspects of life is increasing rapidly. Computer applications can now be found in areas such as management decision-making. Decision-making is one of the most difficult tasks in the field of management; decisions should be sound, reasoned, and acceptable to all affected people. For many years decision-making was considered to be pure art or a talent acquired over time through experience. However, the decision-making environment has been shown to be much more complex in recent years. The main reason for this is the implementation of new technologies that introduce more alternatives. The tremendous increase in the cost of errors makes poor decision-making unacceptable. As a result, computer applications have been employed in the decision-making process to increase accuracy in solving complex problems (Turban, 1998). The main advantage of computer-aided decision-making is the possibility of merging the mathematical capabilities of computers with human experience.

Problems that might face decision-makers can be classified under three main categories:

1) Structured problems, which are routine and repetitive problems that accept standard solutions. Calculating the amount of steel reinforcement in a concrete beam or calculating the monthly payment of an employee are examples of this kind of problems.

2) Unstructured problems, which are fuzzy and complex problems where no previous experience is available and exact solutions can not be found. These are usually problems dealing with social matters or personal preferences.

3) Semi-structured problems, in which there are numerical data and expert opinions and they need to be merged together to come up with an optimum solution. The optimum solution will always vary with the changes in the problem circumstances and the knowledge expansion of the decision-maker (Simon, 1977). Most of construction and infrastructure management problems can be classified under the third category. Figure 3.1 demonstrates the classification of problems and examples of each class.

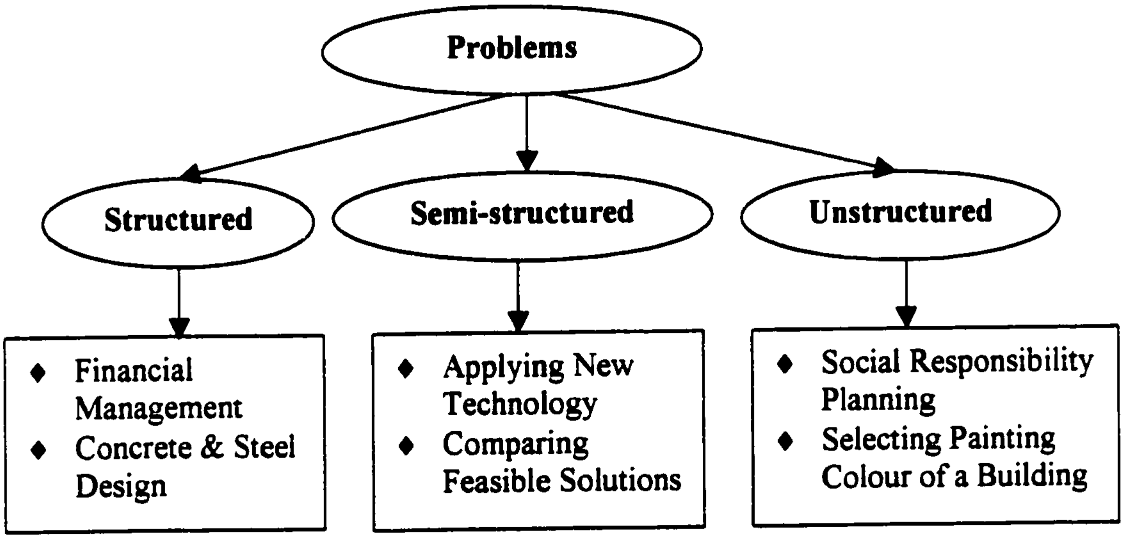


Figure 3.1 Classification of Problems

The decision-making process involves three main phases, as shown in Figure 3.2 (Simon, 1977). The process starts with the intelligent phase, where reality is examined, the problem is identified, and the problem variables are defined. Any related data is collected and analyzed at this time. In the design phase, a model will be constructed to represent the real system. The factors affecting the problem and the relationships between them and the problem variables should be determined. To build the model, assumptions are used to simplify the actual problem such as omitting some of the least important factors or limiting the model to a part of the problem. The model is then validated and criteria are set for the evaluation of the possible alternatives. The choice phase introduces a solution, which will be tested until the results are reasonable and the solution can be implemented. Successful implementation leads to solving the original problem, while failure leads to a return to an earlier phase of the process.

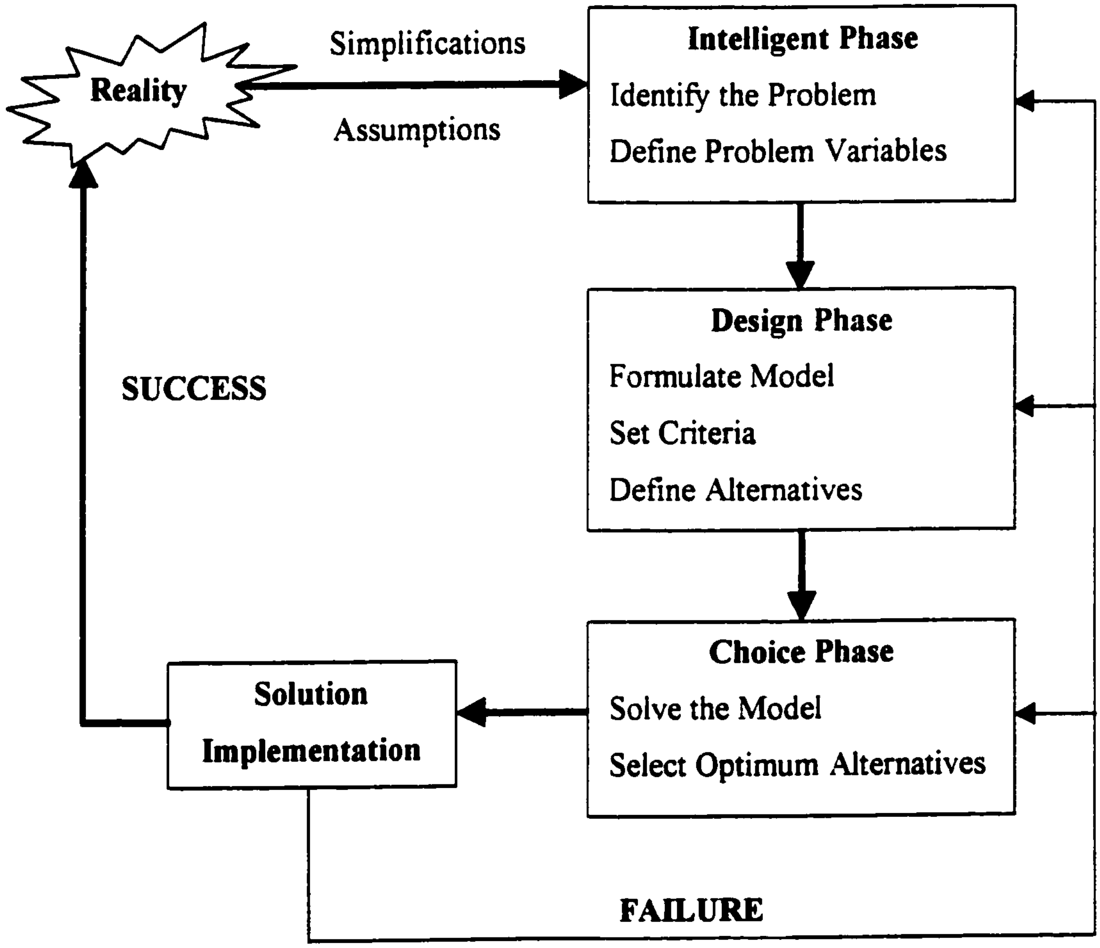


Figure 3.2 Decision-Making Process

3.2 DECISION SUPPORT SYSTEMS (DSS)

Decision Support Systems (DSS) were first defined as "Interactive computer based systems, which help decision-makers utilize data and build models for solving semi-structured problems" (Gorry, 1971). DSS were also defined as a " Model-based set of procedures for processing data and judgements to assist a manager in his decision making" (Little, 1970).

Bronczek defines DSS as follows: "DSS is a computer-based system that consists of three interactive components. The first component is the language system, which is a mechanism to provide communication between the user and the other components of the DSS. The second component is the knowledge system, which is the repository of problem knowledge either in the form of data or rules. The third component is the problem processing system, which is the link between the other two components and usually contains one or more of the general problem-manipulation capabilities required for decision making" (Bronczek, 1980). Another definition is " DSS is a computer based information system consisting of hardware/software and the human element designed to assist any decision-maker at any level" (Bidgoli, 1989).

These definitions show that the main objective of DSS is to support and improve decision-making using computers. They also formalize and organize the thinking process of the decision-makers in order to ensure consistency and constant level of accuracy in the process. DSS offer support mainly in semi-structured problems. User-friendliness and a simple communication language are essential for a successful DSS.

3.3 THE MAIN COMPONENTS OF DSS

The main components of DSS are demonstrated in Figure 3.3. The first component is the data management subsystem, which deals with any data required for the DSS. It might contain its own database or extract data from a Data Base Management System (DBMS). The DSS database is a collection of interrelated data organized in a way to meet the problem solving needs. The system might also contain a query facility to manipulate and query specific pieces of data.

The second component is the knowledge management subsystem. This part of DSS deals with human preferences based on previous experience. Artificial Intelligence (AI) applications can be used to capture human knowledge regarding the problem under investigation. There are different applications of intelligent systems, which can be used to achieve this goal. Knowledge Based Expert Systems (KBES), Artificial Neural Networks (ANN), and Fuzzy Set Theory are examples of these applications. A decision support system including this component is called intelligent DSS (Turban, 1998).

The model management subsystem is the main component of DSS. There are different types of models, which vary in their capabilities based on the problem solving requirements. Statistical, tactical and strategic, and financial and marketing models can all be used for this component of a DSS. The main objective of the model component of an intelligent DSS is to merge the data and expert opinions together to arrive at the desired decision. The Analytical Hierarchy Process (AHP) is one of the most suitable models for this purpose and will be illustrated later.

The last component is the user interface, which allows the end-user to communicate with the DSS. Power, flexibility, and ease of use are the main characteristics of a successful user interface. Some DSS experts argue that the user interface is the most important component of a DSS since it is the only part of the DSS the user deals with (Sprague, 1986). An inconvenient user interface is a major reason for decision-makers to prefer the traditional decision-making process to the DSS.

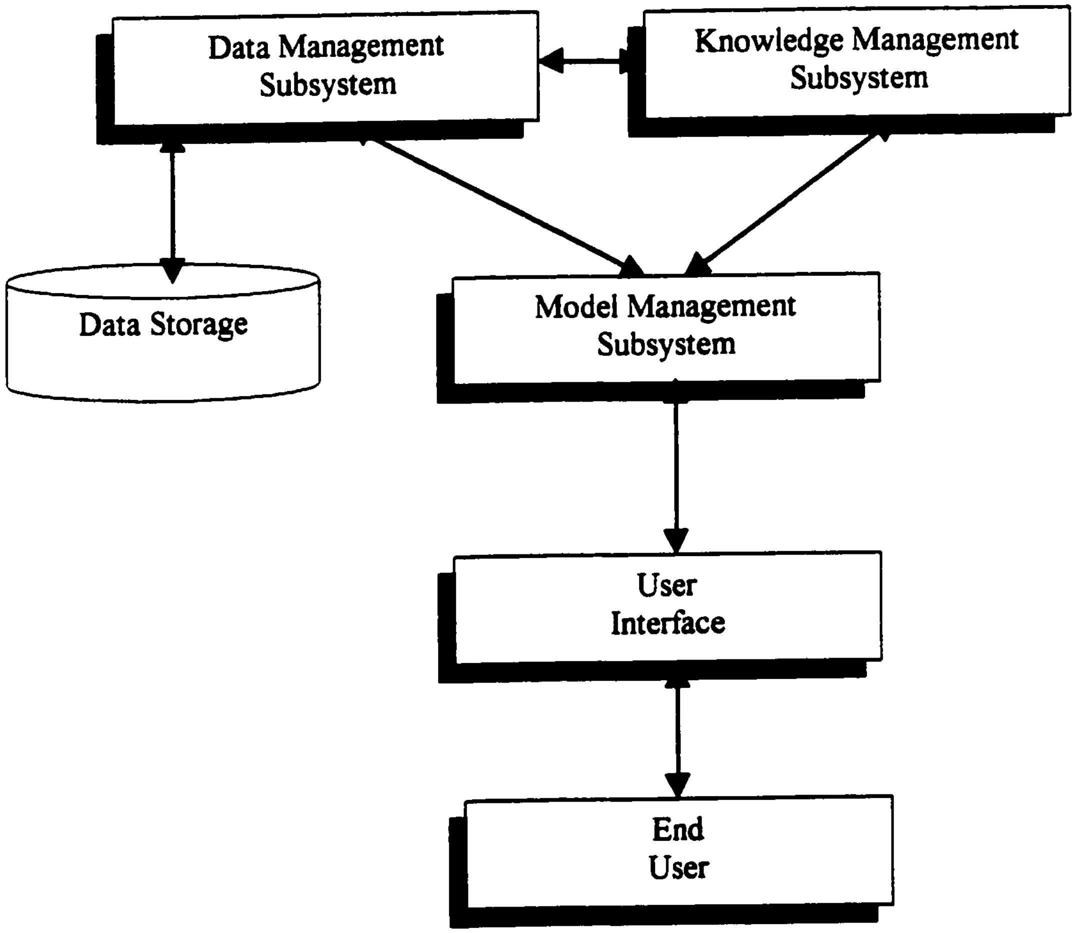


Figure 3.3 Main Components of a DSS

3.4 DSS IN CONSTRUCTION MANAGEMENT

The main objective of DSS is to enhance the efficiency of the decision-making process. The role of the computer in this process is to help, rather than replace, the decision-maker. DSS have been used in wide variety of applications in different management areas. There are a few DSS that have been developed specially for construction management; a brief description for some of them is introduced here.

One of the first applications recorded was in the field of tunneling and underground construction. The system, which was introduced at MIT, consists of a set of decision support tools. The objective of the system is to help decision-makers involved in underground construction (Hastak, 1993). The DSS contains a construction simulation module for estimating and resource allocating decisions. The second module is used for estimating and optimizing construction costs.

Another system was developed at the University of Cincinnati to help contractors decide whether or not to bid on tenders. The system also helps in assigning the percentage of markup in the bid (Ahmed, 1990).

Kakoto et al designed a system for selecting the most suitable equipment for tunneling in soft ground conditions (Kakoto, 1991). The system includes a knowledge base containing data regarding geotechnical issues, soil grouting and freezing possibilities, and different types of machines. The system was tested and implemented in Japan to help select the tunneling machine for the Sanagenya-Chisima project.

Systematic Automated Management Exception Reporting (SAMER) is a prototype DSS used for construction cost control (Abu-Hijleh, 1993). The system combines decision support system concepts with object-oriented programming technology to enhance performance exception reporting. It allows the user to identify the exception criteria and adjust the output reports.

Modular construction means obtaining the largest transportable units after being assembled off site. Modular construction is usually used for constructing petrochemical and power plants. A system was developed for checking the feasibility of modular construction processes in a project (Murtaza, 1993); the system proposes a formal framework for decision making, which includes a knowledge base to determine the feasibility of modularization. The system allows the user to give different weights to decision-making factors and comes up with a final recommendation and a confidence level noting for the recommendation given.

Delay Analysis System (DAS) is a construction decision support tool for determining the possible causes for project delays. It proposes alternative courses of action to prevent future delays (Yates, 1993). The system consists of eight sub-models and contains a database for possible causes of construction delays and several recommendations for each delay. The data comes from a study held by the Construction Industry Institute (CII) in Texas.

ADDSS is a decision support system developed for estimating the duration of construction activities based on the Fuzzy Modus Ponens Deduction (FMPD) technique (Wu, 1994). The FMPD is used to quantify the impact of different factors on the duration of construction activities by converting the linguistic values to numerical values using angular fuzzy set theory. These numerical values are used to submit the user with the most likely duration of the project activities.

Gugel et al introduced a model for selecting the suitable approach for applying constructability based on hierarchical decision levels (Gugel, 1994). Three approaches were considered: formal, informal, and comprehensive tracking. The user input covers the project and owner characteristics and the system output recommends one of the three approaches. The decision support tool integrates a knowledge base containing the decision rules at the lowest level of the decision-making process.

AbouRizk et al developed a DSS for contractor prequalification in 1995. The model applies the AHP to calculate the relative importance of the decision-making factors using a hypertext information management system. All the prequalification candidates are then evaluated in the light of each criterion (AbouRizk, 1995). A Group Decision Model (GDM) was used to allow a group of managers to compare the new technology and the conventional method (Hastak, 1998). AbouRizk et al added risk factors to the decision-making criteria for comparing the feasible alternatives (AbouRizk, 1994). The risk factors' impact on each criteria and feasible alternative is taken into account to obtain the final comparison scores.

3.5 THE ANALYTICAL HIERARCHY PROCESS (AHP)

The human thought process involves identifying objects and relations between them. The purpose of AHP is to organize and introduce consistency to the human thought process. The process requires building a hierarchical representation of the problem and developing priorities in that hierarchy. A hierarchy is a particular type of system assuming that the problem entities can be grouped into disjoint subsets (Saaty, 1982). Figure 3.4 demonstrates a typical example of a hierarchy model. The highest level of the hierarchy is called the focus or objective and it represents the goal to be achieved. Level 2 contains the decision-making criteria and may contain sub-criteria if needed. Level 3 contains all the possible alternatives for solving the problem. After building the hierarchy, it is required to calculate the priorities of the elements in the light of each criterion and the over all priorities.

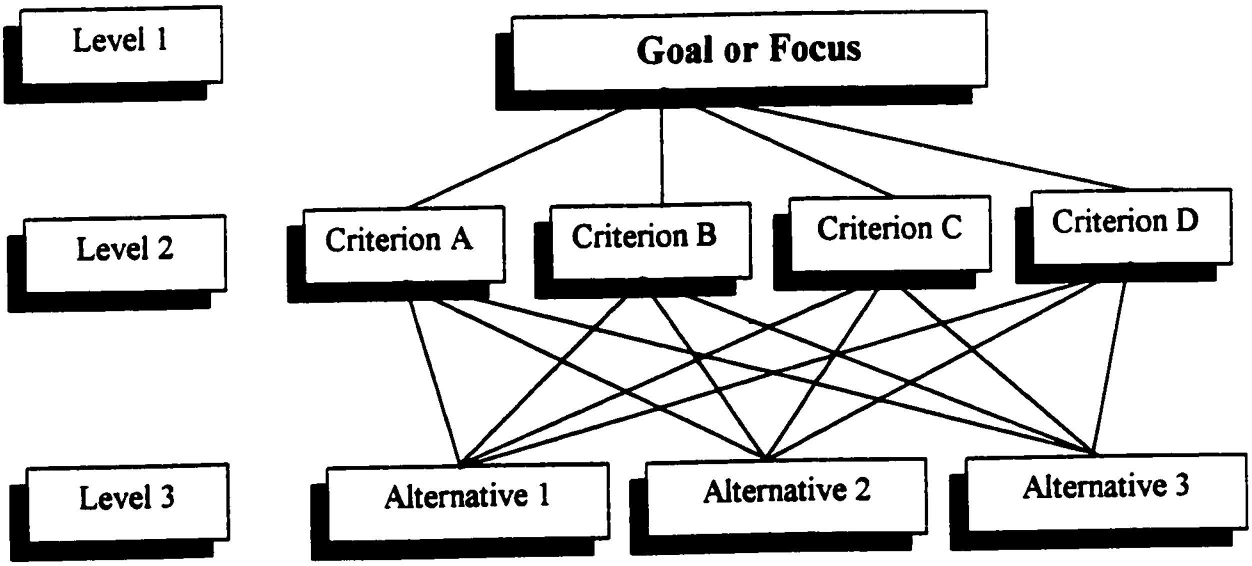


Figure 3.4 Example of a Hierarchy Model

Matrix calculations are used to prioritize the elements in one set and obtain the final priorities. For human experts, it is always easier to apply pairwise comparisons than rank a large set of different alternatives. The AHP builds a square matrix for pairwise comparisons into each set. A scale of 1-9 was found to be suitable for applying the pairwise comparison (Saaty, 1990). The scale is illustrated in Table 3.1; it represents the following qualitative distinctions: equal, weak, strong, very strong, and absolute preference.

Table 3.1 The Pairwise Comparison Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	The two alternatives contribute equally to the objective
3	Weak importance of one over another	The expert slightly prefers one alternative over another
5	Strong importance of one over another	The expert strongly prefers one alternative over another
7	Very strong importance of one over another	The expert very strongly prefers one alternative over another
9	Absolute importance of one over another	The expert has the highest possible preference for one alternative over another
2, 4, 6, 8	Intermediate values between the scale values	When intermediate judgements are required

An element is equally important when compared to itself, so the diagonal elements of the matrix are all 1's. To represent experience, one diagonal half of the matrix has to be filled and the other half will be the reciprocals as shown in Figure 3.5.

	Alternative A	Alternative B	Alternative C
Alternative A	1	1/3	1/7
Alternative B	3	1	1/5
Alternative C	7	5	1

Figure 3.5 Example of a Pairwise Comparison Matrix

For the comparison matrix, a principle eigenvector ($\overline{X}$) corresponding to the maximum eigenvalues of the matrix can be obtained. In mathematical expression, the vector of priorities can be obtained by normalizing the principle eigenvector (Saaty, 1990). There are four different methods of obtaining an estimate of the priority vector, which vary in accuracy. Saaty recommends the following method for obtaining acceptable results.

1) Divide the elements of each column by the sum of that column (i. e., normalize the column) and add the elements in each resulting row.
2) Divided the summation of the rows by the number of elements in the row (i. e., averaging the normalized rows) to obtain the priority vector.

Figure 3.6 demonstrates an example of a pairwise comparison matrix with the required priority vector.

Criterion	A	B	C	D	E	F
A	1	3	7	7	9	9
B	0.333333	1	5	5	7	7
C	0.142857	0.2	1	1	5	5
D	0.142857	0.2	1	1	5	5
E	0.111111	0.142857	0.2	0.2	1	1
F	0.111111	0.142857	0.2	0.2	1	1
Summation of Columns	**1.84127**	**4.685714**	**14.4**	**14.4**	**28**	**28**

Figure 3.6 a) Comparison Matrix and the Summation of Columns

Criterion	A	B	C	D	E	F
A	0.543103	0.640244	0.486111	0.486111	0.321429	0.321429
B	0.181034	0.213415	0.347222	0.347222	0.25	0.25
C	0.077586	0.042683	0.069444	0.069444	0.178571	0.178571
D	0.077586	0.042683	0.069444	0.069444	0.178571	0.178571
E	0.060345	0.030488	0.013889	0.013889	0.035714	0.035714
F	0.060345	0.030488	0.013889	0.013889	0.035714	0.035714

Figure 3.6 b) Normalized Matrix

A	0.466404
B	0.264816
C	0.102717
D	0.102717
E	0.031673
F	0.031673

Figure 3.6 c) The Required Priority Vector

3.6 THE CONCEPT OF CONSISTENCY

The consistency is perfect if all the judgements relate to each other as they should. If an expert prefers alternative (B) 3 times to alternative (A) and prefers alternative (C) 6 times to alternative (A), the consistency would be perfect if he/she prefers alternative (C) 2 times to alternative (B). Figure 3.7 shows the consistent and inconsistent matrices for this case.

	(A)	**(B)**	**(C)**
(A)	1	1/3	1/6
(B)	3	1	1/2
(C)	6	2	1

Consistent Matrix

	(A)	**(B)**	**(C)**
(A)	1	1/3	1/6
(B)	3	1	1/4
(C)	6	4	1

Inconsistent Matrix

Figure 3.7 Example of Consistent and Inconsistent Matrices

Human experts can not be 100% consistent; especially when the number of feasible alternatives gets larger. AHP allows for acceptable deviation, which does not significantly affects the accuracy of the results. To check the significance of the inconsistency in the matrix, it needs to be compared with the inconsistency of a complete random matrix (Saaty, 1990). This requires generating a large number of random matrices and calculating the consistency for each of them. The average random consistencies can be then calculated for different matrix sizes and are illustrated in Table 3.2.

Table 3.2 Random Consistencies for Different Matrix Sizes

Matrix Size	1	2	3	4	5	6	7	8	9	10
Random Consistency	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

To calculate the consistency of the (n × n) matrix, each column of the matrix should be multiplied by the relative priority of it up till the (n) column. The second step is to sum each row in a total row vector. Each element of that vector should be divided by the corresponding element of the priority vector. The average of the result vector is called (λ_{max}) which is the maximum eigenvalue of the matrix. The maximum eigenvalue (λ_{max}) will be used to calculate the Consistency Index (CI) using the following formula:

$$CI = (\lambda_{max} - n) \div (n - 1) \qquad (1)$$

The Consistency Ratio (CR) can be calculated as follows:

$$CR = CI \div RCI \qquad (2)$$

Where RCI is the Random Consistency Index for (n × n) matrix and can be obtained from table 3.2. Empirical studies indicated that a consistency ratio of less than (10 %) is acceptable without significant effect on the results. Figure 3.8 illustrates an example of calculating consistency for a (3 × 3) matrix.

	(A)	(B)	(C)
(A)	1.00	0.33	0.14
(B)	3.00	1.00	0.20
(C)	7.00	5.00	1.00

	Priority vector
(A)	0.08
(B)	0.19
(C)	0.72

Figure 3.8 a) The (3 × 3) Matrix and its Priority Vector

	0.08 * (A)	0.19 * (B)	0.72 * (C)	Row Sums
(A)	0.08331	0.0644	0.10336	0.251
(B)	0.24992	0.19319	0.1447	0.588
(C)	0.58316	0.96593	0.72351	2.273

Figure 3.8 b) Modified Matrix

Row Sums		Priority vector		
0.251		0.08331		3.01366
0.588	÷	0.19319	=	3.04272
2.273		0.72351		3.14108

Figure 3.8 c) Determining λ_{max}

$\lambda_{max} = (3.013 + 3.042 + 3.14) \div 3 = 3.065$

$CI = (\lambda_{max} - n) \div (n - 1)$

$= (3.065 - 3) \div 2 = 0.329$

$CR = CI \div RCI$ [where RCI = 0.58 for (n = 3), Table 3.2]

$= 0.329 \div 0.58$

$= 5.67\ \%$ $< 10\ \%$ (Good Consistency)

Figure 3.8 d) Calculating Consistency Ratio

After obtaining the required eigenvectors, the final priority vector is obtained by multiplying the eigenvector of each criterion by the relative importance of that criterion obtained from the eigenvector of the decision-making criteria comparison matrix and sum all the results.

3.7 DEVELOPING DSS FOR PAVEMENT MAINTENANCE ALLOCATION

The standard decision-making process explained at the beginning of this chapter was used to build the conceptual design of the required DSS. The problem identified was to allocate the most appropriate routine maintenance alternative for defected pavement segments. A computer-aided DSS was required for solving that problem. The second step was to define the factors affecting the problem and determine which of these could be omitted during the analysis. It was found that the distress type and degree of severity are the most important factors for selecting maintenance alternatives; as such they formulate the technical constraints. The term "technical constraints" refers to the applicability of a specified treatment to fix a certain distress. While, density degree might affect the decision in the current practice, researcher decided to omit it from the identification of the technical constraints because it is a fiscal rather than a technical constraint.

The technical constraints represent the main challenge in developing the model because not all treatments can fix all distresses. After several attempts, it was decided to divide the problem into smaller problems with separate sub-models. This required identifying the applicable treatments for the three severity degrees of each distress type, identifying cases that can be fixed by the same treatments, and building separate sub-models for each case. Based on the knowledge obtained, six cases were found to be sufficient for the prototype DSS. The process of selecting these cases will be explained later in this chapter.

Pavement attributes such as soil type and base type might affect the actual service life of maintenance alternatives, however, AT&U maintenance inspectors do not consider this while making their decisions. It was decided to allow the maintenance inspectors to preview these attributes through the system, which will enable them to build better understanding for the effect of these attributes on maintenance activities. This represented the end of the intelligent phase and the beginning of the design phase.

The AHP was found to be suitable for building the required sub-models and prioritizing the feasible alternatives. The six sub-models will be explained in the model management subsystem of the DSS. The AHP offers a single flexible model for solving semi-structured problems and requires identifying the decision-making criteria and assigning them relative weights. This step will also be explained later in this chapter.

Twelve types of maintenance alternatives were selected to develop the models. These treatments were explained in chapter two and represent almost all the alternatives currently used by AT&U's maintenance inspectors. This marked the end of the design phase and the beginning of the choice phase.

The DSS consists of five main components as shown in Figure 3.9. These components are the knowledge management subsystem, data management subsystem, model management subsystem, user interface, and output module. The main objective of the knowledge management subsystem is to capture human knowledge in the field of pavement maintenance allocation. All the steps followed to obtain this knowledge and all the findings are explained in chapter four. The data management subsystem required integrating and modifying several databases from the AT&U data repository to obtain the required data in the desirable format. The model management subsystem was divided into six sub-models all using AHP for assigning priorities to feasible alternatives. These two components will be explained later in this chapter. The development of a prototype DSS in Access including the user interface and the output module will be explained in chapter five.

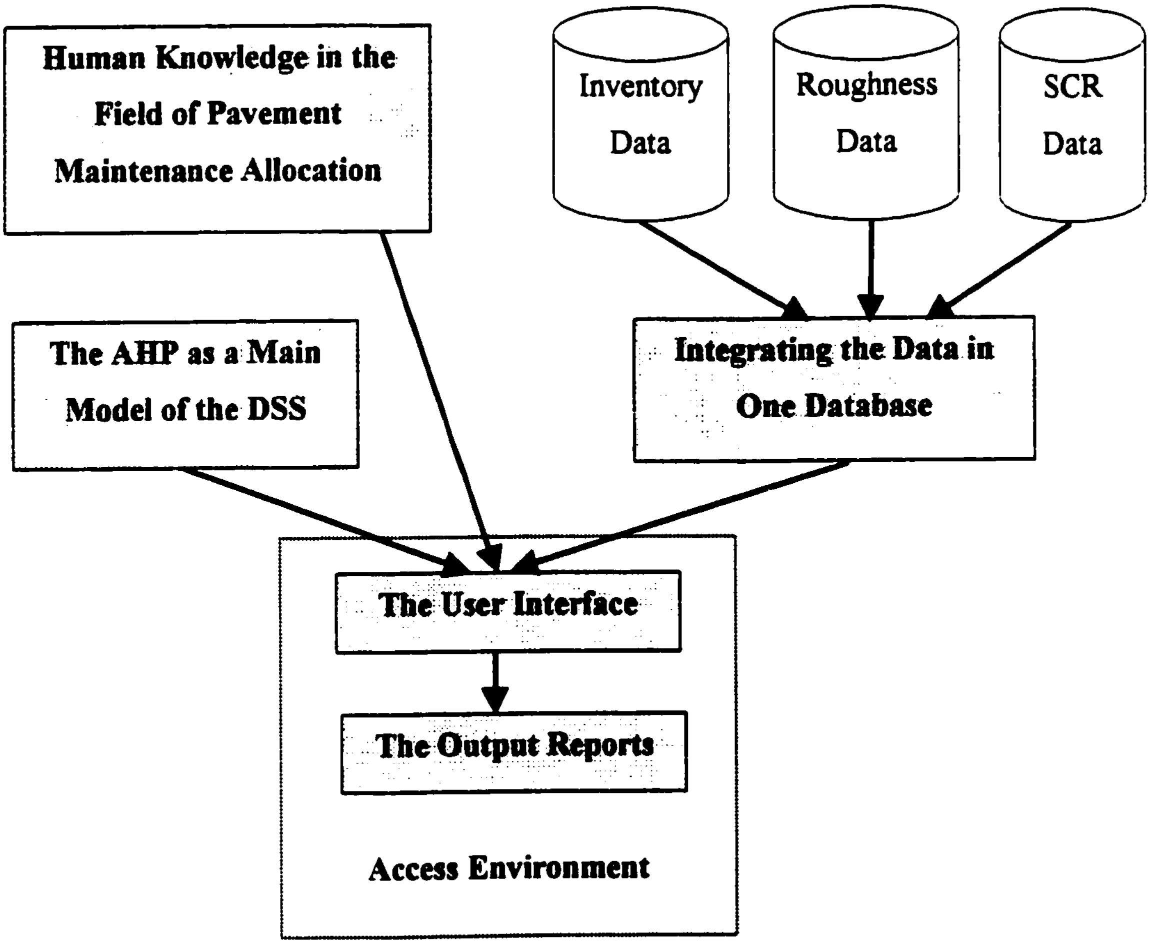


Figure 3.9 Main Components for A Prototype DSS for Pavement Maintenance Allocation

3.8 SELECTING CASES FOR THE PROTOTYPE DSS

Based on the knowledge obtained, it was decided that the DSS would assess nine surface distresses. The analysis of the applicable treatments revealed that four of them could be fixed using more than one treatment, these treatments can be prioritized using AHP. These distresses are cracks, transverse cracks, depressed transverse cracks, and loss of aggregate. Alligator cracks as well as rutting, which are structure related distresses, require testing of the structural adequacy of the road using the Falling Weight Deflectometer (FWD). If that is the case, the treatments must be designed based on the test results. Distortion, which is a soil type related distress, requires investigating soil type on the defected section before making a decision. However, some treatments can be applied to fix these types of distresses before testing. These treatments are only temporary; the problem will arise again soon after. Potholes can be filled using "throw and roll" while severe bleeding is an indication that a skid resistance test is needed.

For the selected distresses, different treatments are required for each degree of severity. It was found that five cases could cover all the possible combinations as shown in Table 3.3. The table illustrates five cases; each contains the distress types, their severity degrees and the three associated maintenance alternatives that can fix the problem. Another case was used to compare the three possible alternatives for fixing all distresses in segments that are in poor condition. The maintenance alternatives contained in this case were: cold mill and inlay, cold in-place recycling, and hot in-place recycling. For each of the previously mentioned cases, a separate sub-model was built using AHP to assign priorities to feasible alternatives.

Table 3.3 The Selected Five Cases

Cases	Treatments	Distresses
Case 1	Hot Pour Cold Pour Rout & Seal	Cracks with ***Moderate*** Severity. Transverse Cracks with ***Slight*** & ***Moderate*** Severity. Depressed Transverse Cracks with ***Slight*** Severity.
Case 2	Hot Pour Cold Pour Spray Patch	Cracks with ***Extreme*** Severity.
Case 3	Hot Pour Spray Patch Mill & Fill	Transverse cracks with ***Extreme*** Severity.
Case 4	Mill & Fill Spray Patch Thermo Patch	Depressed Transverse Cracks with ***Moderate*** & ***Extreme*** Severity.
Case 5	Fog Coat Seal Coat Chip Seal	Loss of Aggregate with ***Moderate*** & ***Extreme*** Severity.

3.9 IDENTIFYING THE DECISION-MAKING CRITERIA

To identify the decision-making criteria, five suggested options were introduced to the pavement experts committee. All the pavement experts in the committee agree that three main factors govern the decision to allocate treatments to the defected pavement segments. These factors are disruption during application, cost per year of expected service life, and previous experience with the treatment. The term disruption during application refers to all the possible hazards that might occur during the treatment process. The time labours are required to be on highway, amount of warning signs, flagmen, traffic closure requirements, and labour safety during applying treatment are some examples of these hazards. To compare the relative importance of each criterion, AHP was introduced to the committee members with special emphasis on the idea of pair comparison. Several examples illustrated to them how experts can input their own preferences through the AHP comparison matrices. The concept of consistency was also introduced to them while filling the matrices.

An AHP comparison matrix was designed to identify the relative importance of each criterion. The comparison matrix led to the development of criteria weights, which will be used for the upcoming steps. The committee groups were asked to fill the lower diagonal half of the matrix; the upper one contained the reciprocals of the values submitted by the experts. The AHP calculations mentioned before were used to obtain the eigenvector corresponding to the maximum eigenvalues for this entire comparison matrix. The pavement experts agreed that previous experience is three times more important than disruption during application and twice as important as cost per year. The consistency ratio for this matrix was found minimum due to the consistent response. Table 3.4 shows the calculated eigenvectors for the comparison matrix of the decision-making criteria.

Table 3.4 Comparison Matrix for Decision-Making Criteria

Criteria	Disruption during Application	Cost per Year	Previous Experience	Eigen vector
Disruption during Application	1	1 / 2	1 / 3	**0.167**
Cost per Year	2	1	2 /3	**0.333**
Previous Experience	3	3 / 2	1	**0.5**

3.10 THE MODEL MANAGEMENT SUBSYSTEM

The AHP can be used as a model to build DSS in different areas. The process requires identifying the goal or focus, defining the decision-making criteria, and then calculating priorities for feasible alternatives. The goal of the developed DSS is to allocate the most appropriate treatment alternative for defected pavement segments. To identify the feasible treatments, human knowledge regarding technical constraints of applying treatments was captured.

Figure 3.10 illustrates the hierarchy of the model based on the previously mentioned criteria. Six sub-models were built for each of the previously described cases. All the sub-models were similar except that each has different feasible alternatives.

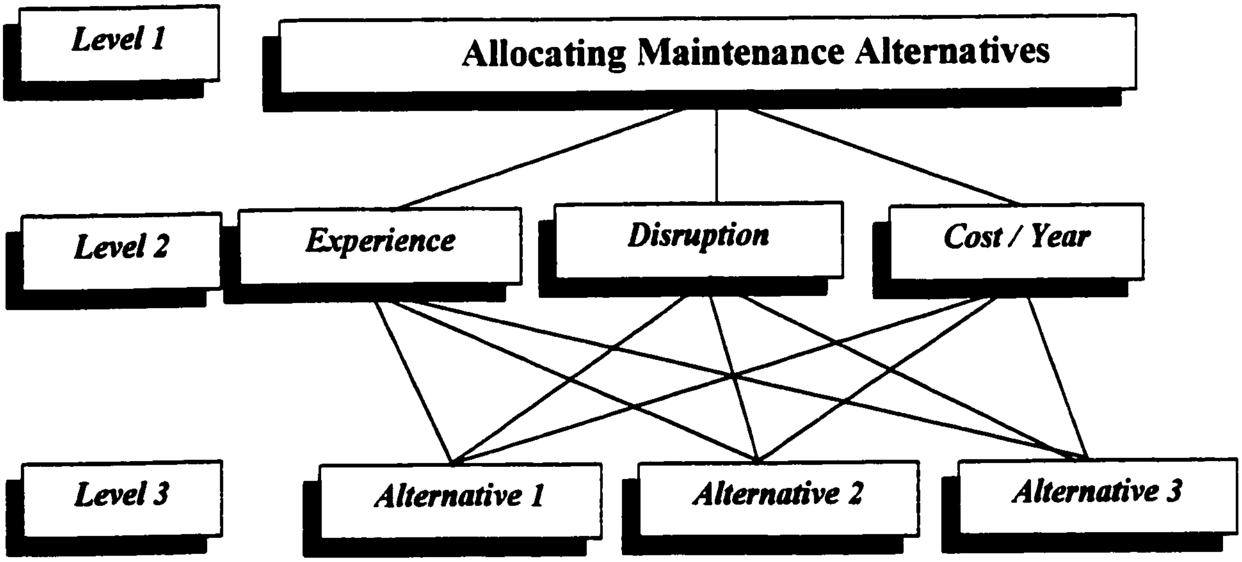


Figure 3.10 Hierarchy of the Decision-Making Problem

To build the six sub-models using the pre-identified criteria, twelve matrices were submitted to the pavement experts committee. For each of the previously mentioned cases, two comparison matrices were prepared one for "previous experience" and one for "disruption during application". The data regarding cost of treatment and expected service life will be left as a user input due to the variation in their values throughout the province and under different conditions. Figure 3.11 illustrates one page of the submitted matrices. The rest of the questionnaire is attached in appendix (2).

The committee was divided into five groups of two members in each. The five responses were reviewed and the predominant values were used to fill one comparison matrix for each case. An MS Excel spreadsheet was prepared to instantly calculate the maximum eigenvectors and consistency ratios after any change in the comparison matrix. To validate the obtained values, these matrices along with the calculated eigenvectors and consistency ratios, were presented one by one to all the committee members. The values were reviewed and modified by the committee members until they were all satisfied and everyone agreed on the results. The final twelve matrices fulfilled the experts' expectancies; all the consistency ratios of the matrices were less than ten percent indicating acceptable consistency level. Figure 3.12 illustrates an example of one of the final matrices while the twelve matrices are attached in appendix (3). The twelve matrices were used to develop the models required for the Prototype DSS. The matrices for the criterion cost per expected year of service life would be generated automatically by the system after the user inputs the required information.

Case 1:

Compare each pair of these maintenance treatment alternative in the light of the mentioned criterion.

Previous Experience	Hot pour	Cold Pour	Rout & Seal
Hot pour	1		
Cold Pour		1	
Rout & Seal			1

Disruption during Application	Hot pour	Cold Pour	Rout & Seal
Hot pour	1		
Cold Pour		1	
Rout & Seal			1

1 = Equal preference of both alternatives.
3 = Weak preference of one alternative over another
5 = Strong preference of one alternative over another
7 = Demonstrated preference of one factor over another
9 = Absolute preference of one factor over another

You can use the reciprocals of the numbers mentioned above (i. e. 1/3, 1/5, 1/7, 1/9) to represent the preference of the item in the top row over the item in the left column.

Figure 3.11 An Example of Pairwise Comparison Matrices Submitted to the Committee

Disruption during Application	Fog Coat	Seal Coat	Chip Seal	Max Eigen Vectors	Consistency Ratio
Fog Coat	1.00	0.50	4.00	0.35	4.64%
Seal Coat	2.00	1.00	4.00	0.54	
Chip Seal	0.25	0.25	1.00	0.11	

Previous Experience	Fog Coat	Seal Coat	Chip Seal	Experience Weight	Consistency Ratio
Fog Coat	1.00	0.50	0.33	0.17	0.00%
Seal Coat	2.00	1.00	0.67	0.33	must be less than
Chip Seal	3.00	1.50	1.00	0.50	10%

Figure 3.12 Examples of the Final Matrices

3.11 THE DATA MANAGEMENT SUBSYSTEM

The data required for the DSS was found in three different databases in the AT&U data repository. All these databases use highway numbers as well as control sections (large portions of the highway with fixed boundaries) to identify all the records. The first database used was the Surface Condition Rating (SCR) data; this was obtained in MS Access format. The database divides the Alberta highway network into almost two thousand segments based on similar surface conditions. This method of segmenting enables AT&U maintenance inspectors to easily allocate maintenance alternatives to segments. The segment boundaries are used only for the SCR data and do not match any other database segment boundaries. For each segment, all information related to its surface conditions is recorded. The most important of this information was the data regarding the severity and density of different distress types located on segments. The database contained more than seventy data fields. Only the required fields were moved to the DSS database. Eight scores could be developed from the available database based on the thresholds outlined in chapter four, however, the modified surface condition rating system for the year 1999 will allow for obtaining alligator crack score. Appendix (4) shows an example of the SCR original data before and after modification.

The second database used was the inventory database, which contains all the Alberta highway network attributes. All highway control sections are divided into smaller segments called inventory sections. For each inventory section, many attributes are recorded. Only six of these attributes were transferred to the DSS database management subsystem. These attributes include base type, soil type, climatic region, Equivalent Single Axle Load (ESAL) representing traffic loads, and either the year the segment was constructed or the last year major rehabilitation was applied to it, depending on which is most recent. This field is used to calculate the age of the segment based on the equation:

$$\text{Age} = 1999 - (\text{year of construction or year of major rehabilitation}) \quad (3)$$

The data was obtained from the AT&U Mainframe in text file format and was transformed into MS Access format. It was important to assign all these attributes to the SCR segments to be used by the DSS. Appendix (5) gives an example of the inventory data before and after modification.

The third database used was the roughness data, which is represented by the International Roughness Index (IRI). The IRI data is collected every one hundred meters on a regular basis. The reason of using roughness data was enabling the pavement maintenance inspectors to check the roughness of specific segments and correlate it to the surface condition and other pavement attributes. It was also used to connect the inventory data to the SCR data. An Access query was designed to spread the SCR data and the inventory data on a one hundred-meter basis. A copy of the SQL sentence used for the query is attached in appendix (11). Using that query, all the required data was obtained in one table, which was the main data storage for the prototype DSS. Appendix (6) illustrates an example of the final database.

CHAPTER 4: THE KNOWLEDGE MANAGEMENT SUBSYSTEM

4.1 INTRODUCTION

As detailed in previous chapters, the main objective of this research is to develop a prototype DSS to help choose the most appropriate routine maintenance alternative for defected pavement segments. The DSS consists of five main components; one of which is the knowledge management subsystem. The knowledge management subsystem transfers human knowledge in the field of maintenance allocation to the system. Figure 4.1 illustrates the steps followed to build the knowledge management subsystem of the prototype DSS in a sequence manner.

The process began with a survey of North American transportation agencies regarding their SCR practices. The survey description and findings are presented in the first part of this chapter. It was essential to unify the syntax for defining pavement surface distresses at the beginning of the process. The distresses to be assessed by the DSS were determined and the most probable causes were defined. The measurement methods and thresholds for different degrees of severity and density were also identified. A specific weight was assigned to each distress type and these weights were used to develop a composite Surface Condition Index (SCI). Finally, the technical constraints regarding the ability of treatments to fix pavement distresses were obtained. The previous six steps are explained in the second part of this chapter along with a complete summary of all the findings for each distress type.

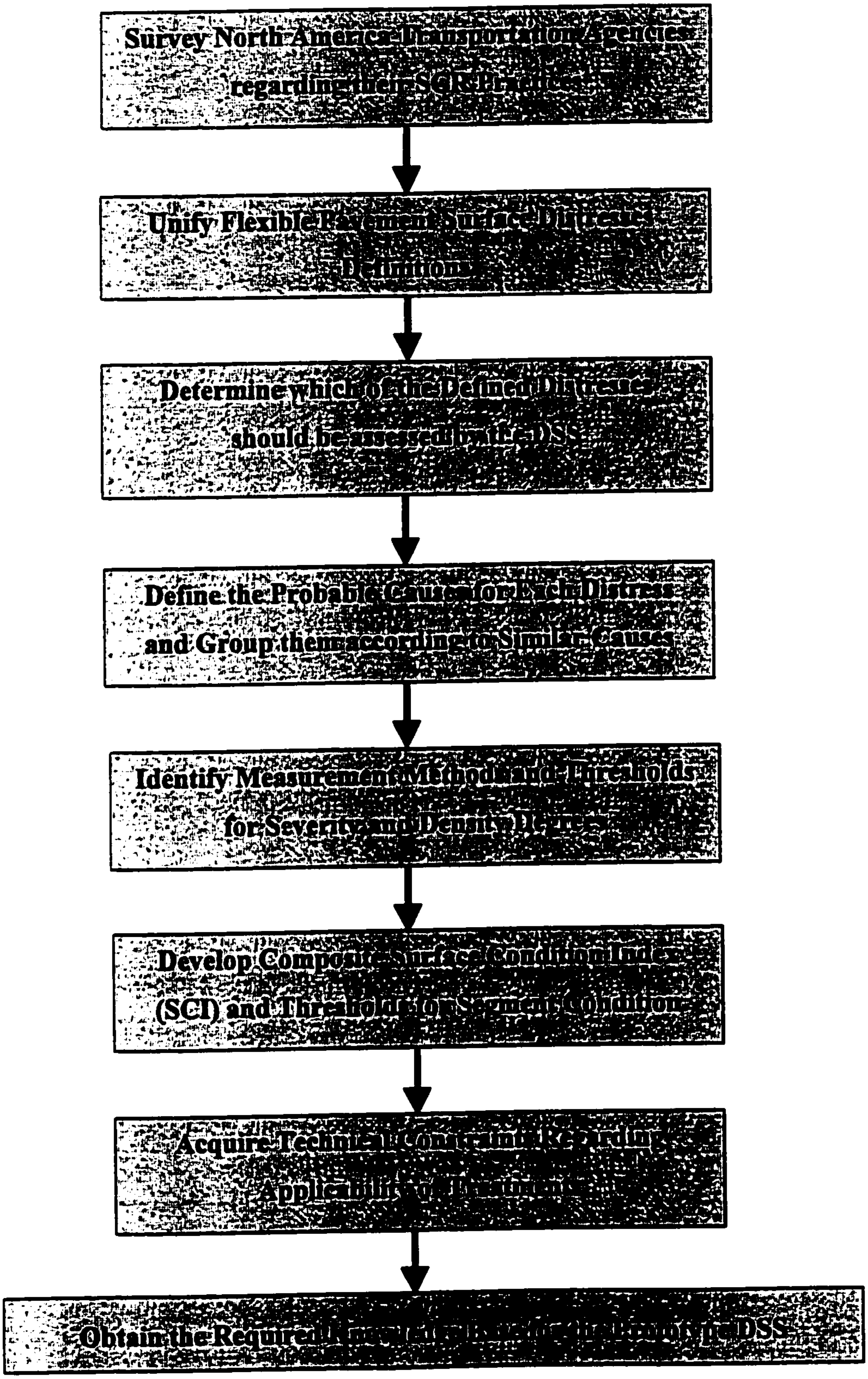


Figure 4.1 Steps Followed to Build the Knowledge Base Component of the DSS

4.2 NORTH AMERICAN SCR PRACTICES SURVEY

A survey was conducted throughout North American departments of transportation to identify their surface condition rating practices. More than fifty surveys were sent to highway agencies. Twenty-nine transportation agencies responded to the survey representing more than 50% of the contacted agencies. A copy of the survey questionnaire is attached in appendix (7). Four main issues were covered in the survey:

- Data collection methods and network segmentation systems.
- Assessment of distress types and their measurement techniques.
- The scoring practice and the availability of distresses composite indices.
- The usage of SCR data in pavement management systems.

4.2.1 Questionnaire Description

The questionnaire consists of 12 questions. The first two questions cover how often departments of transportation collect the surface condition rating data within their provinces/states. In addition, it investigates the percentage of the network covered each time the network is rated. The next two questions cover segmentation systems and test section lengths. The fifth question checks which types of distresses are assessed by the agency during the rating process. The different scoring systems used for severity and density and availability of composite indices were interrogated in questions six and seven. The rest of the questions examine the use of surface condition rating data for managing pavements, budget allocation, and any other purposes. Finally, the agency is asked to submit any references or useful information that might add value to the survey.

4.2.2 Survey Findings

As shown in Figure 4.2, more than 77% of the responding state highway agencies collect surface condition rating data on an annual basis. Approximately 17% of the responding agencies reported that they collect data every second year. About 3% of the agencies measure the distresses every four years; another 3% collect data only for roads under investigation before and after any major rehabilitation. Figure 4.3 demonstrates that approximately 65% of the agencies scan the entire highway network during each SCR process. About 12% of the agencies measure between 70 and 90 percent of their network. Approximately 12% of those responded examine 50% of the network. About eight percent of reported agencies measure 33% of the network. Less than five percent scan only the roads under investigation. These percentages reflect the importance of the surface condition rating data for better pavement management. This also shows that transportation agencies are welling to spend time and money to update the SCR data of their highway network.

Figure 4.4 illustrates the survey results concerning segmentation systems. More than 16% of reporting agencies segment the network based on the visual surface condition. This method gives the best representation for maintenance purposes but it introduces difficulty in using the data for managing pavements. More than 44% employ a system using constant-length segments. This system gives the highest consistency but does not reflect the pavement characteristics and segments with similar surface conditions. Approximately 12% base their segmentation practice on similar pavement attributes (e.g. base type, traffic loads, soil types, etc.). Another method used involves segmenting the network based on construction history and then visual surface conditions. Approximately 23% of agencies are using this method. This method is acceptable for maintenance purposes but segments vary with time. This variation decreases consistency and may not produce reliable results when performing data analysis. Only one agency segments the roads between two structures (e. g. bridges or culverts).

The survey asked highway agencies about their practice in selecting the most appropriate gauging length that represents the segment conditions. More 50% of the state highway agencies measure pavement distresses within the whole segment as shown in Figure 4.5. About 28% measure one hundred to five hundred feet per mile of roads. Approximately 12% use a constant gauging length for each segment.

Figure 4.6 shows all distress types and the percentage of agencies that assess each of them. Table 4.1 shows these types of distresses and the transportation agencies assess them. Rutting, longitudinal cracking, alligator cracking, and transverse cracking are currently being assessed by more than 75% of the surveyed agencies. Most of the agencies assess between eight and twelve different types of distresses during the surface condition rating process. The pie chart in Figure 4.7 shows that almost 80% of the highway agencies adopt a composite surface distresses index for network-level management purposes. It is usually used for monitoring the overall performance of the network within time, predicting network deterioration, and budget allocation.

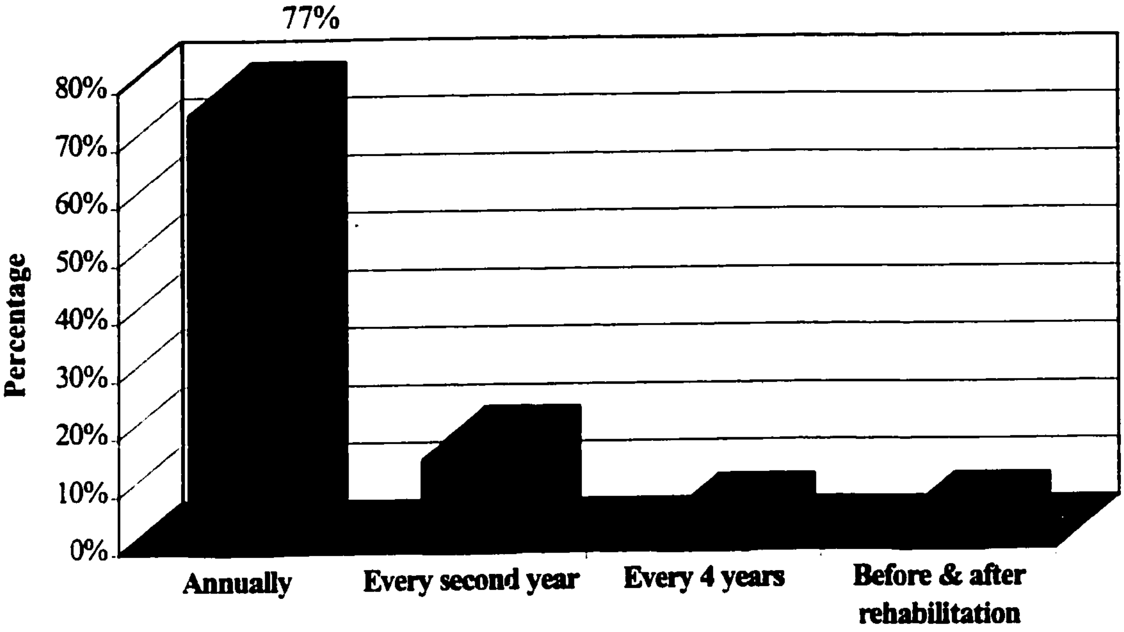


Figure 4.2 Frequency of SCR Data Collection

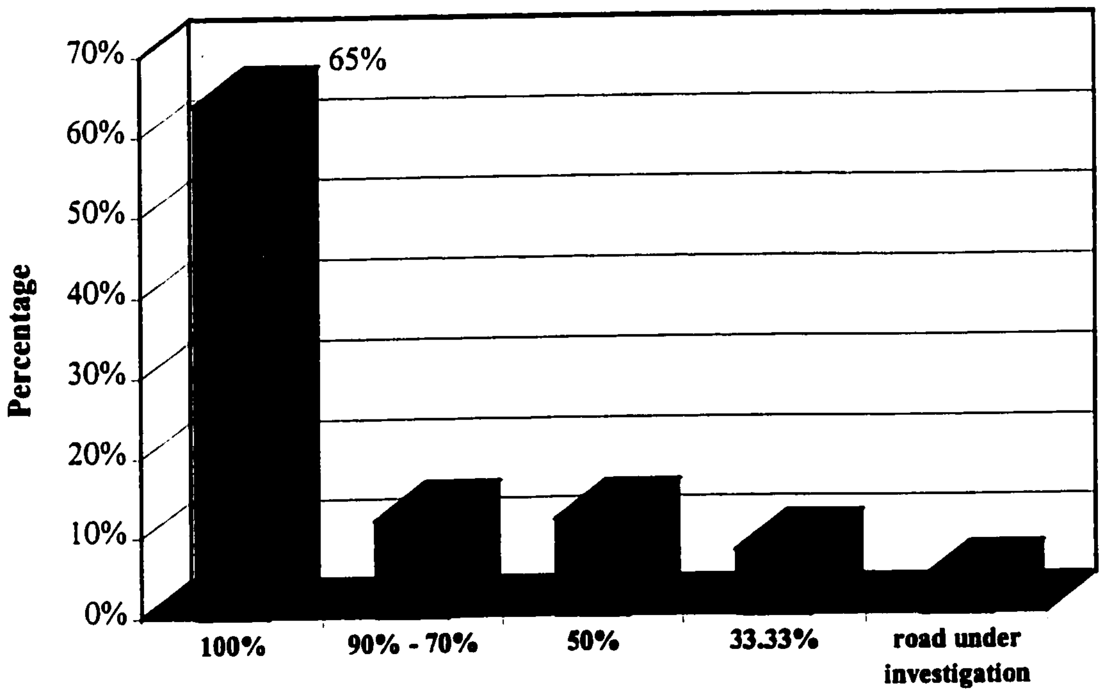


Figure 4.3 Percentage of the Network Measured Every Year

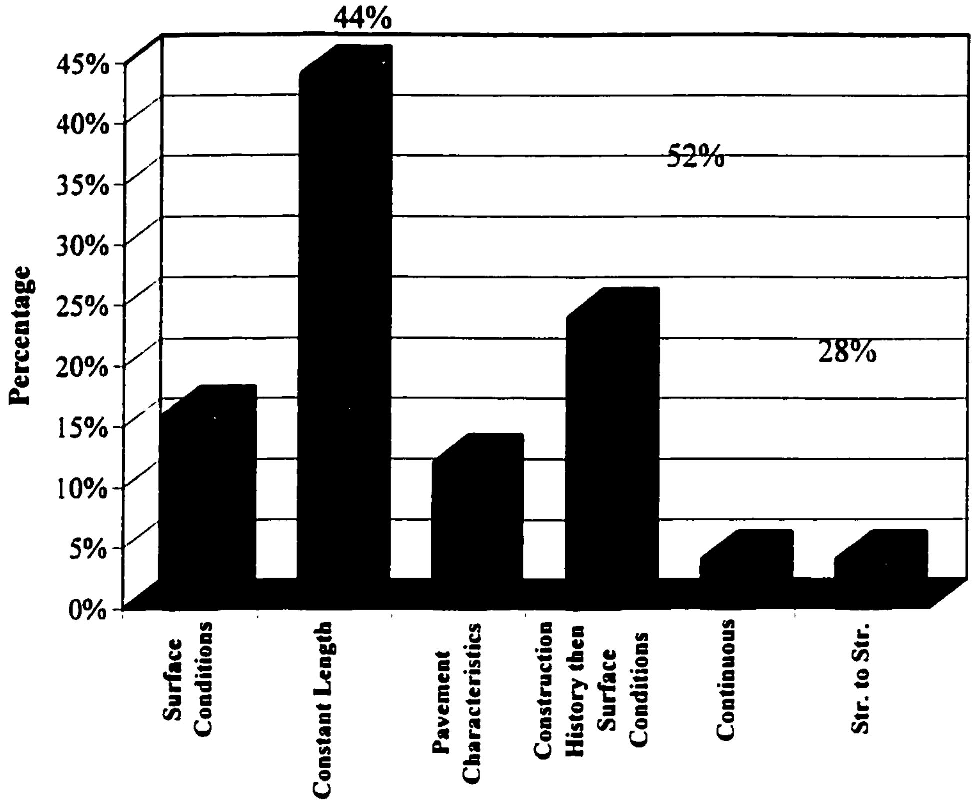


Figure 4.4 Methods Used for Segmenting the Network

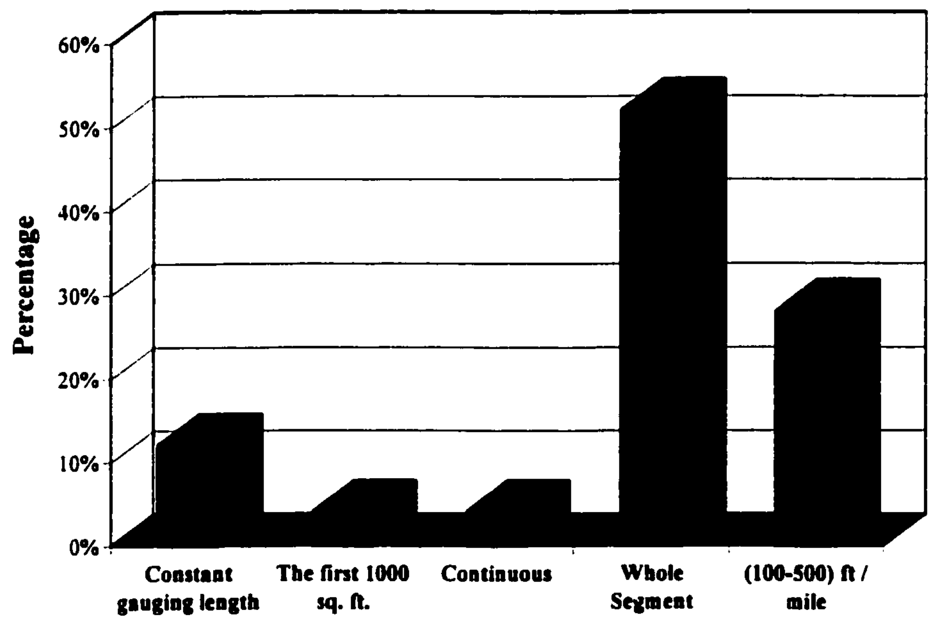


Figure 4.5 Use of Different Measuring Methods within the Segment

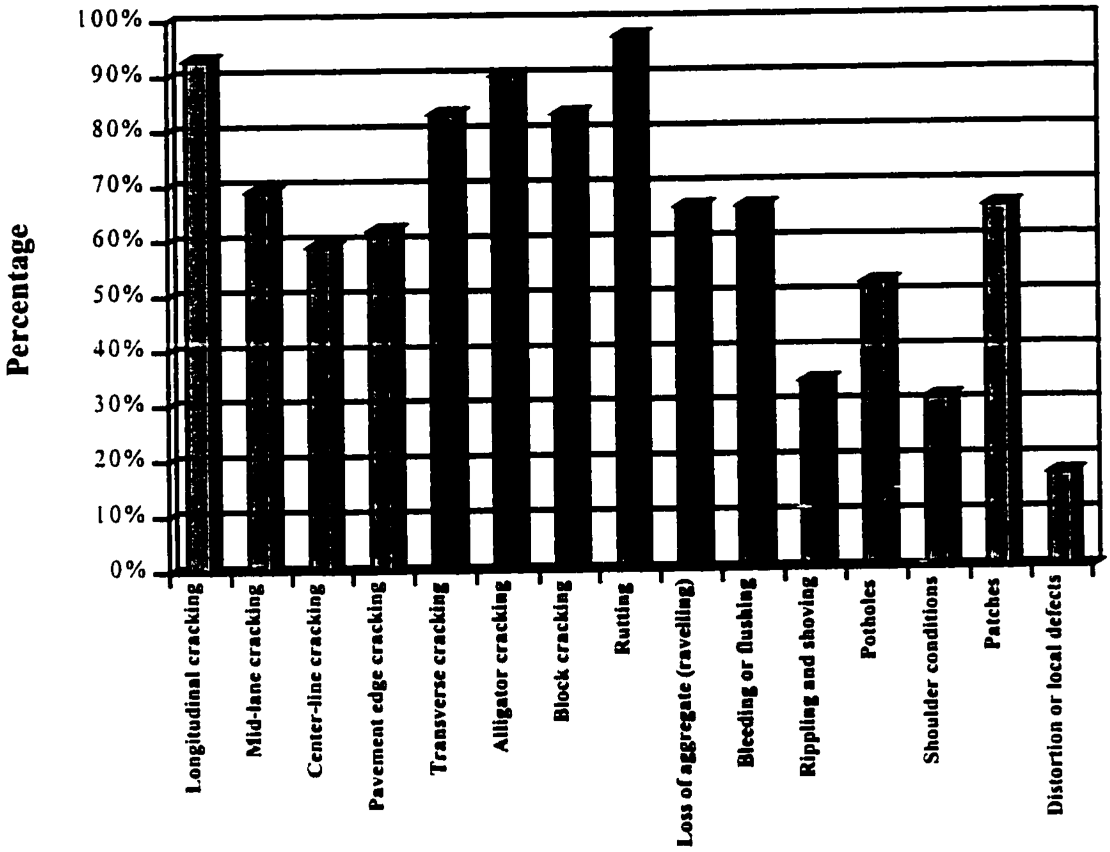


Figure 4.6 Graphical Representation of Pavement Surface Distresses' Assessment

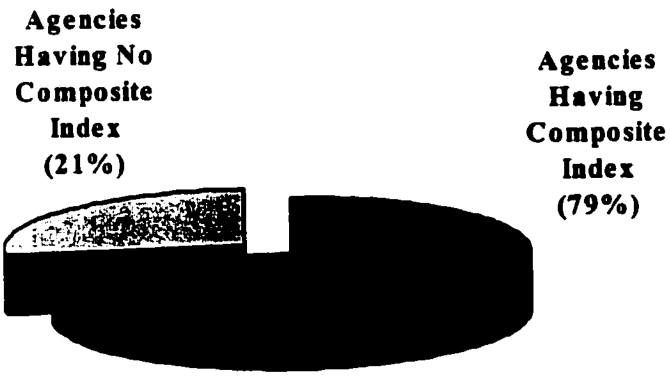


Figure 4.7 Composite Surface Distresses Index

Table 4.1 Pavement Surface Distress Assessment

Distress / Department of Transportation	Longitudinal Cracking	Mid-lane cracking	Center-line cracking	Pavement edge cracking	Transverse cracking	Alligator cracking	Block cracking	Rutting	Loss of aggregate (ravelling)	Bleeding or flushing	Rippling and shoving	Potholes	Shoulder conditions	Patches	Distortion or local defects
Alaska								*							
Alberta	*				*	*	*	*	*	*		*	*		*
Arizona	*	*	*	*	*	*	*	*		*				*	
B. Columbia	*	*	*	*	*	*		*		*		*			*
California	*			*		*	*	*	*	*	*	*	*	*	
Florida	*	*							*	*					
Georgia	*			*	*	*	*	*	*	*	*				
Illinois	*	*	*	*	*	*	*	*	*		*			*	
Indiana	*	*	*	*	*	*	*	*	*			*		*	
Manitoba	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Maryland	*					*	*	*							
Minnesota	*	*			*	*	*	*	*					*	
Montana	*				*	*		*	*	*		*	*		
Nebraska	*	*	*	*	*	*	*	*	*	*		*	*	*	
Nevada	*	*	*	*		*	*	*	*	*	*	*	*	*	

Table 4.1 Continued

Distress / Department of Transportation	Longitudinal Cracking	Mid-lane cracking	Center-line cracking	Pavement edge cracking	Transverse cracking	Alligator cracking	Block cracking	Rutting	Loss of aggregate (ravelling)	Bleeding or flushing	Rippling and shoving	Potholes	Shoulder conditions	Patches	Distortion or local defects
New Brunswick	*	*	*	*	*	*	*	*	*	*	*	*		*	
New Jersey	*	*			*			*					*	*	
New Mexico	*	*	*	*	*	*	*	*	*	*	*	*		*	*
Newfoundland	*	*	*	*	*	*	*	*	*	*	*	*	*		
North Dakota	*	*	*	*	*	*	*	*	*	*				*	
Nova Scotia	*	*	*	*	*	*	*	*	*	*	*	*			*
Ontario	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
South Dakota					*	*	*	*						*	
Texas	*	*	*	*	*	*	*	*	*	*		*		*	
Vermont	*				*	*	*	*						*	
Virginia	*	*	*		*	*	*	*				*		*	
Washington	*	*	*	*	*	*	*	*	*	*				*	
West Virginia	*				*	*	*	*							
Wyoming	*	*	*	*	*	*	*	*		*				*	
Total Number	27	20	17	18	24	26	24	28	19	19	10	15	9	19	5

4.3 BUILDING THE KNOWLEDGE BASE

The survey conducted among North American departments of transportation and the literature review both showed that there are several definitions and sometimes even different names for the same type of distress. It was important to unify pavement surface distresses' definitions to ensure accuracy of all upcoming steps for building the knowledge base. Fifteen types of distresses were selected and a final set of definitions was established for them.

After the definitions were unified, the second step involved determining which of these distresses the DSS should assess. The assessment was based on Alberta highway network conditions using an objective weighing method. The weights obtained for the importance of each distress is used to calculate a composite Surface Condition Index (SCI) to be used for network level management. The composite index can also be used for obtaining statistical measurements regarding the overall highway network conditions accompanied by other performance evaluation measures.

To deal with fifteen different types of distresses with different degrees of severity would make the problem very complicated. Several attempts were made before it was decided to group the distresses based on similar causes. This required identifying the possible causes of each distress and deciding which of them to be used for the grouping task. Grouping distresses, based on similar causes, is also useful to inform maintenance inspectors about the nature of each pavement distress and the factors that might affect the distress deterioration.

For each distress type, the most suitable measuring unit, measurement method, and thresholds for different degrees of severity and density were defined. One scoring system was used with all distress types to enable development of the composite index using the pre-calculated distresses' weights. That was also due to the significant effect of severity degree on allocating the most appropriate treatment to defected pavement segments.

Currently at AT&U, the decision to allocate the suitable treatment to the defected pavement segments is made by an expert. However, such decisions require detailed cost analysis and an awareness of impact on the pavement service life. The expert human knowledge in the field of allocating maintenance treatment alternatives needed to be captured. A proper capturing of knowledge required identifying criteria governing the decision-making process and determining technical constraints for applying treatments. The term "technical constraints" refers to defining which treatments are technically applicable for each degree of severity for a specific distress.

A summary of definitions, possible causes, measurement methods, thresholds for different degrees of severity and density, and applicable treatments are summarized for each of the twelve distress types. The summary is accompanied by pictures showing different degrees of severity for the same distress type.

4.3.1 Obtaining the Human Knowledge

To achieve the previously mentioned sub-objectives, a committee was set including a group of AT&U pavement experts with different backgrounds and long-term experience with pavement surface conditions. The committee members included pavement maintenance inspectors, pavement design engineers, and pavement rehabilitation planners. The names and job titles of the committee members are listed in appendix (8).

A series of workshops were held with the committee members according to a pre-scheduled plan and workshop agenda. These workshops provided all the knowledge required to start building the prototype. The process started by dividing the committee members into five groups. Each group contained two members with similar backgrounds who work in different areas of the province. A four-section questionnaire was designed to organize the knowledge-capturing process. Each section refers to one of the previously mentioned steps. An example of each section is attached in appendix (9). The five groups went through the questionnaire section by section. The responses were analyzed by the researcher, and then differences and conflicts were presented for open discussion at the completion of each section. The purpose of open discussion was to validate the findings and eliminate conflicts within results. Based on the discussion, the results were modified and submitted again to the committee groups. The final conclusions were achieved and approved by all committee members. Figure 4.8 illustrates a flow chart of the process followed to acquire human knowledge for the DSS.

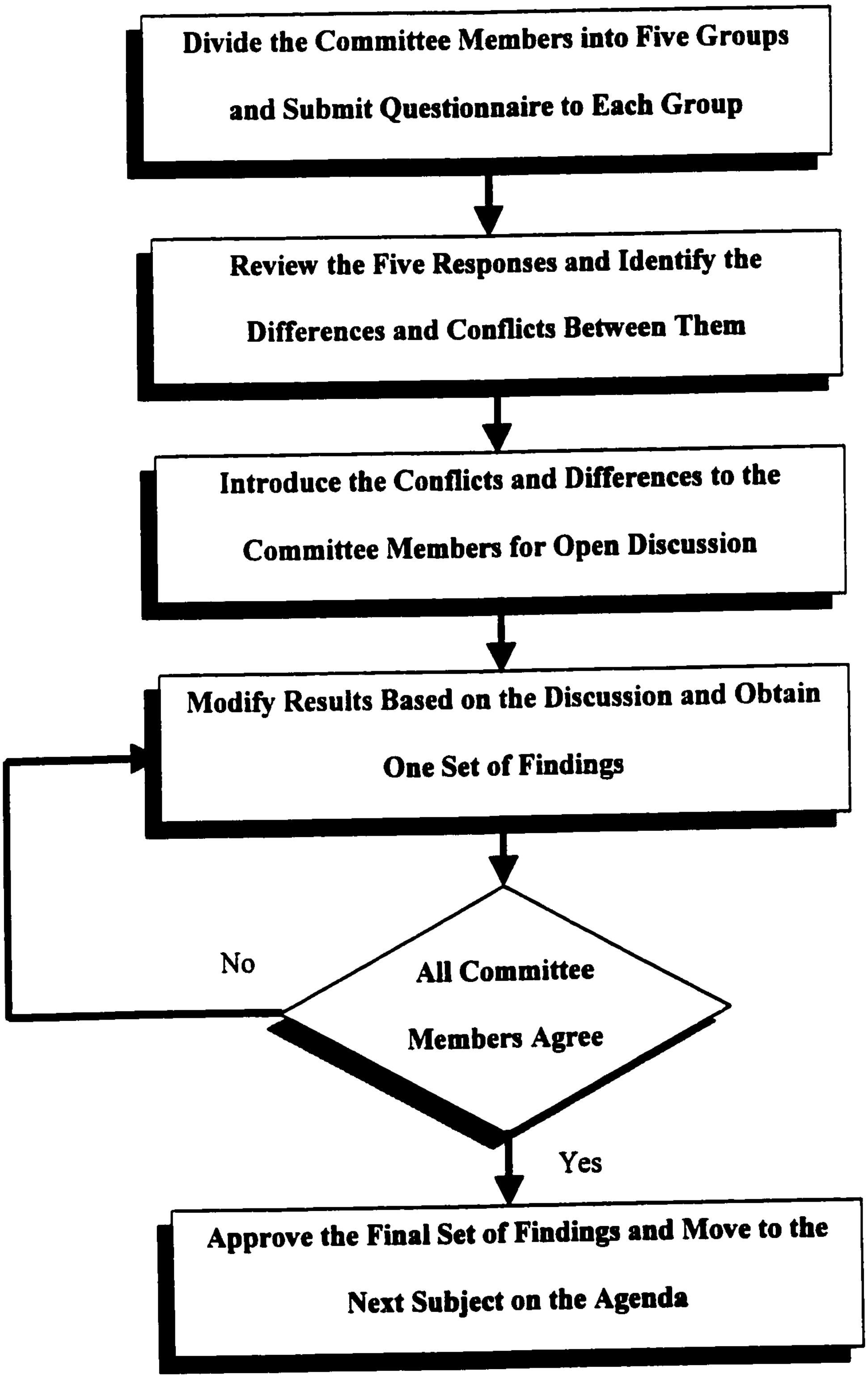


Figure 4.8 Flow Chart for the Process of Capturing the Human Knowledge

4.3.2 Pavement Surface Distresses' Definitions

Both the literature review and the information gained from North American departments of transportation showed that differing definitions are used for the same type of distress. Section (A) of the questionnaire suggested definitions for fifteen selected types of distresses found to be the most common among North America transportation agencies. The committee groups were asked to either agree with the suggested definition or write down their own preferences. After the five responses were analyzed, a new set of definitions was prepared and re-submitted to the committee members for open discussion. The whole committee went through the new set of definitions one by one and suggested modifications. These modifications were used to prepare a final set of definitions, which was approved by all the committee members. The final distresses' definitions are presented at the end of this chapter with the rest of the findings.

4.3.3 Pavement Surface Distress Assessment

The surface condition rating process would be costly and very time consuming if fifteen types of surface distresses must be assessed all over the whole highway network every year. The danger to traffic and pavement raters would also escalate because of the increased rating time. To determine the importance of each distress and decide which of them the DSS should assess, an objective weighting method was used. As mentioned before, pavement surface distresses might affect riding comfort, pavement deterioration, and driving safety. The five pavement expert groups were asked to rank the importance of these three factors to the maintenance activities on a scale of one to three. All the pavement experts agreed that driving safety is the most important factor for maintenance activities giving it a unanimous weight of three. This result reflects the importance of public safety as a governing factor for AT&U. Due to this fact, distresses that affect driving safety will be ranked the most important. Pavement deterioration was ranked second and was given a weight of two. This reflects the importance of maintaining the highway network, as a valuable asset, in the best possible conditions. This is also a sign of the important role of routine maintenance in postponing major rehabilitation and minimizing costs. In spite of being the main factor for planning major rehabilitation, riding comfort was ranked as least important for maintenance activities and was given a weight of one.

Table 4.2 shows the weights given to the different distresses regarding the three factors and the final scores calculated for them. The weights appearing in the table are the mathematical average of the these submitted by the five groups. The final weights were calculated based on the equation:

$$\text{Final Weight} = [\text{Driving safety weight} \times 3 + \text{Pavement deterioration weight} \times 2 + \text{Riding comfort weight} \times 1] / 6 \qquad (4)$$

These decisions were made based on the previous process:

1. Omitting pavement shoulder conditions and patching from the DSS due to their lack of effect on the pavement performance.
2. Omitting pavement edge cracking and ravelling from the DSS because there is virtually no occurrence of them on Alberta highway network.
3. Separating depressed transverse cracks due to their effect on riding comfort.

Table 4.2 Final Scores Sorted According to Importance

Surface Distress \ Weight	Driving Safety	Pavement Deterioration	Riding Comfort	Final Score
Potholes	9.0	8.8	8.4	9
Distortion	8.2	7.6	8.6	8
Rippling or Shoving	7.4	8.0	8.2	8
Rutting	9	7.2	5.6	8
Depressed Transverse Cracking	3.2	7.4	9.0	6
Alligator Cracking	3.2	9.4	6.4	6
Transverse Cracking	3.2	7.4	3.3	5
Block Cracking	2.6	7.4	6.0	5
Ravelling	3	8.2	4.2	5
Meander Cracking	2.0	6.6	4.2	4
Longitudinal Wheel-Track Cracking	2.0	7.6	3.0	4
Bleeding or flushing	3	3.8	1.6	3
Non Wheel-Track Longitudinal Cracking	1.8	6.0	2.2	3
Edge Cracking	1.4	3.2	2.0	2
Patching	1.6	1.4	1.2	1
Shoulder Conditions	1.2	1.4	1.0	1

4.3.4 Distresses' Possible Causes and Grouping

The third part of the questionnaire asked the committee groups to suggest the possible causes of each of the twelve distress types. They were also asked to identify the most predominant cause of the distresses. Grouping was performed based on similar predominant causes. The possible causes are outlined at the end of this part of the chapter. The classified groups and the distresses contained in each group are shown in Table 4.3. The three main groups are asphalt concrete attribute related distresses, environment related distresses and structure related distresses. The distresses contained in the asphalt concrete group are mainly due to defects in the asphalt mix design. A lack of bond between particles and the binder, insufficient asphalt content, asphalt hardening and excessive asphalt content are some of the factors which might cause this type of distress. The second group contains distresses caused mainly by environmental and climatic factors. Cycles of freeze and thaw, high temperatures and frost actions are examples of these factors. The structure related group contains distresses that are caused by traffic loads exceeding the design load or insufficient bearing capacity of the road section due to defected design. These types of distresses lead to fatigue and structural weakness in the pavement section.

Each of the other three groups contains only one distress. The Block crack appearing on the pavement surface originates from the shrinkage of the cement-stabilized soil under the asphalt layer and is classified as a base-type related distress. The "CH" soil, highly plastic clay, usually leads to pavement surface distortions classified as subgrade related distress. The paver joints are the main reason for the non wheel-track longitudinal cracks classified as construction related distress.

Table 4.3 Flexible Pavement Surface Distresses' Grouping

Group	Distresses Contained
1. Asphalt Concrete Related Distresses	Potholes Rippling or Shoving Ravelling Bleeding or Flushing
2. Environmental Related Distresses	Transverse Cracking Depressed Transverse Cracking Meander Cracking
3. Structural Related Distresses	Wheel-Track Longitudinal Cracking Alligator Cracking Rutting
4. Base Type Related Distress	Block Cracking
5. Subgrade Related Distress	Distortion or Local Defects
6. Construction Related Distress	Non Wheel-Track Longitudinal Cracking

4.3.5 Distresses Measurement and Developing Composite Surface Condition Index (SCI)

In the fourth part of the questionnaire, the pavement committee groups were asked to suggest the most suitable measurement method for pavement distresses. They were also asked to suggest thresholds for the three degrees of severity and density. The results are outlined in the summary of findings.

The scores obtained were transferred to numeric values as shown in Table 4.3. These numeric values and the previously developed weights are used to obtain the Surface Condition Index (SCI) using the equation:

$$SCI = \sum_{i=1}^{n} (W_i \times S_i) \qquad (5)$$

Where:

n = Number of distresses. W_i = Calculated weight of the distress.

S_i = Calculated numerical score of the distress.

After identifying a method to calculate the SCI, it was required to identify thresholds for evaluating segment condition. These thresholds are used to evaluate the condition of the entire highway network of Alberta. The pavement committee agreed that a segment is considered to be in excellent condition if the scores for cracks (weight = 4), transverse cracks (weight = 6), and rutting (weight = 8), are less than (S1). This means SCI value to be less than 36 for excellent condition.

A segment is considered to be in acceptable condition if the scores for cracks (weight = 4), transverse cracks (weight = 6), and rutting (weight = 8), are less than (S1), and the scores for distortion (weight = 8) and potholes (weight = 9) are less than (X1). This means the SCI value falls between 36 and 244 for acceptable condition. A segment with an SCI greater than 244 is considered to be in poor condition. Table 4.5 illustrates the percentages of the network in each category for the year 1998. These percentages can be used to check the efficiency of maintenance strategies by comparing the results from year to year.

Table 4.4 Numerical Transfer of the Scores

Severity	Low (1)	Medium (2)	High (3)
Slight	2	3	4
Moderate	5	6	7
Extreme	8	9	10

Table 4.5 Classifying Alberta Highway Network based on the SCI

Category	Percentage
Segments in Excellent Condition	18.44%
Segments in Acceptable Condition	75.33%
Segments in Poor Condition	6.23%

4.3.6 Technical Constraints and Applicability of Treatments

Obtaining the data regarding the applicability of treatments to different pavement surface distresses was the last step in building the knowledge-based module of the decision support system. The allocation of treatments depends mainly on the type of distress and the actual degree of severity. Table 4.6 was designed to obtain this knowledge from the five groups of pavement experts. The table columns represent the assessed types of pavement surface distresses; the table rows represent the most common types of maintenance alternatives available in Alberta (as mentioned before in chapter two). The rows also included the possibility of applying "no action" and "rehabilitation candidate" to cover all the probable decisions. The five pavement expert groups were asked to fill in the table cells with the possible degrees of severity for the distress in the column, which can be fixed by the treatment in the row as shown in the table. The letter "X" represents extreme severity, letter "M" represents moderate severity, and letter "S" represents slight severity.

To simplify the problem, the committee members suggested combining longitudinal, meander and block cracking into one distress because the same maintenance alternatives are appropriate for all of them. Finally, the DSS deals with nine types of distresses: transverse cracks, depressed transverse cracks, alligator cracks, other cracks, bleeding, potholes, loss of aggregate (ravelling), rutting, and distortion.

Table 4.6 Allocating Treatments Matrix

Treatment \ Distress	Longitudinal, Meander, Transverse & Block Cracks	Depressed T. Cracks	Alligator Cracks	Structural Rutting	Distortion
No Action	S	S	S	S	S
Hot Pour	S, M, X	S, M			
Cold Pour	S, M	S, M			
Rout & Seal	M	S, M			
Mill & Fill		M, X			
Spray patch	X	M, X	S, M		
Thermo patch		M, X			
Skin patch		X	M, X	M, X	S, M
Deep patch			M, X	X	M, X
Geogrid Reinforcement		X	X	X	
Rehabilitation Candidate			X	X	X
Fog Coat					
Seal Coat					
Chip Seal					
Microsurfacing					
Cold Mill & Inlay					
Cold In-place Recycling					
Hot In-place Recycling					
Throw & Roll					

Table 4.6 Continued

Distress / Treatment	Rippling & Shoving	Potholes	ACP Rutting	Bleeding	Ravelling
No Action	S	S	S	S	S
Hot Pour					
Cold Pour					
Rout & Seal					
Mill & Fill					
Spray patch	M, X	S, M, X			M, X
Thermo patch					M, X
Skin patch	M, X				M, X
Deep patch	M, X				
Geogrid Reinforcement					
Rehabilitation Candidate					
Fog Coat					S
Seal Coat					S, M
Chip Seal					S, M
Microsurfacing			M, X		S, M
Cold Mill & Inlay			M, X	M, X	M, X
Cold In-place Recycling			M, X	M, X	M, X
Hot In-place Recycling			M, X	M, X	M, X
Throw & Roll		S, M, X			

4.3.7 Summary of Findings

For each of the assessed distresses, the definition, possible causes, unit of measurement, and applicable treatments for different degrees of severity are mentioned below.

4.3.7.1 Longitudinal Wheel-Track Cracking

a) Definition: Cracks that follow a path parallel to the pavement centerline and are located at one of the wheel-tracks. It is a fatigue failure usually develops to alligator cracking in the wheel-tracks.

b) Possible Causes: Repeated heavy traffic loads.

Inadequate bearing capacity in pavement sections.

Poor drainage conditions.

c) Classification: Structural-Related Crack.

d) Measuring Unit: Lineal meter.

e) Measurement Method: the rater follows the cracks with a wheel-meter and records the total length of cracks with different degrees of severity.

f) Severity Degrees: 1) Slight: single cracks less than or equal to three millimeters in width.

2) Moderate: cracks greater than three millimeters but less than ten millimeters in width.

3) Extreme: cracks greater than or equal to ten millimeters in width.

g) Applicable Treatments: 1) Slight severity: No action.

2) Moderate severity: hot pour, cold pour and rout & seal.

3) Extreme severity: hot pour, rout & seal and spray patch.

h) Density Degrees: all cracks are assigned a nominal width of 0.3 meters. A nominal area can then be calculated. The density extension is assigned based on the percentage of defected area as follows; less than 4% = 1

5 - 9% = 2

greater than 9% = 3

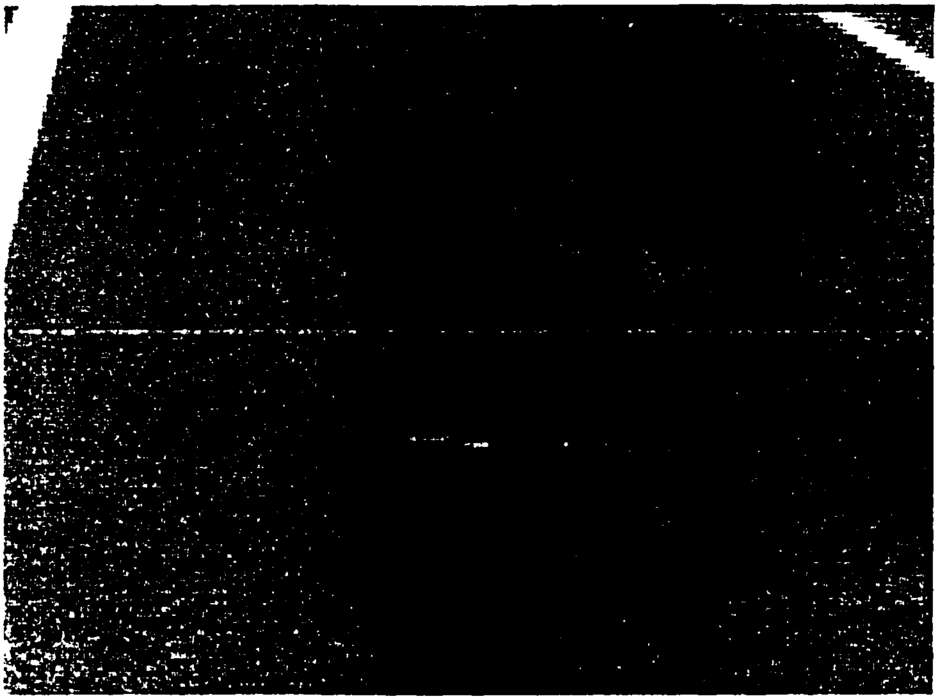


Figure 4.9 Moderate Severity Longitudinal Wheel-Track Crack

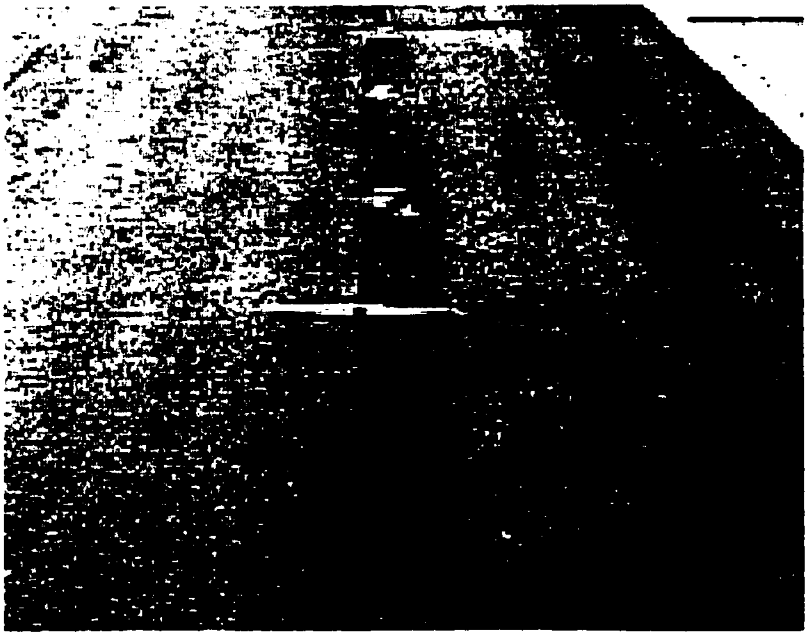


Figure 4.10 Extreme Severity Longitudinal Wheel-Track Crack

4.3.7.2 Non Wheel-Track Longitudinal Cracking

a) Definition: Cracks that follow a path parallel to the pavement centerline and are located out of the wheel-tracks. These can be construction joint cracking, center of paver cracking or white line cracking.

b) Possible Causes: Poor construction practices.

Environmental related causes.

Asphalt concrete attributes.

c) Classification: Construction-Related Crack.

d) Measuring Unit: Lineal meter.

e) Measurement Method: The same as wheel-track cracking.

f) Severity Degrees: The same as wheel-track cracking.

g) Applicable Treatments: The same as wheel-track cracking.

h) Density Degrees: The same as wheel-track cracking.

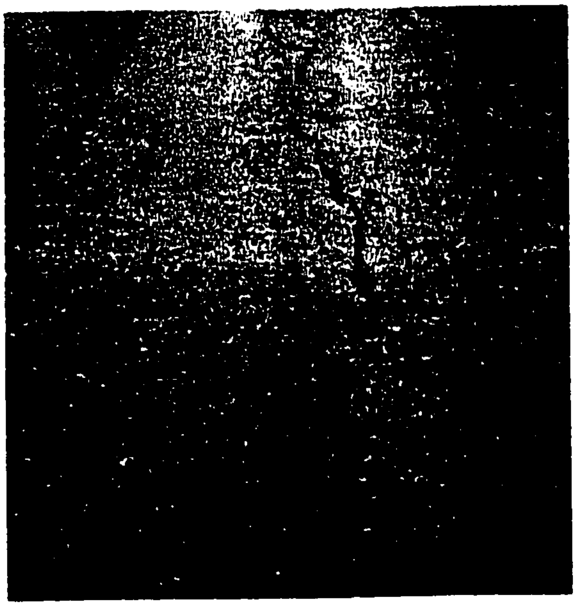


Figure 4.11 Moderate Severity Non Wheel-Track Longitudinal Crack

4.3.7.3 Meander Cracking

a) Definition: Cracks that wander from edge to edge of the pavement without following a specific pattern.

b) Possible Causes: Environmental related causes.

Poor drainage conditions.

Swelling clay related problems.

Poor construction practices.

c) Classification: Environmental-Related Crack.

d) Measuring Unit: Lineal meter.

e) Measurement Method: The same as wheel-track cracking.

f) Severity Degrees: The same as wheel-track cracking.

g) Applicable Treatments: The same as wheel-track cracking.

h) Density Degrees: The same as wheel-track cracking.

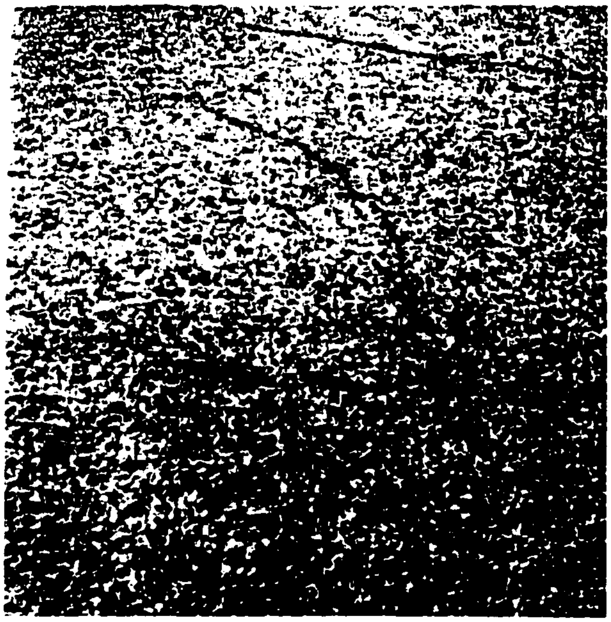


Figure 4.12 An Example of Meander Cracking

4.3.7.4 Block Cracking

a) Definition: Cracks that divide the pavement into rectangular blocks. The area of the blocks might vary between 0.1 and 10 square meters.

b) Possible Causes: Using cement stabilized soil as pavement base.

Asphalt concrete mix aging.

c) Classification: Base Type-Related Crack.

d) Measuring Unit: Lineal meter.

e) Measurement Method: The same as wheel-track cracking.

f) Severity Degrees: The same as wheel-track cracking.

g) Applicable Treatments: The same as wheel-track cracking.

h) Density Degrees: The same as wheel-track cracking.

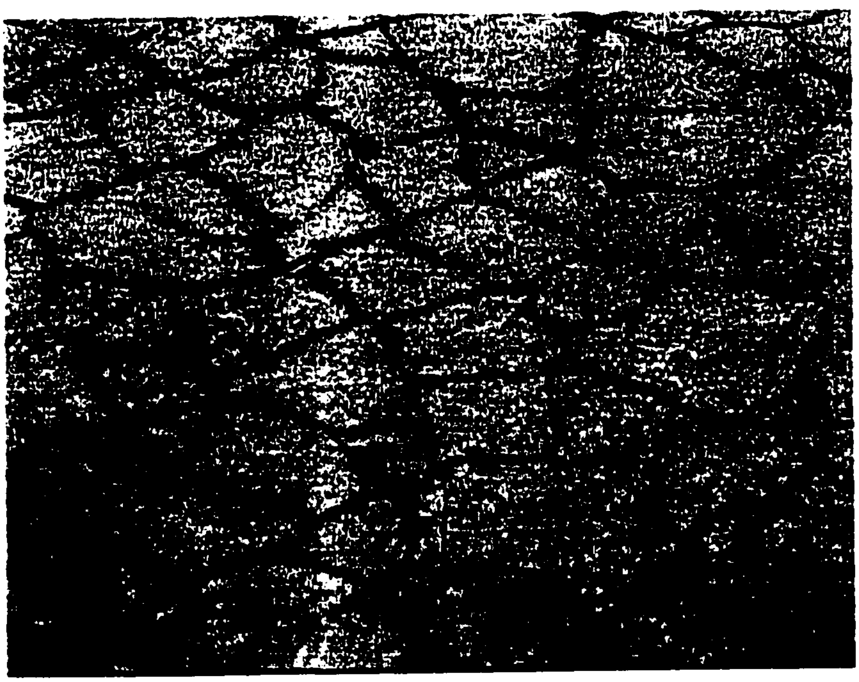


Figure 4.13 An Example of Block Cracking

4.3.7.5 Transverse Cracking

a) Definition: Cracks that are perpendicular to the pavement centerline, cross at least one full lane width, and have depressions less than three millimeters.

b) Possible Causes: Shrinkage of the asphalt pavement due to very low temperatures.

Frost action and other environmental related causes.

Asphalt concrete attributes.

c) Classification: Environmental-Related Crack.

d) Measuring Unit: Lineal meter.

e) Measurement Method: Most of the cracks have different degrees of severity within the full lane width. To rate the crack, the most predominant severity will be assigned to it. Except the combined total of moderate and extreme exceeds half the length of the crack, it will be assigned the predominant severity of these two.

f) Severity Degrees: 1) Slight: single cracks less than or equal to three millimeters in width.

2) Moderate: cracks greater than three millimeters but less than ten millimeters in width.

3) Extreme: cracks greater than or equal to ten millimeters in width.

g) Possible Treatments: 1) Slight severity: No action.

2) Moderate severity: hot pour, cold pour and rout & seal.

3) Extreme severity: hot pour, rout & seal and spray patch.

h) Density Degrees: the total area of the cracks is calculated similarly to longitudinal cracks, then the density extension is assigned as follows; less than 1% = 1

1 - 1.5% = 2

greater than 1.5% = 3

4.3.7.6 Depressed Transverse Cracking

a) Definition: Cracks that are perpendicular to the pavement centerline, cross at least one full lane width, and have depressions greater than three millimeters.

b) Possible Causes: similar to transverse cracks.

c) Classification: Environmental-Related Crack.

d) Measuring Unit: Lineal meter.

e) Measurement Method: Depression is measured using 1.2 meters straight edge and a calibrated wedge. The rater must obtain the most severe depression in the wheel tracks; this will be assigned to the whole crack.

f) Severity Degrees: 1) Slight: depression from three millimeters to six millimeters.

2) Moderate: depression from seven millimeters to thirteen millimeters.

3) Extreme: depression greater than 13 millimeters.

g) Possible Treatments: 1) Slight severity: hot pour, cold pour, rout & seal.

2) Moderate severity: mill & fill, spray patch, and thermo patch.

3) Extreme severity: mill & fill, spray patch, and thermo patch.

h) Density Degrees: Similar to transverse cracks.

Figure 4.14 Extremely Depressed Transverse Crack

4.3.7.7 Alligator Cracking

a) Definition: A series of interconnected cracks that resemble a continuous chicken wire or alligator pattern.

b) Possible Causes: Repeated heavy traffic loads.

Inadequate bearing capacity of the pavement section.

Poor drainage conditions.

Poor construction practices.

c) Classification: Structural-Related Crack.

d) Measuring Unit: Square meter.

e) Measurement Method: Measure the length and width of defected areas in the test section and obtain the total area of alligator cracks per segment.

f) Severity Degrees: All alligator cracks are noted as extreme severity.

g) Applicable Treatments: The alligator cracks are structural related distress, which requires further investigation. The Falling Weight Deflectometer (FWD) test may be used to test the structural adequacy of the road section. Based on the test results, Skin Patch, Deep Patch, or Geogrid reinforcement might be applied.

h) Density Degrees: The total defected area is calculated. The density extension is assigned based on the percentage of defected area as follows; less than 0.2% = 1

0.2 - 0.6% = 2

greater than 0.6% = 3

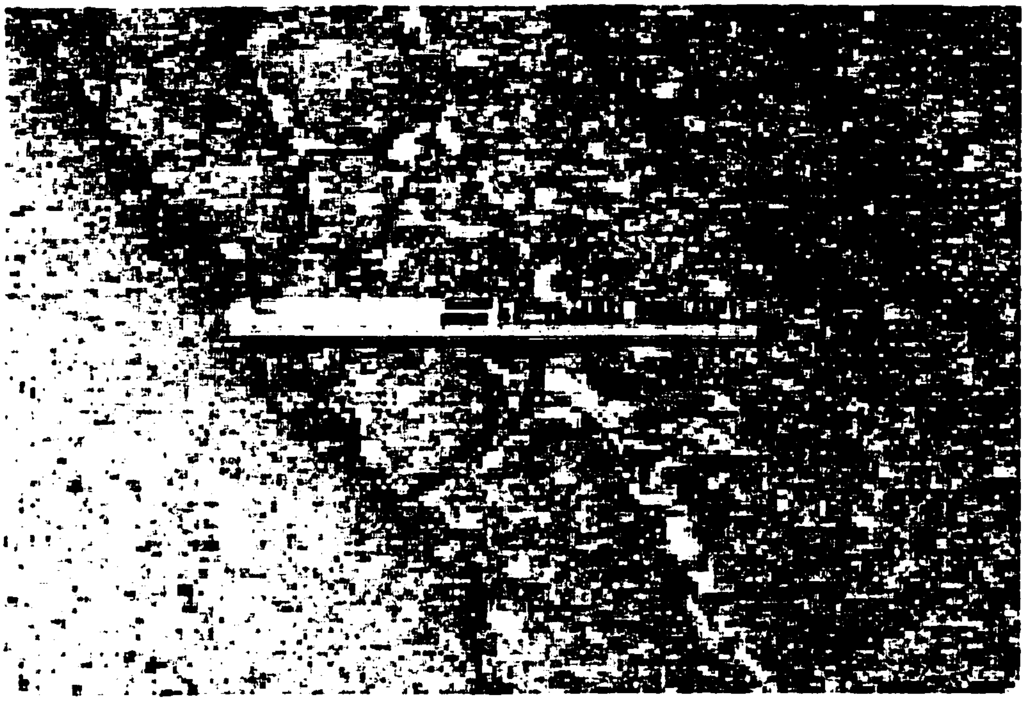


Figure 4.15 Alligator Crack

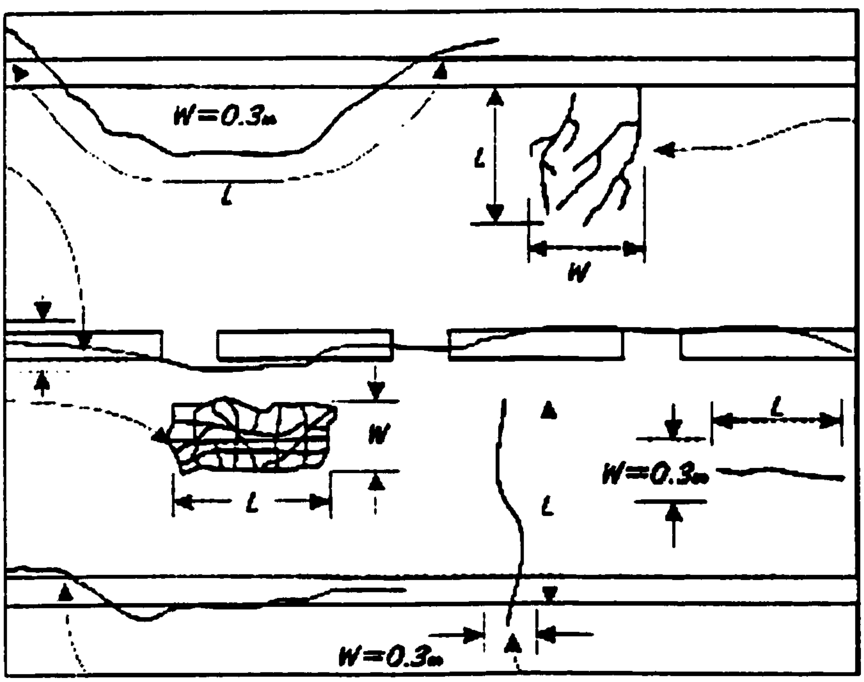


Figure 4.16 Measuring Length and Width of Cracks

4.3.7.8 Bleeding or Flushing

a) Definition: The appearance of excess bituminous binder on the pavement surface. Often first seen in the wheel-paths.

b) Possible Causes: Asphalt concrete attributes.

Poor construction practices.

c) Classification: Asphalt concrete attributes-related distress.

d) Measuring Unit: Square meter.

e) Measurement Method: The width and length of defected areas are measured through a windshield survey over the whole segment.

f) Severity Degrees: Bleeding is described as extremely severe once it exists.

g) Applicable Treatments: Flag a skid resistance test to ensure driving safety.

h) Density Degrees: The total defected area is calculated. The density extension is then assigned based on the percentage of defected area as follows; less than 10% = 1

10 - 25% = 2

greater than 25% = 3

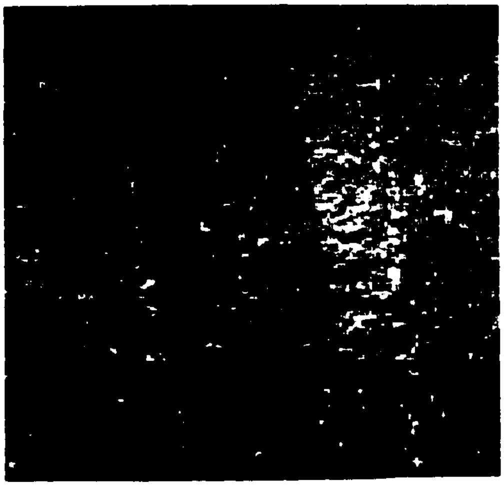


Figure 4.17 Tire Marks Appearing due to Bleeding

4.3.7.9 Ravelling or Loss of Aggregate

a) Definition: The progressive loss of pavement materials from its surface downwards, leaving an open texture surface. Each of the lost particles leaves a pickout on the pavement surface.

B) Possible Causes: Asphalt concrete attributes.

Poor construction practices.

c) Classification: Asphalt Concrete-Related.

d) Measuring Unit: Square meter.

e) Measurement Method: Counting the number of pickouts in one square meter in the test section.

f) Severity Degrees: 1) Slight: five to 25 pickouts per square meter.

2) Moderate: 26 to 50 pickouts per square meter.

3) Extreme: Greater than 50 pickouts per square meter.

g) Applicable Treatments: 1) Slight severity: No action.

2) Moderate and Extreme severity: Fog Coat, Seal Coat, and Chip Seal.

h) Density Degrees: All degrees of severity are assigned extension 3.

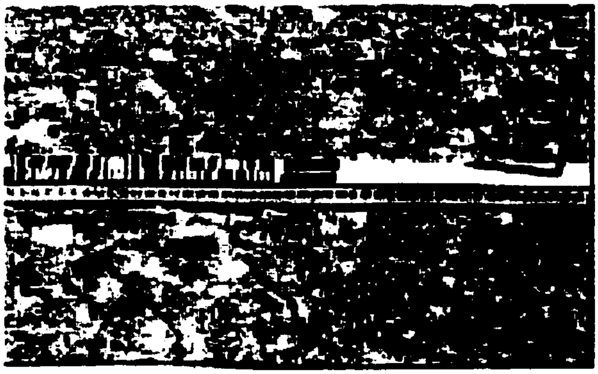


Figure 4.18 Extreme Ravelling

4.3.7.10 Rutting

a) Definition: Longitudinal surface depressions in the wheel-tracks might occur due to structural or asphalt concrete related causes.

b) Possible Causes: For Structural-Related Rutting:

Repeated heavy traffic loads.

Inadequate bearing capacity of the pavement sections.

For Asphalt Concrete-Related Rutting:

Poor construction practices.

Asphalt concrete attributes.

c) Classification: Structural-Related Distress.

d) Measuring Unit: Square meter.

e) Measurement Method: Rutting can be measured manually using the standard rut bar and wedge. Twenty measurements are taken at ten-meter intervals all over the gauging length in both wheel tracks. The average is then calculated to represent the rutting condition in the segment. Rutting can be also measured automatically using special sensors attached to a standard vehicle during measuring roughness.

f) Severity Degrees: 1) Slight: rut depths of three to eight millimeters.

2) Moderate: rut depths of nine to 13 millimeters.

3) Extreme: rut depths greater than 13 millimeters.

g) Applicable Treatments: Rutting requires further investigation to identify whether it is a structural related or asphalt concrete related problem. The Falling Weight Deflectometer (FWD) test can be used to check the structural adequacy of the road section. If the rutting is a structural problem, skin patch, deep patch, or Geogrid reinforcement might be applied to fix the segment. If the rutting is asphalt concrete related problem, Microsurfacing or Profiling can be applied to fix the segment.

h) Density Degrees: The total rutting area is calculated. The density extension is assigned based on the percentage of defected area as follows; less than 12% = 1

12 - 16% = 2

greater than 16% = 3

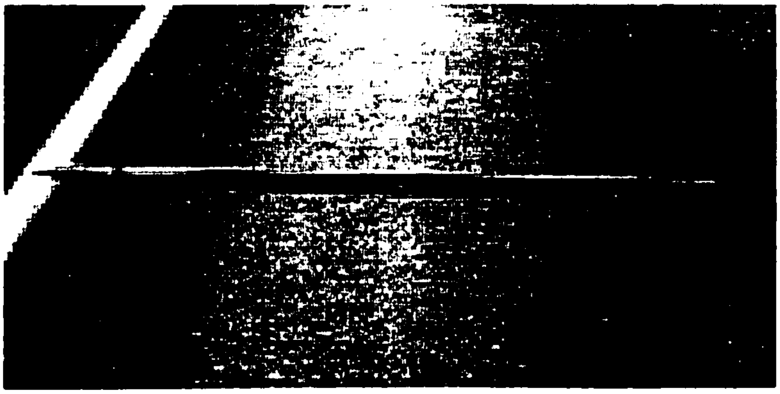


Figure 4.19 An Example of Wheel-Track Rutting

Figure 4.20 Measuring Rutting Depression Using Rut Bar and Wedge

4.3.7.11 Rippling or Shoving

a) Definition: A series of ridges and valleys or singular and multiple waves and humps located on the pavement surface. They are usually located on hills, curves, and intersections and form ripples higher than pavement surface.

b) Possible Causes: Repeated heavy traffic loads.

Inadequate bearing capacity of the pavement sections.

Poor drainage conditions.

c) Classification: Structural-Related Distress.

d) Measuring Unit: Lineal meter.

e) Measurement Method: Measured as a local defect throughout the windshield survey of the segment.

f) Severity Degrees: Always recorded as extreme once it exists.

g) Applicable Treatments: Similar to distortion.

h) Density Degrees: Always recorded under distortion.

Figure 4.21 An Example of Shoving

4.3.7.12 Potholes

a) Definition: Bowl-shaped holes varying in size between 0.1 and 0.5 square meter appear in the pavement surface.

b) Possible Causes: Poor construction practices.

Asphalt concrete attributes.

Poor surface drainage.

Environmental causes.

c) Classification: Asphalt Concrete Related Distress.

d) Measuring Unit: Number.

e) Measurement Method: Counting the number of existing potholes during the windshield survey of the segment.

f) Severity Degrees: Always measured as Extreme.

g) Applicable Treatments: Manual throw and roll and local spray patch.

h) Density Degrees: The total number of potholes per segment is calculated. The density extension is the assigned based on that number as follows; less than two = 1

two - five = 2

greater than five = 3

Figure 4.22 An Example of Pothole

4.3.7.13 Distortion or Local Defects

a) Definition: Any deviation of the pavement surface from its original shape (e. g. heaving, local settlement, etc.) other than these described before.

b) Possible Causes: Swelling clay problems.

Environmental causes.

Poor drainage conditions.

Poor construction practices.

c) Classification: Subgrade-related distress.

d) Measuring Unit: Square meter.

e) Measurement Method: Measure the width and length of defected areas through the windshield survey of the segment and then calculate the total percentage of defected area.

f) Severity Degrees: Always counted as extreme severity.

g) Applicable Treatments: Distortion is a subgrade-related distress, which requires further soil investigation. Based on the test results, skin patch, deep patch, or Geogrid reinforcement might be applied.

h) Density Degrees: The total distortion area is calculated. The density extension is assigned based on the percentage of defected area as follows; less than 0.2% = 1

0.2 - 0.6% = 2

greater than 0.6% = 3

CHAPTER 5: USING ACCESS TO DEVELOP THE DSS PROTOTYPE

5.1 REASONS FOR SELECTIN MS ACCESS

The database management system MS Access was selected to build the prototype DSS for these reasons:

- It is able to deal with the entire data repository required for the DSS and to obtain the necessary information directly from the saved tables.
- It is able to integrate Visual Basic (VB) code to perform the required calculations.
- It provides User-friendly interface to facilitate data entry.
- It allows the user to obtain the system output in the form of a screen display or printed reports containing the required information.
- It is available for all AT&U maintenance inspectors.

5.2 STRUCTURE OF THE SYSTEM

The main components of the system are the tables used for data storage, the queries used for manipulating the data, and a module for suggesting recommended treatments and calculating their priorities. The system also contains forms and reports to interact with the end-user and organize the input-output process. The tables contained in the system and the relationships between them are shown in Figure 5.1.

The first four tables were explained in chapter three; the "Cost" table is used to store the unit prices and expected service lives of the treatments. The "Treatment" table is used to save the results of the calculation module. For each of the distresses in the segment, three suggested treatments with their associated priorities will be saved in this table. The table is updated each time the user introduces any change in the treatments unit prices or expected service lives. Storing all the output of the system in one table enables user to extract several useful reports from this data.

The relationship "one to many" between two tables reflects the fact that, for each record in one table there is more than one corresponding record in the related table. Because the highway network is divided into variable length segments in the "SCR data" and "Inventory data" tables while the network is divided into one hundred-meter unit in the "DSS" table, the "one to many" relationship is used to connect them. However, the relationship "one to one" is used to connect the "IRI data" table to the "DSS" table. That means, for each record in one of the connected tables there is only one corresponding record in the other table. The "one to one" relationship is used also to connect "DSS" table to "Treatment" table as shown in Figure 5.1.

The information stored in the "Cost" table is used by the code to calculate treatment priorities and the table is not connected to other tables.

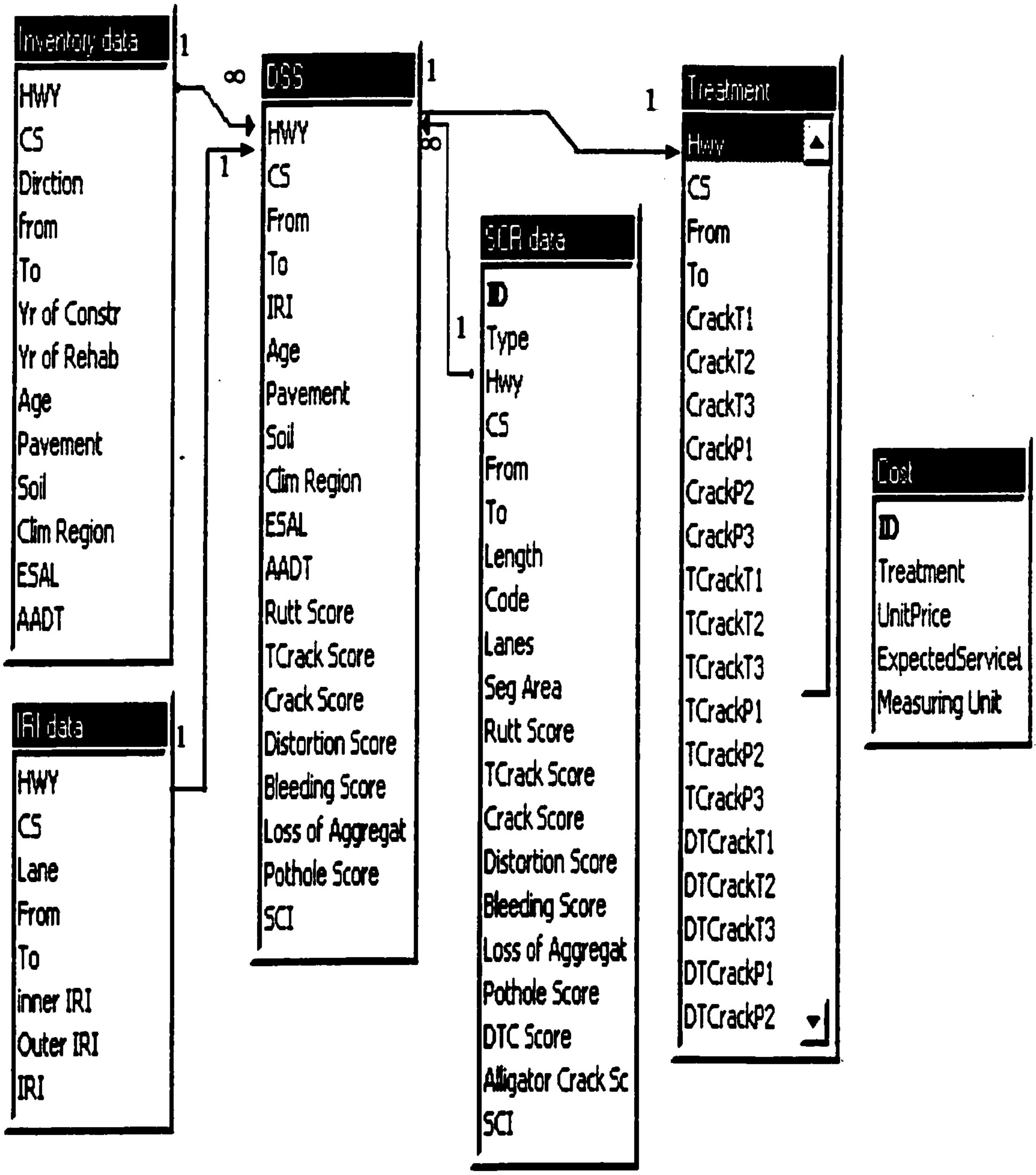


Figure 5.1 Tables and Relationships between them

5.3 CONCEPTUAL DESIGN OF THE PROTOTYPE DSS

The prototype is designed to be used by maintenance inspectors in each district separately. The reason for this is that the treatments' unit prices and expected service lives vary between districts across the province of Alberta. The database repository of the system contains the pre-prepared SCR data, Roughness data, and Inventory data in the form of Access tables. Figure 5.2 illustrates the flowchart of the DSS. The system starts by asking the user to submit the unit prices and expected service lives for the twelve assessed treatments in his/her district. After obtaining the required information, the system automatically suggests possible treatments and calculates treatment priorities for each of the segments in the SCR table. The priorities are calculated based on the segment surface condition as well as the unit prices and the expected service lives for treatments that have been previously submitted by the user. The suggested treatments and calculated priorities are saved in the table "Treatments". The VB code and SQL statement used to obtain this will be explained in the next section of this chapter.

The system then allows the user to select a specific segment from the stored segments in the database. For the selected segment, the user can view its surface condition represented through the existing distresses and their scores and the overall Surface Condition Index. The average IRI that represents the segment roughness is also calculated from the "Roughness" table and presented to the user. The user can then view segment attributes or the suggested treatments for the selected segment. The last step of the system involves allowing the user to print several reports such as suggested treatments. The user can then either select another segment or exit the system.

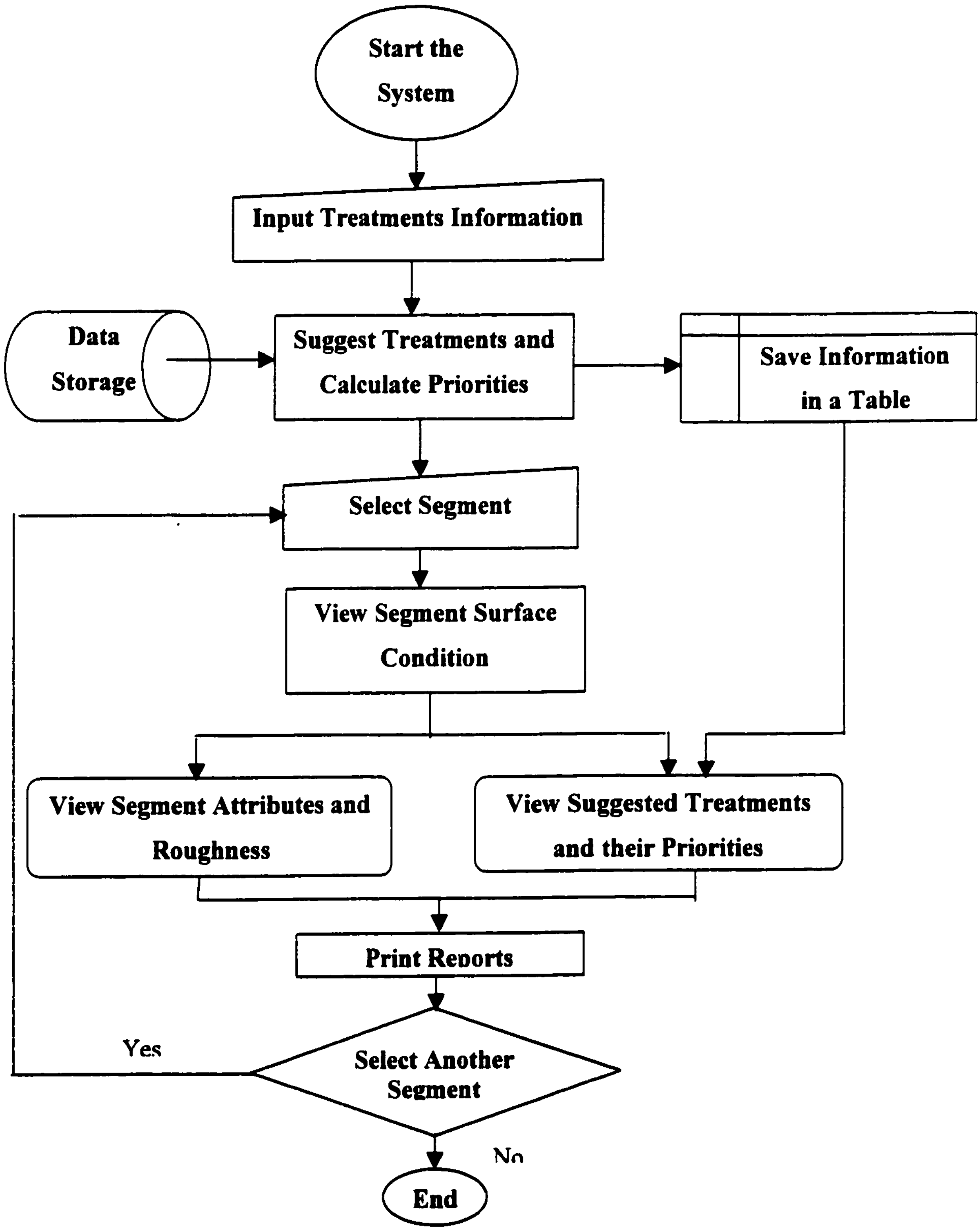


Figure 5.2 Flow Chart of the Prototype DSS

5.3.1 AHP Calculation Module

The code developed to calculate the maximum eigenvalues for all the comparison matrices was saved as MS Access module. The module starts by declaring the variables required for the calculations as arrays. Several arrays were declared for this purpose as shown in table 5.1. The array values change for each of the previously mentioned six cases.

Table 5.1 Declarations of Variables

Variable Name	Assignment
Exp(3, 3)	Values of Previous Experience Comparison Matrix
Dis(3, 3)	Values of Disruption during Application Comparison Matrix
Cost(3, 3)	Values of Cost per Year Comparison Matrix
NormExp(3, 3)	Values of Normalized Previous Experience Matrix
NormDis(3, 3)	Values of Normalized Disruption during Application Matrix
NormCost(3, 3)	Values of Normalized Cost per Year Matrix
TotExp(3)	Summation of Columns for Previous Experience
TotDis(3)	Summation of Columns for Disruption during Application
TotCost(3)	Summation of Columns for Cost per Year
VecExp(3)	Previous Experience Maximum Eigenvector
VecDis(3)	Disruption during Application Maximum Eigenvector
VecCost(3)	Cost per Year Maximum Eigenvector
Priority(3)	Final Priority of Treatment
Yearlycost(3)	Cost per Year of Treatment.
Criteria(3)	Final Eigenvector of the Decision Making Criteria

For each comparison matrix, the summations of columns, the normalized matrix, and the eigenvectors were calculated using VB code. All the VB code used for developing the prototype DSS is attached in appendix (10).

The treatments' unit prices and expected service lives are saved in the "Cost" table and the Access function DLookup was used to reveal them from the table. The function makes it possible to obtain the value of a certain record in a field by assigning the field name, the table name, and the condition to be used. The comparison matrix for cost per year was identified and the eigenvector was calculated in the same way as the other two matrices. The final priority of the treatments was calculated and saved in the variable priority (3). The calculated priorities were saved in the "Treatments" table to be used in queries and reports.

5.3.2 Managing the Data throughout the System

Several queries and VB code were used to manipulate data throughout the system. Two "Make Table" queries were used to facilitate the process of plotting segment attributes. The queries create the "DSS" table, which contains a record for each of the segment attributes based on one hundred meter intervals to match the roughness data. All the SQL statements used for developing the prototype DSS are attached in Appendix (11). Another "Make Table" query was used to calculate the segment age by creating a new field in the table inventory data.

The table "treatment" contains three fields for the suggested treatments and another three for their priorities for each distress. To store the suggested treatments and their priorities in the table, VB code was used. The code is written as an "On Click" event for a command button in the form "Cost" and it starts after the user defines the required information. The first step is clearing the table of any previous records using the command "CurrentDb.Excute ("Delete * from Treatment")".

Two record sets were declared, one as source record set (SourceRS) and one as target record set (TargetRS). Several intermediate variables were used to transfer data from the SCR table and store the suggested treatments and their priorities for each segment. The subroutine copies the segments' data from the "SCR data" table to the "Treatment" table. This data include highway number, control section, and the start and end kilometer of the segments. The code copies the required data from the source table to an intermediate variable and then from the variable to the target table.

Sixteen modules were written to assign the appropriate treatments for each distress according to its severity. These modules also store "No action" in the treatment fields if the distress does not exist on the segment. The "Do Loop" function was used to add the treatments and their priorities until the end of the source table using the command "Do until SourceRS.EOF". This process is repeated automatically each time the user changes any of the unit prices or expected service lives. This allows the user to check the change effect on the priorities of the treatments.

5.4 INPUT MODULE (USER-INTERFACE)

The user interface was designed with MS Access forms including command buttons to navigate through the DSS. The system starts by a welcoming screen that informs the user about the system and its requirements. The user can then select either to identify unit prices and expected service lives for the pre-specified treatments in his/her district or accept the default ones. Figure 5.3 illustrates these two screens. The user can then select a specific segment and review its surface condition. This required first identifying highway number and control section of the segment. A screen appears with all the segments included in that control section; the user can select only one of these segments. Figure 5.4 illustrates the screens used for selecting segment.

After specifying a segment, the user can opt to view the segment surface condition or plot the segment attributes. The segment surface condition screen contains the scores for nine distresses, the SCI of the segment, and the average roughness of it. The attributes contained are roughness (represented through IRI), segment age, base type, soil type, climatic region, and ESAL. Each of these can be plotted on a separate tab on the segment attributes form. Figure 5.5 illustrates these two screens. After viewing the segment surface condition, the suggested treatments and their priorities can be accessed. The screen is divided into three tabs: environment related distresses, structure related distresses, and asphalt concrete related distresses. Finally, the user can access the output screen. The output screen enables the user to print several useful reports regarding segment attributes, surface condition, and suggested treatments as shown in Figure 5.6.

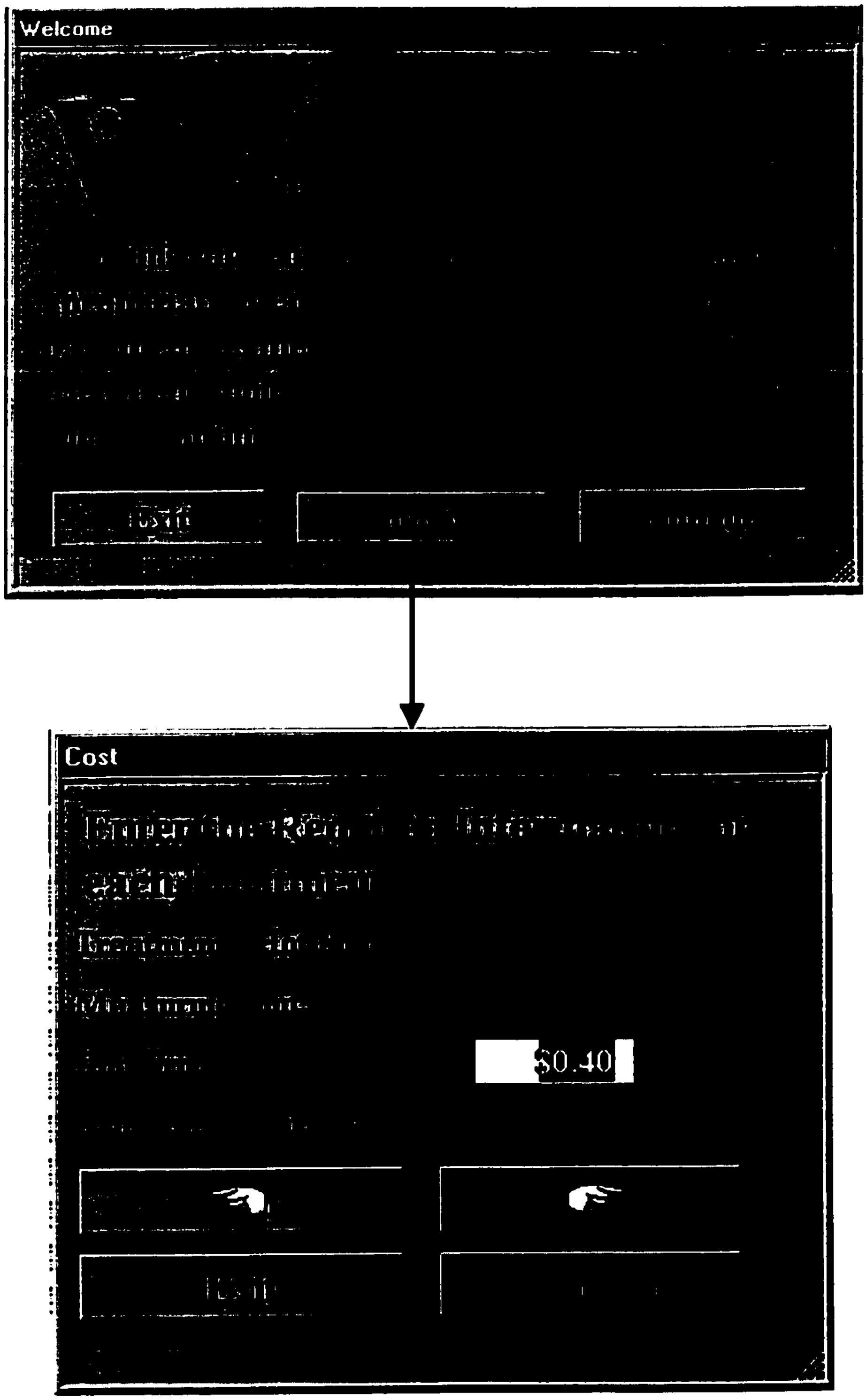


Figure 5.3 The First Two Screens of the System

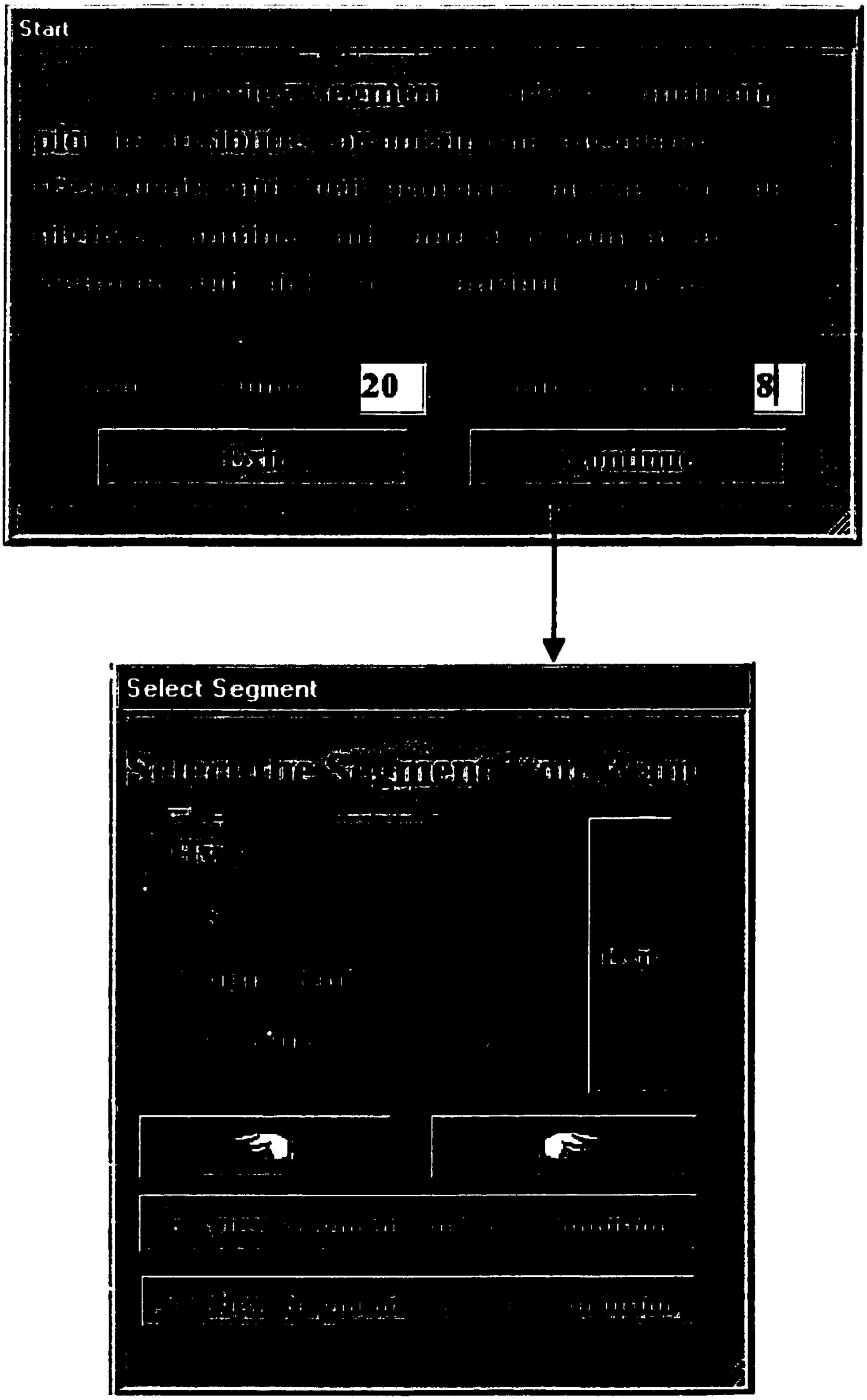


Figure 5.4 Screens for Selecting a Specific Segment

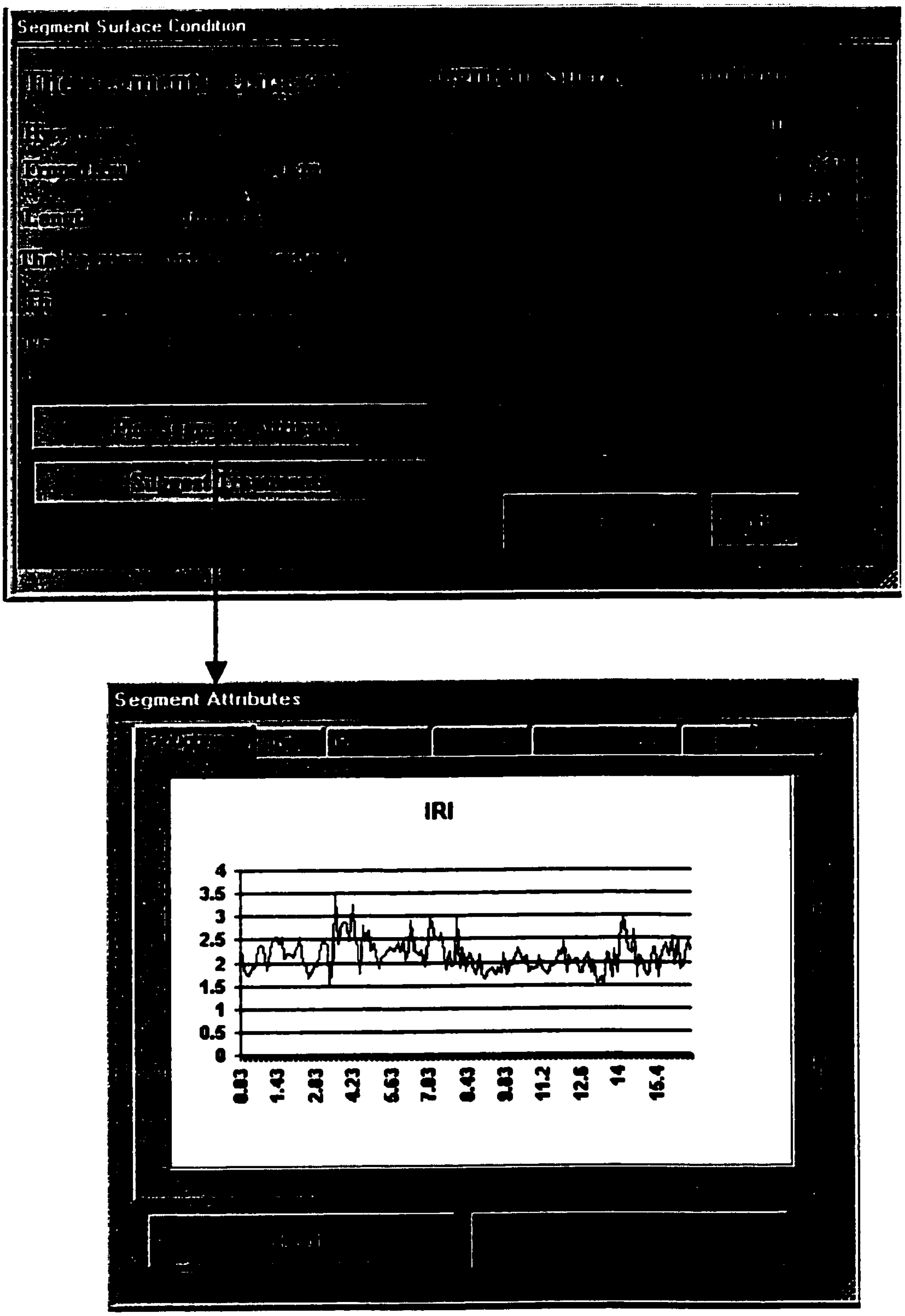


Figure 5.5 Segment Surface Condition and Attributes

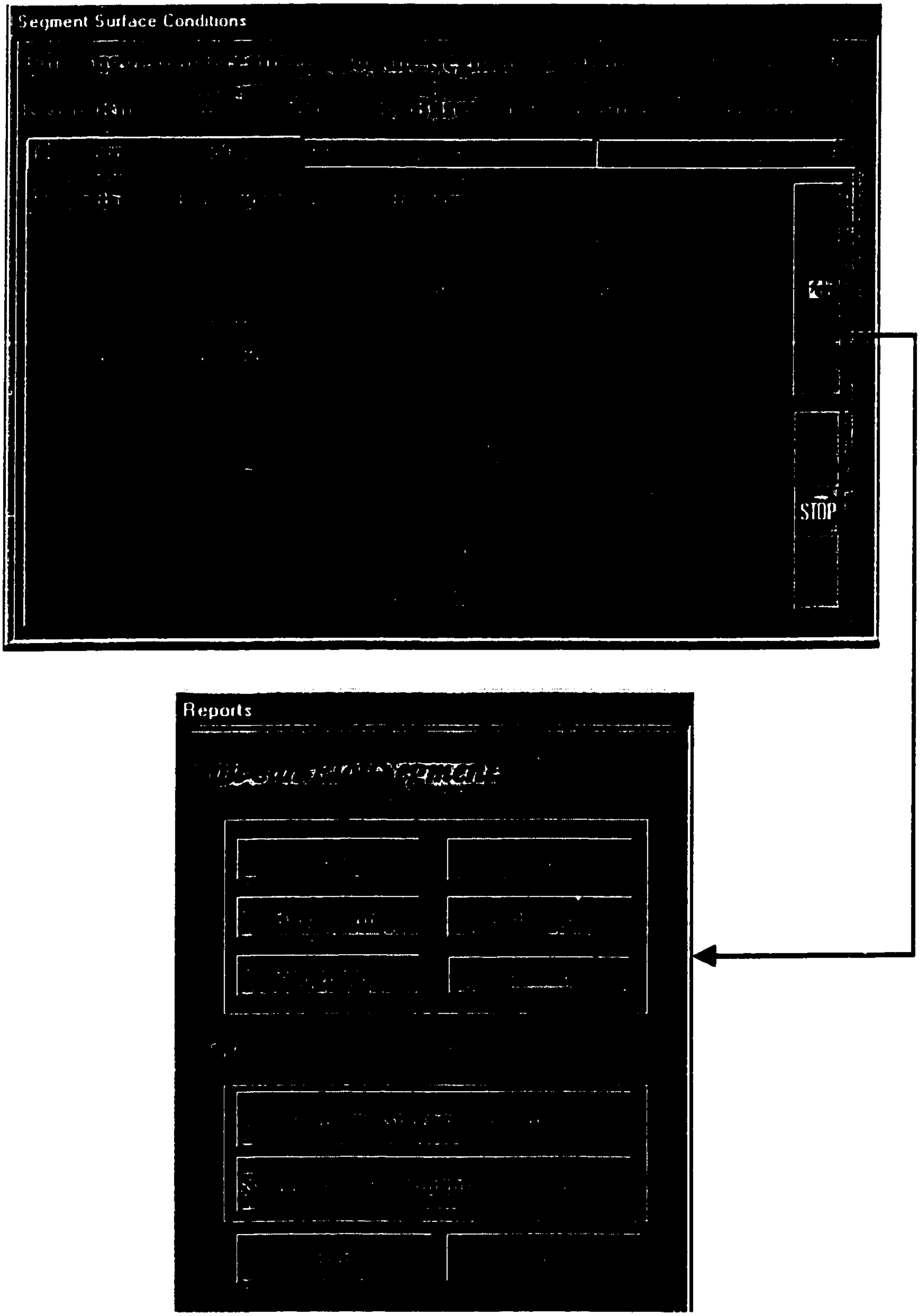


Figure 5.6 Suggested Treatments and Output Screens

For the segments in poor condition, a warning message appears to the user saying that the segment is a rehabilitation candidate as shown in Figure 5.7. The "General Treatment" command button will be activated in the "segment surface condition" form. Clicking that button activates the "General Treatment" form illustrating the suggested general treatments and their priorities as shown in Figure 5.8.

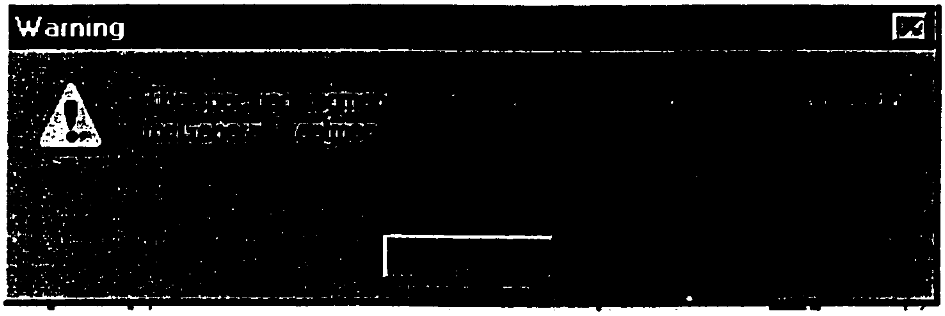


Figure 5.7 The Warning Message

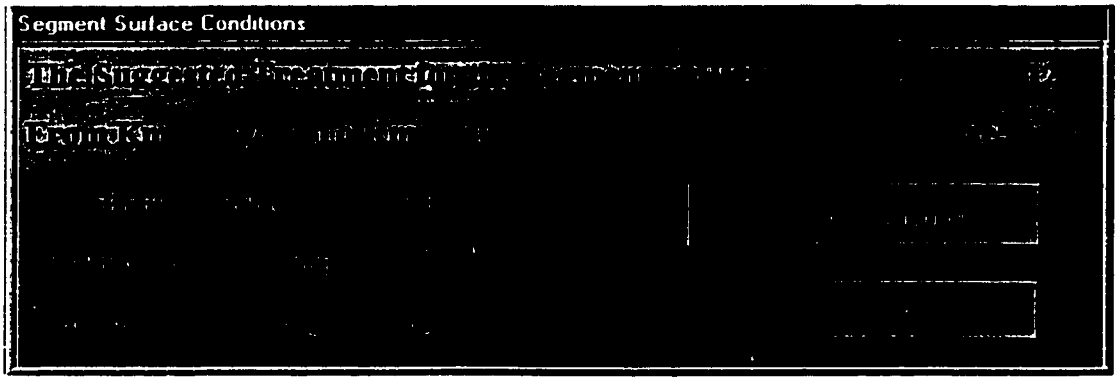


Figure 5.8 The General Treatments Form

5.5 OUTPUT MODULE

The output of the DSS can either be viewed on screen or printed out. By clicking any of the command buttons in the output screen, the user can get a pre-designed report regarding the specified segment. The first six reports illustrate the segment attributes graphically. The x-axis of the graph represents distance in kilometers from the segment's beginning to its end. The y-axis can be any of the six available attributes. The attached report shows an example of plotting one segment roughness. For comparison purposes, the report also illustrates the average roughness for the segment. An example of the roughness report is illustrated in Figure 5.9. Examples of each of the other five reports are attached in appendix (12).

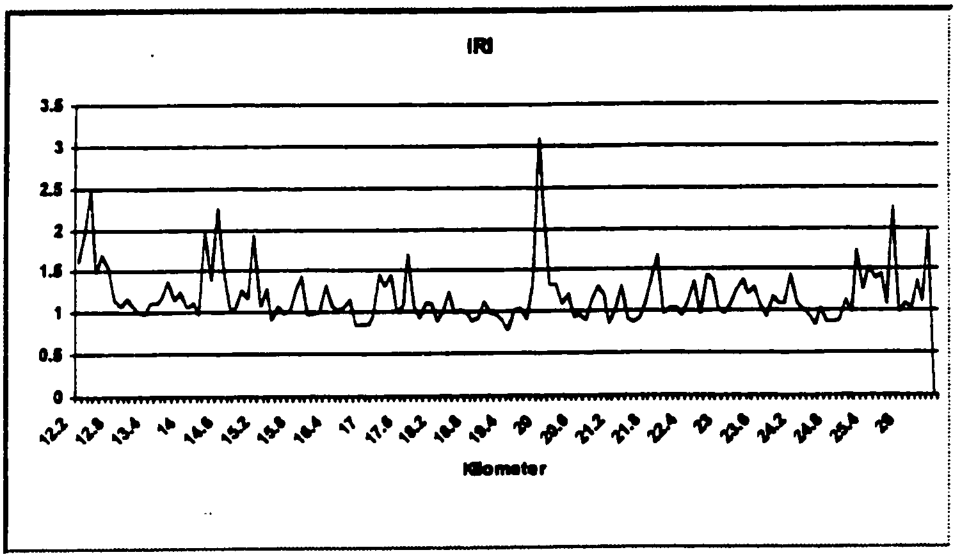
The segment surface condition report illustrates the scores for nine different types of distresses, the segment Surface Condition Index (SCI), and the condition of the segment based on the SCI as shown in Figure 5.10. The SCI is calculated based on the scores and weights outlined in chapter four. The suggested treatments report illustrated in Figure 5.11 presents three suggested treatments and their priorities for the first four types of distresses. It also suggests recommendations for fixing the last five types of distresses. The treatments with highest priority are the most highly recommended for fixing the problems. All the reports start by showing segment data that includes highway number, control section, start kilometer, end kilometer, and segment's length. Another report was also designed to show segments in poor conditions in the district as shown in Figure 5.12. The report can be accessed through the select segment screen as shown in Figure 5.4.

Segment Roughness Report

Segment Data:

Highway	20	*Control Section*	8		
From (Km)	12.13	*To (Km)*	26.58	*Segment Length =*	14.45 *Km*

Segment Roughness Plot:



Average Segment Roughness 1.1922

Figure 5.9 Segment Roughness Report

Segment Surface Condition Report

Segment Data:

Highway 22   *Control Section* 12

From (Km) 22.68   *To (Km)* 36.1   *Segment Length =* 13.42 *Km*

Segment Surface Condition:

Environmental Related Distresses:

Crack Score 9   *Depressed Transverse Crack Scor* 10

Transverse Crack Score 9

Asphalt-Concrete Related Distresses

Loss of Aggregate Score 10

Pothole Score 10   *Bleeding Score* 8

Structural Related Distresses

Alligator Crack Score 10   *Distortion Score* 8

Rutting Score 10

Segment Surface Condition Index = 398

The Segment is in Poor Condition

Legend

0 = None	2 = S1	5 = M1	8 = X1
	3 = S2	6= M2	9 = X2
	4 = S3	7 = M3	10 = X3

Figure 5.10 Segment Surface Condition Report

Suggested Treatments For the Segment

For the Segment on:

Highway	22	*From (Km)*	22.68	*With Length =*	13.42	*(Km)*
Control Section	12	*To (Km)*	36.1			

1. Treatments for Cracks:

Treatment (1)	Hot Pour	*With Priority*	0.348
Treatment (2)	Lineal Spray Patch	*With Priority*	0.362
Treatment (3)	Cold Pour	*With Priority*	0.29

2. Treatments for Transverse Cracks:

Treatment (1)	Hot Pour	*With Priority*	0.439
Treatment (2)	Lineal Spray Patch	*With Priority*	0.427
Treatment (3)	Mill and Fill	*With Priority*	0.134

3. Treatments for Depressed Transverse Cracks:

Treatment (1)	Mill and Fill	*With Priority*	0.417
Treatment (2)	Lineal Spray Patch	*With Priority*	0.244
Treatment (3)	Thermo Patch	*With Priority*	0.45

4. Treatments for Loss of Aggergate:

Treatment (3)	Fog Coat	*With Priority*	0.242
Treatment (3)	Seal Coat	*With Priority*	0.366
Treatment (3)	Chip Seal	*With Priority*	0.392

BleedingTreatment	You Need to Apply (Skid Resistance Test) to the Segment
PotholesTreatment	You can Apply (Manual Throw and Roll)or Spray Patch to Fill the Potholes
AlligatorTreatment	You Need to Apply Structural Adequacy Test (FWD) to the Segment
DistortionTreatment	You Need to Apply Soil Investigation Test to the Segment
RuttingTreatment	You Need to Apply Structural Adequacy Test (FWD) to the Segment

Figure 5.11 Suggested Treatments for the Segment Report

Segments in poor condition

Hwy	CS	From	To	Length	Rutting	T. Crack	Crack	Distortion	Bleeding	Ravelling	Potholes	D.T. Crack	Alligator	SCI
9	6	20.23	22.1	1.87	5	6	7	8	9	7	8	9	0	250
21	14	7.73	11.86	4.13	3	6	6	8	8	0	9	2	9	253
21	16	5.84	7.46	1.62	3	5	7	9	0	10	8	0	10	276
22	12	22.68	36.1	13.42	10	9	9	8	8	10	10	10	10	398
22	14	33.4	40.28	6.88	4	5	2	10	8	0	8	0	8	246
22	30	9.57	10.29	0.72	4	6	3	10	8	0	8	6	0	256

Figure 5.12 Segments in Poor Condition in the District

5.6 LIMITATIONS OF THE PROTOTYPE DSS

The system is developed using MS Access, thus Access must also be available on the end user' s terminal. However, the model can be transferred to the Intranet available on the AT&U for all maintenance inspectors. Furthermore, the system is designed to be used by individual maintenance inspectors with only one set of treatments' unit prices and expected service lives. This can be enhanced to allow entering more than one district. The prototype enables the user to preview only one specified segment at the time; a pick list offering more than one segment can be introduced. Only the data of the year 1998 was used to develop the prototype, however, more than one year of data can be used for comparison purposes.

5.7 VALIDATION OF THE SYSTEM

The system was tested using the "what-if analysis". It is structured as what will happen to the solution if an input value is changed (Turban, 1998). A MS Excel spreadsheet was prepared to calculate instantly the eigenvectors and final priority vectors for the six sub-models of the problem. The experts were asked to submit their expectations if one of the parameter values is changed. Their expectations were compared to the output of the DSS and the priorities after the change were found to be acceptable and comply with the experts' expectations. The experiment was repeated 15 times to ensure that the obtained priorities are always satisfying. Finally, the pavement experts strongly recommended implementing the DSS as the maintenance module in the new Pavement Management System (PMS) currently under development at AT&U.

CHAPTER 6: CONCLUSION

6.1 SUMMARY

The North American highway network is a multi-billion dollar investment and is essential for the economic growth of the continent. Paved roads represent the main component of this network; as such, they must be maintained in acceptable serviceability. The cost of maintaining this network is increasing rapidly every year; it consumes the major part of the funds assigned to transportation agencies. Allocating the optimum maintenance strategy for defected pavement segments is a daily problem facing transportation agencies. This problem is a good candidate for computer-aided Decision Support Systems (DSS). The main objective of this research was to develop a prototype DSS to aid in allocating the optimum maintenance alternative for defected flexible pavements. The Prototype DSS consists of five main components: the knowledge management subsystem, data management subsystem, the prioritizing module, user interface, and the output module.

Maintenance alternatives are usually allocated based on a visual inspection of the road surface condition using the Surface Condition Rating (SCR) process. A survey was conducted throughout North America transportation agencies to identify their SCR practices. Based on the survey results, a questionnaire was designed and a series of workshops was arranged with a committee of pavement experts from Alberta Transportation and Utilities (AT&U). These workshops resulted in obtaining the required human knowledge for the prototype DSS. This knowledge included obtaining one set of definitions for twelve types of pavement surface distresses, and identifying their causes, measurement methods, and thresholds for different degrees of severity and density. These findings resulted in the development of one composite Surface Condition Index (SCI) and determination of the technical constraints regarding applicability of treatment alternatives to fix pavement surface distresses.

The data required for the data management subsystem was obtained from the AT&U data repository and was modified to fit the prototype DSS requirements. It includes the SCR records for the year 1998, the inventory data containing all the pavement attributes of the Alberta highway network (soil type, base type, traffic load, and climatic region), and the roughness data represented in the International Roughness Index (IRI).

The Analytical Hierarchy Process (AHP) proved to be of great benefit in solving decision-making problems, which require integrating human knowledge and mathematical calculations. The AHP was used as the main module for the prototype DSS to prioritize the feasible alternatives based on pre-specified criteria. A hierarchy model requires identifying the goal, determining the decision-making criteria, and outlining the feasible alternatives. The human knowledge is captured using pair-wise comparison matrices. The AHP transfers the pair-wise comparison matrices created by experts to eigenvectors representing the priority. Due to the technical constraints of the problem, it could not be solved using only one hierarchy model. The decision-making process was divided into six sub-models, each with the same feasible alternatives. Each one was solved to obtain the maximum eigenvalues representing the required priorities.

The DSS contains a user-friendly interface to organize the input-output process. The user can enter the treatment's unit prices and expected service lives in his/her district or accepts the default ones. After that, the user can select a specified segment to plot its characteristics, view its surface distress scores, or obtain suggestions of treatment alternatives with their priorities for the distresses existing in this segment. The output module enables the user to print out all these useful reports for any specified segment in the district.

The prototype DSS introduces consistency to the decision-making process and transfers the knowledge of some of the best pavement experts in AT&U to new and less experienced staff. The DSS also introduces maximum usage of SCR data and offers an example for integrating this data with inventory and roughness data for better pavement management. The DSS was tested and validated by AT&U pavement experts who recommended implementing it as a component in the new Pavement Management System (PMS) currently under development.

All the expected contributions mentioned in section 1.7 are fully achieved. These contributions include the development of a composite Surface Condition Index (SCI), integrating the SCR and roughness data with pavement attributes, and offering an easy access with graphical representation to these databases.

6.2 FUTURE ENHANCEMENTS

The Alberta highway network is divided into 10 districts and each has different costs for maintenance alternatives and different expected service lives for them. The prototype DSS developed in this research contains only the data of one district and accepts one set of unit prices and expected service lives to suggest treatment alternatives with their priorities for each segment. However, the system can be enhanced to include all the data of the Alberta highway network, i. e. allowing for the data of the 10 districts. The obtained priorities can then be used to quantify and predict a prioritized maintenance needs list for the entire network. That future prediction can be used to allocate funds to districts based on their actual needs thus optimizing budget allocation. Operation Research (OR) techniques such as linear programming can be used to maximize the benefits obtained from the available funds.

The results of this research could be implemented through the AT&U Intranet as a part of the new Infrastructure Management System (IMS). This would allow the users easy access to the SCR data and the suggestions of treatment alternatives with their priorities. The users could also easily obtain a graphical representation of pavement segments' attributes for better management of the highway network and then get a report regarding all the segments in one district or the whole network. More than one year of collected data can be stored in the enhanced DSS to check the efficiency of maintenance strategies and their effect on pavements' deterioration with time.

The prototype can be enhanced to enable use of the SCR data accompanied with roughness data and deterioration models to plan for major rehabilitation. The current application depends only on the roughness data, which may not be sufficient for accurate prediction of the network needs. The more data involved, the more optimally the available limited budgets can be allocated. This helps in achieving the main goal of transportation agencies, which is to maintain the highway network in the maximum possible serviceability with the minimum possible costs.

The same approach can be also applied to allocate maintenance alternatives to any other infrastructure component such as bridges or railway tracks.

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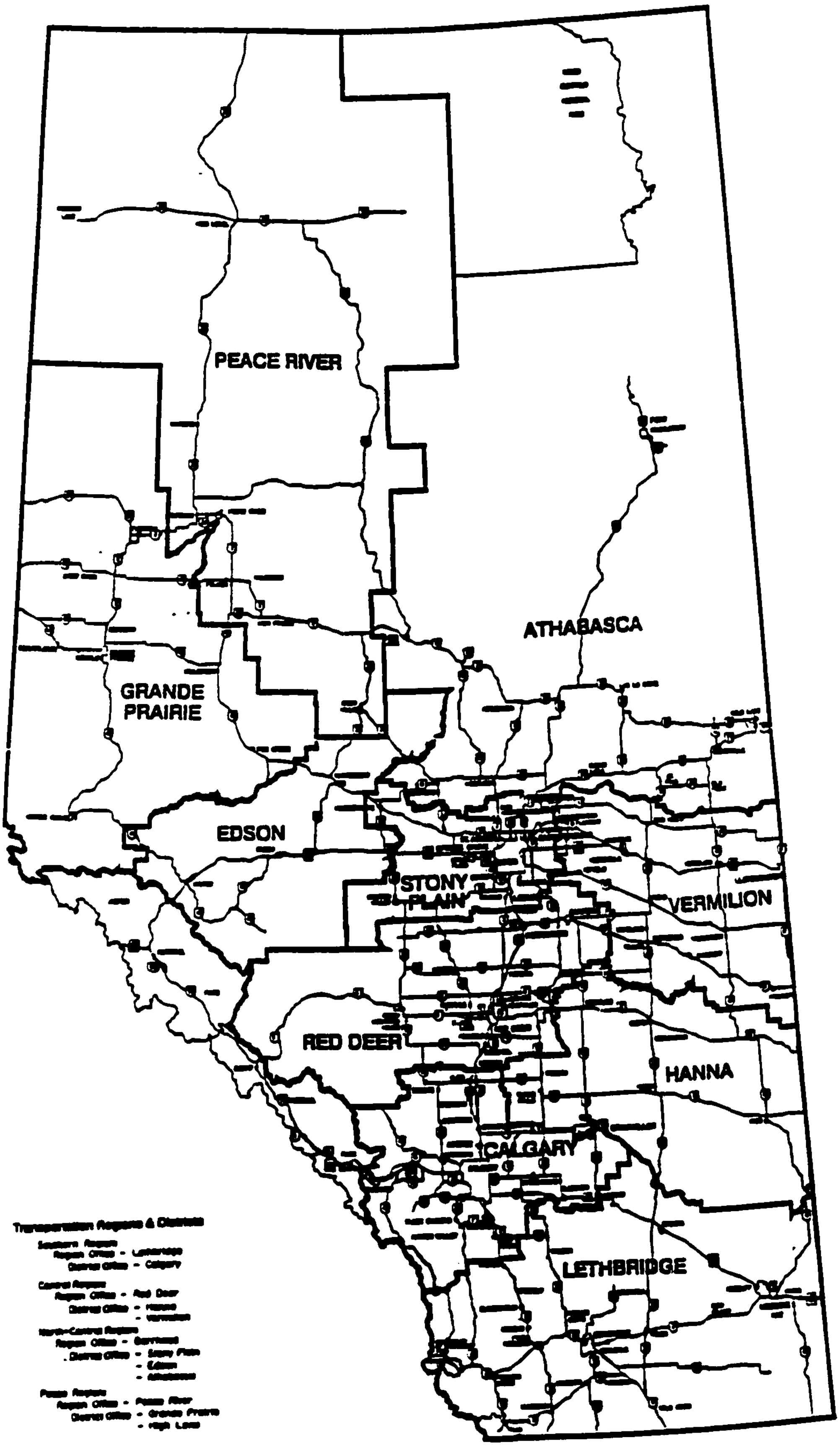
Appendix (1)

Map of Primary Highway Network in Alberta


PEACE RIVER
ATHABASCA
GRANDE PRAIRIE
EDSON
STONY PLAIN
VERMILION
RED DEER
HANNA
CALGARY
LETHBRIDGE

Appendix (2)

The Comparison Matrices Submitted to the Pavement Experts

Case 1:

Compare each pair of these maintenance treatment alternative in the light of the mentioned criterion.

Previous Experience	Hot pour	Cold Pour	Rout & Seal
Hot pour	1		
Cold Pour		1	
Rout & Seal			1

Disruption during Application	Hot pour	Cold Pour	Rout & Seal
Hot pour	1		
Cold Pour		1	
Rout & Seal			1

1 = Equal preference of both alternatives.
3 = Weak preference of one alternative over another
5 = Strong preference of one alternative over another
7 = Demonstrated preference of one factor over another
9 = Absolute preference of one factor over another

You can use the reciprocals of the numbers mentioned above (i. e. 1/3, 1/5, 1/7, 1/9) to represent the preference of the item in the top row over the item in the left column.

Case 2:

Compare each pair of these maintenance treatment alternative in the light of the mentioned criterion.

Previous Experience	Hot Por	Spray Patch	Cold Pour
Hot Por	1		
Spray Patch		1	
Cold Pour			1

Disruption during Application	Hot Por	Spray Patch	Cold Pour
Hot Por	1		
Spray Patch		1	
Cold Pour			1

1 = Equal preference of both alternatives.
3 = Weak preference of one alternative over another
5 = Strong preference of one alternative over another
7 = Demonstrated preference of one factor over another
9 = Absolute preference of one factor over another

You can use the reciprocals of the numbers mentioned above (i. e. 1/3, 1/5, 1/7, 1/9) to represent the preference of the item in the top row over the item in the left column.

Case 3:

Compare each pair of these maintenance treatment alternative in the light of the mentioned criterion.

Previous Experience	Hot Por	Spray Patch	Mill & Fill
Hot Por	1		
Spray Patch		1	
Mill & Fill			1

Disruption during Application	Hot Por	Spray Patch	Mill & Fill
Hot Por	1		
Spray Patch		1	
Mill & Fill			1

1 = Equal preference of both alternatives.
3 = Weak preference of one alternative over another
5 = Strong preference of one alternative over another
7 = Demonstrated preference of one factor over another
9 = Absolute preference of one factor over another

You can use the reciprocals of the numbers mentioned above (i. e. 1/3, 1/5, 1/7, 1/9) to represent the preference of the item in the top row over the item in the left column.

Case 4:

Compare each pair of these maintenance treatment alternative in the light of the mentioned criterion.

Previous Experience	Mill & Fill	Spray Patch	Thermo Patch
Mill & Fill	1		
Spray Patch		1	
Thermo Patch			1

Disruption during Application	Mill & Fill	Spray Patch	Thermo Patch
Mill & Fill	1		
Spray Patch		1	
Thermo Patch			1

1 = Equal preference of both alternatives.
3 = Weak preference of one alternative over another
5 = Strong preference of one alternative over another
7 = Demonstrated preference of one factor over another
9 = Absolute preference of one factor over another

You can use the reciprocals of the numbers mentioned above (i. e. 1/3, 1/5, 1/7, 1/9) to represent the preference of the item in the top row over the item in the left column.

Case 5:

Compare each pair of these maintenance treatment alternative in the light of the mentioned criterion.

Previous Experience	Fog Coat	Seal Coat	Chip Seal
Fog Coat	1		
Seal Coat		1	
Chip Seal			1

Disruption during Application	Fog Coat	Seal Coat	Chip Seal
Fog Coat	1		
Seal Coat		1	
Chip Seal			1

1 = Equal preference of both alternatives.
3 = Weak preference of one alternative over another
5 = Strong preference of one alternative over another
7 = Demonstrated preference of one factor over another
9 = Absolute preference of one factor over another

You can use the reciprocals of the numbers mentioned above (i. e. 1/3, 1/5, 1/7, 1/9) to represent the preference of the item in the top row over the item in the left column.

Case 6:

Compare each pair of these maintenance treatment alternative in the light of the mentioned criterion.

Previous Experience	Cold Mill & Inlay	Cold In-place Recycling	Hot In-place Recycling
Cold Mill & Inlay	1		
Cold In-place Recycling		1	
Hot In-place Recycling			1

Disruption during Application	Cold Mill & Inlay	Cold In-place Recycling	Hot In-place Recycling
Cold Mill & Inlay	1		
Cold In-place Recycling		1	
Hot In-place Recycling			1

1 = Equal preference of both alternatives.
3 = Weak preference of one alternative over another
5 = Strong preference of one alternative over another
7 = Demonstrated preference of one factor over another
9 = Absolute preference of one factor over another

You can use the reciprocals of the numbers mentioned above (i. e. 1/3, 1/5, 1/7, 1/9) to represent the preference of the item in the top row over the item in the left column.

Appendix (3)

The Final Matrices Used for Developing the Prototype DSS

Criteria	Disruption during Applicatio	cost / Year	Previous Experienc e	Criteria Weight
Disruption during Application	1.00	0.50	0.33	0.167
cost / Year	2.00	1.00	0.67	0.333
Previous Experience	3.00	1.50	1.00	0.5

Case 1; Longitudinal & Meander Cracks with ***Moderate*** Severity.
Transverse Cracks with ***Slight*** Severity.
Transverse Cracks with ***Modrate*** Severity.
Depressed Transverse Cracks with ***Slight*** Severity.

Previous Experience	Hot Pour	Cold Pour	Rout & Seal	Experience Weight	Consistency Ratio	Cost / meter	Expected Service Life
Hot Pour	1.00	2.00	0.25	0.19	0.79%	$ 0.40	1
Cold Pour	0.50	1.00	0.17	0.11	must be less than	$ 0.60	1
Rout & Seal	4.00	6.00	1.00	0.70	10%	$ 3.50	5

Disruption during Application	Hot Pour	Cold Pour	Rout & Seal	Disruption Weight	Consistency Ratio	Final Weight
Hot Pour	1.00	0.67	4.00	0.36	0.00%	0.31
Cold Pour	1.50	1.00	6.00	0.55		0.24
Rout & Seal	0.25	0.17	1.00	0.09		0.45

Cost / Year	Hot Pour	Cold Pour	Rout & Seal	Cost / year	Cost / Year Weight	Consistency Ratio
Hot Pour	1.00	1.50	1.75	$ 0.40	0.45	0.00%
Cold Pour	0.67	1.00	1.17	$ 0.60	0.30	
Rout & Seal	0.57	0.86	1.00	$ 0.70	0.26	

[redacted]

Criteria	Disruption during Applicatio	cost / Year	Previous Experienc e	Criteria Weight
Disruption during Application	1.00	0.50	0.33	0.167
cost / Year	2.00	1.00	0.67	0.333
Previous Experience	3.00	1.50	1.00	0.5

Case 2; **Longitudinal & Meander Cracks with *__Extreme__* Severity.**

Previous Experience	Hot Pour	Spray Patch	Rout & Seal	Experience Weight	Consistency Ratio	Cost / meter	Expected Service Life
Hot Pour	1.00	0.33	1.50	0.23	1.58%	$ 0.40	1
Spray Patch	3.00	1.00	3.00	0.60	must be less than	$ 10.00	3
Cold Pour	0.67	0.33	1.00	0.17	10%	$ 0.60	1

Disruption during Application	Hot Pour	Spray Patch	Rout & Seal	Disruption Weight	Consistency Ratio	Final Weight
Hot Pour	1.00	2.00	0.67	0.33	0.00%	0.36
Spray Patch	0.50	1.00	0.33	0.17		0.35
Cold Pour	1.50	3.00	1.00	0.50		0.30

Cost / Year	Hot Pour	Spray Patch	Rout & Seal	Cost / year	Cost / Year Weight	Consistency Ratio
Hot Pour	1.00	8.33	1.50	$ 0.40	0.56	0.00%
Spray Patch	0.12	1.00	0.18	$ 3.33	0.07	
Rout & Seal	0.67	5.56	1.00	$ 0.60	0.37	

[illegible]

Criteria	Disruption during Applicatio	cost / Year	Previous Experienc e	Criteria Weight
Disruption during Application	1.00	0.50	0.33	0.167
cost / Year	2.00	1.00	0.67	0.333
Previous Experience	3.00	1.50	1.00	0.5

Case 3;

Transverse Cracks with *Extreme* Severity.

Previous Experience	Hot Pour	Spray Patch	Mill & Fill	Experience Weight	Consistency Ratio	Cost / meter	Expected Service Life
Hot Pour	1.00	0.33	3.00	0.23	0.00%	$ 0.40	1
Spray Patch	3.00	1.00	9.00	0.69	must be less than	$ 4.00	3
Mill & Fill	0.33	0.11	1.00	0.08	10%	$ 15.00	15

Disruption during Application	Hot Pour	Spray Patch	Mill & Fill	Disruption Weight	Consistency Ratio	Final Weight
Hot Pour	1.00	3.00	9.00	0.69	0.00%	0.43
Spray Patch	0.33	1.00	3.00	0.23		0.44
Mill & Fill	0.11	0.33	1.00	0.08		0.13

Cost / Year	Hot Pour	Spray Patch	Mill & Fill	Cost / year	Cost / Year Weight	Consistency Ratio
Hot Pour	1.00	3.33	2.50	$ 0.40	0.59	0.00%
Spray Patch	0.30	1.00	0.75	$ 1.33	0.18	
Mill & Fill	0.40	1.33	1.00	$ 1.00	0.24	

Criteria	Disruption during Applicatio	cost / Year	Previous Experienc e	Criteria Weight
Disruption during Application	1.00	0.50	0.33	0.167
cost / Year	2.00	1.00	0.67	0.333
Previous Experience	3.00	1.50	1.00	0.5

Case 4;

Depressed Transverse Cracks with *Extreme* Severity.
Depressed Transverse Cracks with *Moderate* Severity.

Previous Experience	Mill & Fill	Spray Patch	Thermo Patc	Experience Weight	Consistency Ratio	Cost / meter	Expected Service Life
Mill & Fill	1.00	0.25	0.20	0.10	0.32%	$ 15.00	5
Spray Patch	4.00	1.00	0.67	0.37	must be less than	$ 6.00	3
Thermo Patch	5.00	1.50	1.00	0.53	10%	$ 10.00	5

Disruption during Application	Mill & Fill	Spray Patch	Thermo Patch	Disruption Weight	Consistency Ratio	Final Weight
Mill & Fill	1.00	0.20	0.50	0.13	0.00%	0.15
Spray Patch	5.00	1.00	2.50	0.63		0.42
Thermo Patch	2.00	0.40	1.00	0.25		0.43

Cost / Year	Mill & Fill	Spray Patch	Thermo Patch	Cost / year	Cost / Year Weight	Consistency Ratio
Mill & Fill	1.00	0.67	0.67	$ 3.00	0.25	0.00%
Spray Patch	1.50	1.00	1.00	$ 2.00	0.38	
Thermo Patch	1.50	1.00	1.00	$ 2.00	0.38	

[redacted]

Criteria	Disruption during Applicatio	cost / Year	Previous Experienc e	Criteria Weight
Disruption during Application	1.00	0.50	0.33	0.167
cost / Year	2.00	1.00	0.67	0.333
Previous Experience	3.00	1.50	1.00	0.5

Case 5;

Loss of Aggregate with *Moderate* Severity
Loss of Aggregate with *Extreme* Severity

Previous Experience	Fog Coat	Seal Coat	Chip Seal	Experience Weight	Consistency Ratio	Cost / meter	Expected Service Life
Fog Coat	1.00	0.14	0.11	0.06	0.01%	\$ 0.15	1
Seal Coat	7.00	1.00	0.80	0.42	must be less than	\$ 1.20	15
Chip Seal	9.00	1.25	1.00	0.53	10%	\$ 1.50	15

Disruption during Application	Fog Coat	Seal Coat	Chip Seal	Disruption Weight	Consistency Ratio	Final Weight
Fog Coat	1.00	9.00	9.00	0.82	0.00%	0.24
Seal Coat	0.11	1.00	1.00	0.09		0.37
Chip Seal	0.11	1.00	1.00	0.09		0.39

Cost / Year	Fog Coat	Seal Coat	Chip Seal	Cost / year	Cost / Year Weight	Consistency Ratio
Fog Coat	1.00	0.53	0.67	$ 0.15	0.23	0.00%
Seal Coat	1.88	1.00	1.25	$ 0.08	0.43	
Chip Seal	1.50	0.80	1.00	$ 0.10	0.34	

[redacted]

Criteria	Disruption during Applicatio	cost / Year	Previous Experienc e	Criteria Weight
Disruption during Application	1.00	0.50	0.33	0.167
cost / Year	2.00	1.00	0.67	0.333
Previous Experience	3.00	1.50	1.00	0.5

Case 6;

Apply General Treatment to the whole Entire Segment

Previous Experience	Cold Mill & Inlay	Cold In-place Recycling	Hot In-plac Recycling	Experience Weight	Consistency Ratio	Cost / meter	Expected Service Life
Cold Mill & Inlay	1.00	7.00	1.50	0.53	1.58%	$ 5.50	14
Cold In-place Recycling + Seal Coat	0.14	1.00	0.14	0.07	must be less than	$ 7.00	15
Hot In-plac Recycling	0.67	7.00	1.00	0.40	10%	$ 4.00	10

Disruption during Application	Cold Mill & Inlay	Cold In-place Recycling	Hot In-plac Recycling	Disruption Weight	Consistency Ratio
Cold Mill & Inlay	1.00	7.00	1.00	0.47	0.00%
Cold In-place Recycling	0.14	1.00	0.14	0.07	
Hot In-plac Recycling	1.00	7.00	1.00	0.47	

Cost / Year	Cold Mill & Inlay	Cold In-place Recycling	Hot In-plac Recycling	Cost / year	Cost / Year Weight	Consistency Ratio
Cold Mill & Inlay	1.00	1.19	1.02	$ 0.39	0.35	0.00%
Cold In-place Recycling	0.84	1.00	0.86	$ 0.47	0.30	
Hot In-plac Recycling	0.98	1.17	1.00	$ 0.40	0.35	

Appendix (4.a)

An Example of Surface Condition Rating Data before Modification

strSEGN	dtmDate	dtmEnter	strWeather	dblGLS	intGLL	dblGLW	dblADDA	intLanes	dblGaugeA	dblSegA
AR002- 32 00.000 01.1	09/8/1998	10/23/1998	CLEAR 17	00.705	100	03.8	2356	1	380	6760.2
AR016- 20 00.000 01.0	10/1/1998	12/9/1998	CLOUDY WIND	00.192	100	04.0	1973.5	1	400	6241.5
AR055- 12 00.000 01.5	09/15/1998	10/7/1998	SUNNY, WARM	01.048	050	07.5	0	2	375	11625
AR056- 10 00.000 01.1	09/14/1998	10/28/1998	Cloudy +12c	00.523	050	07.3	240	2	365	8525.5
AR057- 10 00.000 02.8	09/14/1998	10/28/1998	Cloudy +11c	02.040	050	07.3	210	2	365	20766.8
AR068- 18 00.000 00.7	09/21/1998	11/30/1998	+ 8 c , sunny.	00.375	050	08.6	0	2	430	6303.8
AR071- 16 00.000 00.5	10/5/1998	10/26/1998	SUNNY, COOL	00.219	050	07.3	0	2	365	4015
AR074- 00 00.000 00.4	09/14/1998	10/7/1998	+12 OVERCAST	00.180	050	10.4	0	3	520	4992
AR084- 22 00.000 01.1	09/23/1998	11/6/1998	+ 12 c , cloudy.	00.725	050	07.8	105	2	390	8763
AR086- 18 00.000 00.5	10/7/1998	11/13/1998	SUNNY	00.100	050	07.2	0	2	360	3888
AR087- 20 00.000 02.9	10/7/1998	11/13/1998	SUNNY	00.100	050	07.6	0	2	380	22496
AR089- 16 00.000 03.2	10/5/1998	10/26/1998	SUNNY, COOL	01.151	050	07.0	1020	2	350	23840
AR090- 18 00.000 03.6	10/5/1998	10/26/1998	SUNNY, WARM	01.246	050	07.1	40	2	355	25955
AR096- 00 00.000 03.0	09/22/1998	10/5/1998	+7 OVERCAST	00.632	050	07.4	0	2	370	22200
AR096- 00 00.000 03.5	09/22/1998	10/7/1998	+7 OVERCAST	00.632	050	07.4	0	2	370	25937
AR104- 00 00.000 00.8	09/14/1998	10/7/1998	+11 OVERCAST	00.405	050	07.1	0	2	355	5964
AR108- 20 00.000 10.5	10/7/1998	11/13/1998	SUNNY	00.100	050	07.6	0	2	380	79952
AR110- 02 00.000 02.0	10/27/1998	11/10/1998	16	01.360	050	07.0	28	2	350	14392
AR113- 10 00.000 00.7	10/7/1998	10/26/1998	WARM	00.454	050	07.6	50	2	380	6054
AR114- 08 00.000 03.2	09/17/1998		+15C Sunny	01.773	050	07.2	0	2	360	23155.2
AR115- 10 00.000 00.9	09/3/1998	11/5/1998	+20 c , clear.	00.050	050	07.5	80	2	375	7565
AR116- 00 00.000 00.1	09/29/1998	10/7/1998	OVERCAST +12	00.140	050	07.6	0	2	380	1444
AR122- 08 00.000 02.2	11/20/1998	12/2/1998	clear, cold	01.622	050	07.2	0	2	360	16056
AR124- 48 00.000 00.5	10/30/1997	12/4/1997	CLOUDY	00.202	050	07.0	0	2	350	4060
AR125- 48 00.000 01.8	10/30/1997	12/4/1997	CLOUDY	00.098	050	07.4	0	2	370	13542
AR128- 28 00.000 00.8	10/27/1998	10/29/1998	Sunny +15C	00.100	050	07.2	0	2	360	5817.6
AR131- 08 00.000 00.7	09/17/1998	12/10/1998	CLOUDY 8	00.337	050	07.4	55.5	2	370	5849.7
AR133- 12 00.000 08.2	09/22/1998	10/14/1998	Sunny 17 C	05.027	050	07.3	630	2	365	60811.2
AR133X 04 00.000 03.7	09/23/1998	10/13/1998	SUNNY 10 C	02.823	050	07.3	0	2	365	27688.9
AR137- 14 00.000 07.1	08/31/1998	10/27/1998	Light overcast +1	02.815	050	07.2	0	2	360	51746.4

intRUTS	intRUTM	intRUTX	intRUT10	intRUT11	intRUT12	intRUT13	intRUT14	intRUT15	intRUT16	intRUT17	intRUT18	intRUT19
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	6	6	6	6	8	0	3	3	0	0
6	0	0	3	3	2	0	2	2	2	2	2	2
11	0	0	4	8	5	0	0	4	4	0	7	4
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	1	1	0	0	0	0	3	0
8	0	0	0	0	0	0	0	3	3	3	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
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2	0	0	0	3	0	0	0	0	3	0	0	0
6	0	0	0	0	0	5	0	0	0	6	4	0
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5	0	0	1	2	1	1	2	1	6	2	2	2
6	0	0	4	4	0	0	4	0	0	0	0	0
2	0	0	0	0	0	0	3	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	4	0	0	0	0	0
12	0	0	4	4	8	0	0	0	6	4	4	5
0	0	0	1	0	0	0	0	2	0	0	0	0
17	0	0	4	4	5	5	5	0	3	3	3	3
0	0	0	0	0	0	0	0	0	0	0	0	0

dblRUT1AVG	intRUT20	intRUT21	intRUT22	intRUT23	intRUT24	intRUT25	intRUT26	intRUT27	intRUT28	intRUT29	dblRUT2AVG
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0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3	3	3	6	1.5
0	0	0	0	0	0	0	0	0	0	0	0
3.8	0	0	0	0	0	7	4	5	4	7	2.7
2	7	4	4	2	4	2	1	0	1	1	2.6
3.6	3	3	5	0	0	0	0	0	0	3	1.4
0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	1	0	0	0	0	0	0	0	0.1
0.9	0	0	0	0	0	5	4	4	5	6	2.4
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
3.3	9	7	6	6	7	12	7	6	6	8	7.4
0.6	0	0	0	0	0	0	0	0	0	0	0
1.5	0	0	5	0	4	0	0	0	4	0	1.3
0	0	0	0	0	0	0	0	0	0	0	0
2	4	2	2	2	2	0	4	4	8	2	3
1.2	0	0	0	0	0	0	4	3	0	4	1.1
0.3	0	0	0	0	0	0	0	0	0	3	0.3
0	0	0	0	0	0	0	5	0	0	0	0.5
0	0	0	0	0	0	0	0	0	3	0	0.3
0.4	0	0	0	0	0	0	5	0	0	0	0.5
3.5	0	3	3	4	0	3	0	3	0	0	1.6
0.3	0	0	0	0	0	0	0	2	0	1	0.3
3.5	6	3	7	4	0	0	3	4	7	3	3.7
0	0	0	0	0	0	0	0	0	0	0	0

dblASRS	dblAMRS	dblAXRS	strRUTT	intTDBL	intSegFilled	intTPushRaz	intTCNN	intTCNNRaw	intTCNS
0	0	0	0	No	No	0	00		00
0	0	0	0	No	No	0	00		02
1256.7567567568	0	0	0	No	Yes	0	08	0,0,0,0,0,0,0,0	00
0	0	0	0	No	No	0	00		02
6735.1783783784	0	0	S1	No	No	0	00		00
1022.2378378378	0	0	0	Yes	No	0	00		00
1193.6486486487	0	0	S1	No	Yes	-1	00		03
0	0	0	0	No	No	-1	00		00
236.83783783784	0	0	0	No	No	0	00		00
840.64864864865	0	0	0	No	No	0	00		00
0	0	0	0	No	No	0	00		02
0	0	0	0	No	No	0	00		00
0	0	0	0	No	No	0	00		00
0	0	0	0	Yes	No	0	00		00
0	0	0	0	Yes	No	0	00		00
0	0	0	0	No	No	0	00		01
32412.972972973	4321.7297297297	0	S3	No	No	0	00		00
777.94594594595	0	0	0	No	No	0	00		00
981.72972972973	0	0	0	No	No	-1	00		00
0	0	0	0	No	Yes	0	02	0,0	00
1022.2972972973	0	0	0	No	No	0	00		02
234.16216216216	0	0	0	No	No	-1	00		00
867.89189189189	0	0	0	No	No	0	00		00
109.72972972973	0	0	0	No	No	0	00		00
366	0	0	0	No	No	0	00		01
314.46486486487	0	0	0	Yes	No	0	00		02
1897.2	0	0	S1	No	No	0	00		01
0	0	0	0	No	No	0	00		00
12721.927027027	0	0	S3	No	No	0	00		00
0	0	0	0	No	No	0	00		00

intTCNSRaw	intTCNM	intTCNMRaw	intTCNX	intTCNXRaw	intTCSN	intTCSS	intTCSSRaw	intTCSM	intTCSMRaw	intTCSX
	00		00		00	00		00		00
0,0	00		00		00	02	5,3	00		00
	00		00		00	00		00		00
0,0	03	0,0,0	00		00	00		00		00
	00		00		00	00		00		00
	00		05	2,2,2,2,2	00	00		00		08
0,0,0,	05	0,0,0,0,0	00		00	02	5 3	05	6,3,3,3,4	03
	02	0,0	04	0,0,0,0	00	00		00		03
	00		00		00	00		00		00
	00		00		00	00		00		00
0,0	06	0,0,0,0,0,0	00		00	00		00		00
	03	0,0,0	00		00	02	3,4	01	6	00
	07	0,0,0,0,0,0,0	01	0	00	00		00		00
	00		00		00	00		00		01
	00		00		00	00		00		01
0	01	0	07	0,0,0,0,0,0,0	00	00		00		01
	00		00		00	00		02	6,5	04
	00		00		00	00		02	5.4	00
	00		00		00	00		03	5,6,6	01
	00		00		02	00		00		00
2,2	03	2,2,2	00		04	00		03	5,3,3	00
	01	0	08	0,0,0,0,0,0,0,0	00	00		00		00
	00		00		00	01	4	01	5	00
	01	0	00		00	00		00		00
0	01	0	00		00	00		00		09
0,0	02	0,0	00		00	02	4,4	00		00
0	00		00		00	01	6	00		00
	06	0,0,0,0,0,0	02	0,0	00	00		00		00
	01	0	00		00	00		03	5,3,5	00
	01	0	03	0,0,2	00	01	3	00		01

intTCSXRaw	intTCMN	intTCMS	intTCMM	intTCMX	intTCMXRaw	intTCXN	intTCXS	intTCXM	intTCXX	intTCTOT	strTC
	00	00	00	00		00	00	00	00	0	0
	00	00	00	00		00	00	00	00	4	S1
	00	00	00	00		00	00	00	00	8	0
	00	00	00	00		00	00	00	00	5	M1
	00	00	00	00		00	00	00	00	0	0
3,3,4,6,4,3,3,4	00	00	00	01	7	00	00	00	00	14	X3
5,4,3	00	00	00	00		00	00	00	00	18	M2
4,4,6	00	00	00	00		00	00	00	00	9	X2
	00	00	00	00		00	00	00	00	0	0
	00	00	00	00		00	00	00	00	0	0
	00	00	00	00		00	00	00	00	8	M1
	00	00	00	00		00	00	00	00	6	M1
	00	00	00	00		00	00	00	00	8	M1
4	00	00	00	03	13,13,9	00	00	00	00	4	X1
4	00	00	00	03	13,13,9	00	00	00	00	4	X1
5	00	00	00	00		00	00	00	00	10	X3
4,5,6,5	00	00	00	00		00	00	00	00	6	X2
	00	00	00	00		00	00	00	00	2	M1
5	00	00	00	00		00	00	00	00	4	M1
	00	00	00	00		00	00	00	00	4	S1
	00	00	00	00		00	00	00	00	12	M2
	00	00	00	00		00	00	00	00	9	X2
	00	00	00	00		00	00	00	00	2	M1
	00	00	00	00		00	00	00	00	1	M1
5,5,6,6,4,4,4,4,	00	00	00	00		00	00	00	00	11	X3
	00	00	00	07	8,9,11,11,12,1	00	00	00	01	14	X3
	00	00	00	00		00	00	00	00	2	S1
	00	00	00	00		00	00	00	00	8	M1
	00	00	00	00		00	00	00	00	4	M1
3	00	00	00	00		00	00	00	00	6	X2

dblLSTCS	dblLMTCS	dblLXTCS	intCRAKN	intCRAKS	intCRAKM	intCRAKX	strCrack	dblPANC	dblPASC
0	0	0	0	7.53	22.53	6.93	M2	0	1.9815789474
115.46775	0	0	0	26.37	0	0	S2	0	6.5925
0	0	0	17.4	1.8	0	0	0	4.64	0.48
86.422876712	129.63431507	0	0	49.2	11.55	1	S3	0	13.479452055
0	0	0	0	40.65	0	33.4	S3	0	11.136986301
0	0	759.388	0	0	10.2	94.4	X3	0	0
101.75	203.5	61.05	0	41.1	37.5	4.8	S3	0	11.260273973
0	71.04	248.64	0	45.72	0	36.37	S3	0	8.7923076923
0	0	0	0	0	0	0	0	0	0
0	0	0	0	6.96	1.68	16.2	X2	0	1.9333333333
219.04	657.12	0	0	12.39	0	0	S1	0	3.2605263158
252.02285714	504.04571429	0	0	3.93	0	0	S1	0	1.1228571429
0	946.80915493	135.25845070	0	8.1	3.03	0	S1	0	2.2816901408
0	0	888	0	4.38	0	1.98	S1	0	1.1837837838
0	0	1037.48	0	4.38	0	1.98	S1	0	1.1837837838
62.16	62.16	497.28	0	41.34	9.9	0.7	S3	0	11.645070423
0	1556.96	3113.92	0	30.45	1.41	16.3	S3	0	8.0131578947
0	152.144	0	0	0	0	0	0	0	0
0	88.420263158	29.473421053	0	25.35	18.06	12.55	S3	0	6.6710526316
237.984	0	0	20.25	2.31	0	0	0	5.625	0.6416666667
223.924	223.924	0	4.44	6.93	5.7	0	S1	1.184	1.848
0	14.06	112.48	0	13.17	14.43	34.38	X3	0	3.4657894737
82.51	82.51	0	0	2.22	0	0	S1	0	0.6166666667
0	21.46	0	0	0	12.75	8.97	M2	0	0
135.42	135.42	1218.78	0	0.3	0	0	S1	0	0.0810810811
239.168	119.584	478.336	0	0.45	4.41	0.3	M1	0	0.125
58.497	0	0	0.3	24.48	13.59	0.9	S3	0.081081	6.6162162162
0	1849.3269041	616.44230137	0	16.23	12.06	0.78	S2	0	4.4465753425
0	561.364	0	0	1.11	0.66	6	X1	0	0.3041095890
531.838	531.838	2127.352	0	1.74	0.39	0	S1	0	0.4833333333

dblRAMC	dblRAXC	dblANCS	dblASCS	dblAMCS	dblAXCS	intLSHOV	intLRUT	intLSLR	intLMLR
5.9289473684	1.8236842105	0	360.43137631579	1078.4221658	331.71174474	0	0	0	0
0	0	0	1107.3463453125	0	0	0	0	0	250
0	0	596.936	61.752	0	0	0	0	0	0
3.1643835616	0.2739726027	0	1638.0691762057	384.54672734	33.294088947	0	0	0	0
0	9.1506849315	0	3159.9187870145	0	2596.3416356	0	0	0	0
2.3720930233	21.953488372	0	0	149.532	1383.904	0	0	0	0
10.273972603	1.3150684932	0	575.96301369863	525.51369863	67.265753425	0	0	0	0
0	6.9942307692	0	438.912	0	349.152	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0.4666666667	4.5	0	104.4	25.2	243	0	0	0	0
0	0	0	829.99957894737	0	0	0	0	0	0
0	0	0	286.79054693878	0	0	0	0	0	0
0.8535211268	0	0	676.53558817695	253.07442373	0	0	0	0	0
0	0.5351351351	0	277.00540540541	0	125.22162162	0	0	0	0
0	0.5351351351	0	323.63464864865	0	146.30059459	0	0	0	0
2.7887323944	0.1971830986	0	733.63943661972	175.69014085	12.422535211	0	0	0	0
0.3710526316	4.2894736842	0	6912.4705263158	320.08484211	3700.2715789	0	0	0	0
0	0	0	0	0	0	0	0	0	21
4.7526315789	3.3026315789	0	502.85341412742	358.24586427	248.94715374	0	0	0	150
0	0	1374.84	156.8336	0	0	0	0	0	0
1.52	0	112.0135	174.831888	143.80112	0	0	0	0	0
3.7973684211	9.0473684211	0	52.0215	56.9985	135.801	0	0	0	0
0	0	0	119.6395	0	0	0	0	0	0
3.6428571429	2.5628571429	0	0	147.9	104.052	0	0		0
0	0	0	13.057297297297	0	0	0	0		0
1.225	0.0833333333	0	9.797	96.0106	6.5313333333	0	0	0	0
3.672972973	0.2432432432	7.031311	573.75496216216	318.51837973	21.093932432	0	0	0	18.5
3.3041095890	0.2136986301	0	3102.4423759805	2305.3268672	149.10074265	0	0	0	76
0.1808219178	1.6438356164	0	102.66040273973	61.041320548	554.92109589	0	0	0	0
0.1083333333	0	0	291.7922	65.4017	0	0	0	0	0

intLXLR	intLPF	intLXR	intSURC	dblSWIDTH	intSESC	intSEB	intSHOU	intSEC	strLCOM	strREM	strRater1
0	0	0	1	5.1	0	0	1	35	NONE	ONE-WAY SE	Cousineau Wilf
0	0	0	2	5.5	30	0	1	0		ADDITIONAL	Kreller Robert
0	0	0	1	0.8	0	0	1	0		BIG VALLEY A	Engel Allan
0	0	0	1	2.9	0	0	1	0		Lots of fine cra	Horpestad Nor
0	5	0	1	2.6	0	0	1	0	2.578 Paveme	Lots of minor ru	Horpestad Nor
0	200	0	2	0	0	0	1	0		Patched from 0	Corner Cliff
0	0	0	1	2	0	0	1	0		ACCESS ROA	Engel Allan
0	0	0	1	0	0	0	1	0		SEGMENT SH	Shapka Brian
0	0	0	1	1	0	0	1	0		New pavement	Corner Cliff
0	0	0	1	2.8	0	0	1	0		AR ROAD	CHUCK STER
0	0	0	1	1	0	0	1	0		AR ROAD	CHUCK STER
0	0	0	1	0.2	0	0	1	0		ACCESS ROA	Engel Allan
0	0	0	1	1	0	0	1	0		ACCESS ROA	Engel Allan
0	0	1871	3	0.4	0	0	1	0	EXTREME CR	SHOULD BE O	Shapka Brian
0	0	1871	3	0.4	0	0	1	0		SHOULD BE O	Shapka Brian
0	0	0	1	0.4	0	0	1	0		SEGMENT SH	Shapka Brian
0	0	0	1	0.6	0	0	1	0		NONE	CHUCK STER
0	0	0	1	0.7	0	0	1	0	MLR 1.2 PATC	X	SCHEELAR
0	600	0	4	1.8	0	0	1	0		ACCESS ROA	Engel Allan
0	0	0	1	0.4	0	0	1	0		None	Dean Scott
0	0	0	1	1.8	3	0	1	30		Chainage on H	Comer Cliff
0	0	0	1	0.3	0	0	1	0		.	Shapka Brian
0	0	0	1	1.5	0	0	1	0		ACCESS ROA	Stern Chuck
0	0	0	1	0	0	0	1	0		FAILURES AC	Bickell Fred
0	0	0	1	1.4	0	0	1	0		NO COMMENT	Ireland Harold
0	1814	0	5	2.5	0	0	1	0		GAUGE LENG	Dell Bill
0	0	0	1	3.5	0	0	1	20		NO REMARKS	Cousineau Wilf
0	0	0	1	1	0	0	2	240	MLR @ km 1.5	Access Rd - Ro	DOUG GOODI
0	0	0	1	1.6	0	0	1	100		1998	Perry Roberts
0	0	1	1	1.2	0	0	1	0		Good Shape, tr	Arke Lorne

strRater2	intAADT	intCSEC3	dblSum1	dblSum2	dblSum3	strSurfBleed	intSType	intSCount	dblLaneADD	strSTYPE
VASS ALEC	0	32	190.025	107.13	2392	S	0	72	0	X
Chipeniuk Edw	0	20	132.292	91.9	2253.5	S	0	15	0	S
Vidmar Frank	0	12	171.238	72	0	N	0	102	0	X
Charchun Andy	0	10	182.223	208.5	240	S	0	114	0	X
Charchun Andy	0	10	181.94	168.9	215	S	0	106	0	X
Yagos Daryl	0	18	64.475	142.4	201	S	-1	0	0	?
Vidmar Frank	0	16	71.719	284.8	1	N	-1	0	0	?
Gilbertson Ralp	0	0	162.08	197.77	0	S	0	96	0	X
Yagos Daryl	0	22	72.125	0	105	N	0	2	0	N
KROPINSKE B	0	18	92.4	45	0	S	0	19	0	S
KROPINSKE B	0	20	138.2	49.3	0	N	0	72	0	X
Vidmar Frank	0	16	65.551	19.1	1020	N	-1	0	0	?
Vidmar Frank	0	18	178.246	45.1	43	N	0	111	0	X
Gilbertson Ralp	0	0	89.932	20.58	1876	S	0	26	0	M
Gilbertson Ralp	0	0	89.932	20.58	1876	S	0	26	0	M
Gilbertson Ralp	0	0	203.405	181.5	0	S	0	140	0	X
KROPINSKE B	0	20	140.5	128.5	0	S	0	64	0	X
STONEHOUS	0	2	67.56	2	49	S	-1	0	0	?
Vidmar Frank	0	10	107.654	161.25	800	N	0	37	0	M
Rob Parenteau	0	8	75.373	79.2	0	S	0	16	0	S
Swan Brian	0	10	81.25	68.9	113	S	0	11	0	S
Gilbertson Ralp	0	0	165.84	135.38	3	S	0	100	0	X
STERN, CHUC	0	8	97.922	9.4	0	N	0	32	0	M
HAROLD IREL	0	48	122.902	52.47	24	N	0	60	0	X
Bickell Fred	0	48	69.298	12	15	N	0	4	0	N
Watts, Russ	0	26	161.7	30.5	1815	S	0	101	0	X
VASS ALEC	0	8	72.237	130.8	94	S	-1	0	0	?
EDDY HUISH	0	12	99.427	103.08	946	N	0	29	0	M
Paul Prout	0	4	115.523	15.9	100	N	0	40	0	M
Reynolds Neal	0	14	153.715	13.1	1	N	0	84	0	X

intPotCnt	dblLCRAKN	dblLCRAKS	dblLCRAKM	strSEGREM	intW	intLn	intL	intL	intBlk	strD	strTC
1	0	25.1	75.1	SAFEWAY SER	No	No	Yes	Yes	No	N	N
0	0	87.9	0	SERVICE ROA	No	No	Yes	No	No	S	S
0	58	6	0	ACCESS ROAD	No	No	Yes	No	No	N	N
0	0	164	38.5	AR Road	No	Yes	Yes	Yes	Yes	N	M
0	0	135.5	0	AR Road.	No	No	Yes	Yes	Yes	N	N
1	0	0	34	End of A.R.	No	No	No	Yes	No	S	X
1	0	137	125	ACCESS ROAD	No	Yes	Yes	Yes	Yes	S	M
0	0	152.4	0	ACCESS INTO	No	Yes	No	No	Yes	N	X
0	0	0	0	End of Access	No	No	No	No	No	N	N
0	0	23.2	5.6	ACCESS ROAD	No	No	No	No	No	N	N
0	0	41.3	0	ACCESS ROAD	No	No	No	No	No	N	M
0	0	13.1	0	ACCESS ROAD	No	No	No	Yes	No	S	M
3	0	27	10.1	ACCESS ROAD	No	Yes	No	Yes	No	N	M
5	0	14.6	0	ACCESS INTO	No	No	No	No	No	M	X
5	0	14.6	0	ACCESS INTO	No	No	No	No	No	M	X
0	0	137.8	33	ACCESS INTO	No	No	No	Yes	No	N	X
0	0	101.5	4.7	APPROACH RO	No	No	No	No	No	S	X
0	0	0	0	JCT 36	No	No	No	No	No	S	M
0	0	84.5	60.2	ACCESS ROAD	No	Yes	Yes	Yes	Yes	S	M
0	67.5	7.7	0	End of Access R	No	Yes	No	No	No	S	N
0	14.8	23.1	19	End of AR115	No	No	No	No	No	S	M
3	0	43.9	48.1	ACCESS INTO	No	Yes	Yes	Yes	No	N	X
0	0	7.4	0	ACCESS ROAD	No	No	No	No	No	S	M
24	0	0	42.5	END OF ACCES	No	No	No	No	No		
15	0	1	0	END OF ACCES	No	No	No	No	No		
1	0	1.5	14.7	END OF ACCES	No	No	No	No	No	M	X
0	1	81.6	45.3	ACCESS ROAD	No	No	Yes	Yes	No	S	S
0	0	54.1	40.2	Separate access	No	No	Yes	Yes	No	N	M
0	0	3.7	2.2	MORLEY ROAD	No	No	No	No	Yes	S	M
0	0	5.8	1.3	Access to Galah	No	No	No	No	No	N	X

Appendix (4.b)

An Example of Surface Condition Rating Data after Modification

ID	Type	Hwy	CS	From	To	Length	Lanes	Seg Area	Rutt Score	Transverse Crack Score	Crack Score	Distortion Score
145	PH	9	2	0	15.85	15.85	2	121430	0	0	0	8
146	PH	9	2	15.85	28.95	13.11	2	104682.6	2	0	0	0
147	PH	9	2	28.95	45.27	16.32	2	138056.9	0	0	0	0
148	PH	9	2	45.27	48.21	2.95	2	25992.6	2	2	2	0
149	PH	9	2	48.21	64.85	16.63	2	128280.5	0	2	2	0
150	PH	9	4	0	7.57	7.57	2	61204.4	3	7	5	0
151	PH	9	4	7.57	13.36	5.78	2	46446	4	3	0	8
152	PH	9	4	13.36	24.64	11.28	2	87540	3	7	2	8
153	PH	9	4	24.77	27.75	2.98	2	22648	4	9	10	0
154	PH	9	4	27.75	39.63	11.88	2	93741.8	0	3	2	0
155	PH	9	4	39.63	43.2	3.57	2	43415.5	0	2	2	0
156	PH	9	6	0	2.59	2.59	2	24771	0	0	0	0
157	PH	9	6	2.59	19.14	16.55	2	149184	0	2	0	0
158	PH	9	6	19.14	20.23	1.09	2	9316	0	0	10	0
159	PH	9	8	0	0.58	0.58	2	7209	3	5	0	0
160	PH	9	8	0.58	23.9	23.32	2	178692	0	0	0	0
161	PH	9	8	23.9	61.01	37.11	2	470783	3	2	2	0
162	PH	9	10	2.67	16.8	14.13	2	104576.8	4	6	0	0
163	PH	9	10	16.8	19.2	2.4	2	19060	0	3	0	0
164	PH	9	10	19.2	20.1	0.9	2	6750	0	2	2	0
165	PH	9	10	20.1	25.6	5.5	2	40150	0	2	3	0
166	PH	9	10	25.6	46.6	21	2	156170	0	2	0	0
167	PH	9	12	0	55.02	55.02	2	413465.4	0	3	0	0
168	PH	9	14	0	33.02	33.02	2	252622	0	2	3	0
268	PH	14	6	7.13	12.25	5.12	2	40857.2	2	2	2	0
269	PH	14	6	12.25	19.82	7.57	2	59046	3	3	2	8
270	PH	14	6	19.82	32.66	12.84	2	100820	0	0	0	0
271	PH	14	6	32.66	39.69	7.03	2	53836.6	0	5	2	8
272	PH	14	8	0	19	15.32	2	109471	0	3	2	8
273	PH	14	8	19	33.59	14.59	2	115900.5	5	3	4	8

Bleeding Score	Loss of Aggregate Score	Pothole Score	Depressed Transverse Crack Score	Alligator Score	SCI
0	0	0	6	8	64
0	0	0	2	0	16
0	0	0	6	9	0
8	0	0	2	0	60
0	0	0	2	10	20
0	0	8	2	0	158
0	0	8	0	0	186
0	0	8	2	0	210
0	0	8	0	9	198
0	0	0	6	8	26
0	0	0	0	0	20
0	0	0	2	0	0
0	0	0	6	0	12
0	4	8	2	0	132
0	0	10	2	9	144
0	0	8	2	0	72
8	0	8	2	0	140
8	0	8	2	0	164
0	7	9	0	0	134
0	7	0	2	0	55
8	7	8	0	0	155
0	0	0	2	0	12
0	0	0	0	0	18
0	4	0	0	0	44
8	0	8	2	0	132
9	0	8	0	0	213
8	0	0	0	0	24
8	0	8	2	9	198
8	0	8	0	9	186
8	0	8	0	9	234

Appendix (5.a)

An Example of Inventory Data before Modification

PRIMARY HIGHWAYS PMS STATUS SUMMARY (Data Year 1998) Apr 23, 1999.
Alberta Transportation & Utilities, Technical Standards Branch

HWY	CS	LN	BEGIN KM	END KM	LEN KM	WID M	SOIL TYPE	GB MM	SC MM	CS MM	SA MM	OB MM	YR BASED	ACP MM	YEAR PAVED	COMMT	O/L MM	O/L YR	YR SEAL COAT	PQI	RCI	SAI	VCI	RUT MM	PREDICTED NEED YR	INDEX TYPE	PRESENT ESAL	AADT /DAY
43	20	&	23.17	24.89	1.72	12.5	SC	200				100	1954	80	1955		100	1981	1982	5.1	5.7	5.3	5.2	5	2000	PQI	767	4509
	Total Length (km):				2.17							Paved Length (km):			2.17													
43	20	WBL E. CHERHILL TO E. GUNN											1981	150	1981				1982	3.5	3.6	4.3	5.2	7	1996	PQI	767	4510
43	20	&	22.72	23.06	0.34	12.5	SC	300					1981	150	1981													
43	20	&	23.06	24.89	1.83	12.3	SC	300					1981	150	1981		80	1994		7.2	6.7	6.2	8.3		2009	RCI	767	4509
	Total Length (km):				2.17							Paved Length (km):			2.17													
43	22	EBL E. GUNN TO JCT 16																										
43	22	&	0.00	0.80	0.80	12.5	SC	200				100	1954	80	1955		100	1981	1982	4.5	5.8	2.6	6.0	4	1998	PQI	1051	6730
43	22	&	0.80	1.35	0.55	12.5	SC	300					1981	150	1981				1982	3.7	4.9	1.8	6.3	7	1995	RCI	1051	6730
43	22	&	1.35	2.51	1.16	12.5	SC	200				100	1954	80	1955		100	1981	1982	4.5	5.8	2.7	5.9	4	1998	PQI	1051	6730
43	22	&	2.51	2.96	0.45	12.5	SC	300					1981	150	1981				1982	4.2	5.6	2.3	5.9	6	1997	PQI	1051	6730
43	22	&	2.96	3.94	0.98	12.5	SC	200				100	1954	80	1955		100	1981	1982	4.6	5.9	2.7	6.0	5	1998	PQI	1051	6730
43	22	&	3.94	4.76	0.82	12.5	SC	300					1981	150	1981				1982	4.0	4.9	2.7	6.0	8	1995	RCI	1051	6730
43	22	&	4.76	6.63	1.87	12.5	CL	200				100	1954	80	1955		100	1981	1982	5.1	5.9	3.5	6.3	4	2000	PQI	1019	6767
43	22	&	6.63	9.48	2.85	12.5	CL	300					1981	150	1981				1982	4.4	5.6	3.1	5.3	5	1997	PQI	935	6870
43	22	&	9.48	11.14	1.66	12.5	CL	200				100	1954	80	1955		100	1981	1982	5.0	6.0	3.5	6.1	5	2000	PQI	935	6870
43	22	&	11.14	12.47	1.33	12.4	CL	300					1981	150	1981		80	1994		7.7	7.2	6.1	8.3		2011	PQI	935	6870
43	22	&	12.47	12.83	0.36	12.4	CL	200				100	1954	80	1955		50	1976										
																	100	1981										
																	80	1994		8.3	7.8	6.1	8.3		2012	PQI	935	6870
			12.83	15.00	2.17	11.6	CL		180			50	1975	100	1976		80	1998		9.2	9.0	4.7	9.0		2002	SAI	890	7374
			15.00	20.00	5.00	11.2	CL		180			50	1975	100	1976		100	1998		9.2	9.0	4.7	9.0		2002	SAI	829	8060
			20.00	23.85	3.85	11.6	CL		180			50	1975	100	1976		80	1998		9.2	9.0	4.7	9.0		2002	SAI	829	8059
	Total Length (km):				23.85							Paved Length (km):			23.85													
43	22	WBL E. GUNN TO JCT 16																										
43	22	&	0.00	7.31	7.31	12.3	CL	300					1981	150	1981		80	1994		7.5	7.0	6.2	8.3		2010	PQI	1032	6752
43	22	&	7.31	9.03	1.72	12.3	CL	300					1981	190	1981		80	1994		7.3	6.7	6.4	8.3		2009	RCI	935	6870
43	22	&	9.03	12.00	2.97	12.3	CL	300					1981	150	1981		80	1994		7.3	6.8	5.8	8.3		2009	PQI	935	6870
43	22	&	12.00	12.70	0.70	12.5	CL	300					1981	150	1981				1982	4.2	5.3	3.3	5.2	8	1997	PQI	935	6870
43	22	&	12.70	13.73	1.03	9.8	CL	200				100	1954	80	1955		100	1976	1979	4.0	5.4	2.5	5.3	4	1997	PQI	935	6870
43	22	&	13.73	14.95	1.22	12.5	CL		180			50	1975	100	1976				1979	4.7	5.0	7.3	4.3	5	1997	RCI	860	7717
43	22	&	14.95	23.21	8.26	9.1	CL	200				100	1954	80	1955		100	1976	1979	3.8	5.5	2.4	4.7	7	1997	PQI	829	8060
43	22	&	23.21	23.85	0.64	12.5	CL	360				100	1962	100	1963		100	1976		4.0	5.0	3.1	5.3	6	1997	PQI	829	8059
	Total Length (km):				23.85							Paved Length (km):			23.85													
44	02	UND JCT 18 TO N. FAWCETT																										
44	02		0.00	1.63	1.63	TOWN OF WESTLOCK (91)																						
44	02		1.63	14.00	12.37	11.4	CL	250				50	1963	80	1967		80	1988	1990	6.1	6.4	5.4	6.6	4	2006	PQI	459	3150
44	02		14.00	18.00	4.00	11.3	CL	250				50	1963	80	1967		80	1985	1990	5.2	5.9	4.2	5.8	5	2001	PQI	459	3150
44	02		18.00	22.37	4.37	11.4	CL	250				50	1963	80	1967		80	1988	1990	6.5	6.5	6.0	6.9	5	2007	PQI	429	2963
44	02		22.37	25.26	2.89	11.4	CL-CI		150			50	1964	80	1967		80	1988	1990	6.9	6.5	7.9	6.9	5	2005	RCI	336	2067
44	02		25.26	27.50	2.24	11.4	CL-CI		150			50	1964	80	1967		80	1988	1991	6.6	6.4	7.1	6.8	5	2004	RCI	333	2010
44	02		27.50	44.71	17.21	11.3	CL-CI		150			50	1964	80	1967		100	1985	1991	5.5	6.2	4.9	5.7	6	2001	PQI	333	2010

HWY	CS	LN	BEGIN KM	END KM	LEN KM	WID M	SOIL TYPE	GB MM	SC MM	CS MM	SA MM	OB MM	YR BASED	ACP MM	YEAR PAVED	COMMT	O/L MM	O/L YR	YR SEAL COAT	PQI	RCI	SAI	VCI	RUT MM	PREDICTED NEED YR	INDEX TYPE	PRESENT ESAL	AADT /DAY
20	06		28.00	36.74	8.74	11.0	CL-CI		150				1972	50	1972		90	1982										
																	80	1998		9.6	9.0	5.8	9.0		2008	SAI	227	1459
Total Length (km): 36.74																												
Paved Length (km): 36.74																												
20	08		UND JCT 13 TO JCT 39																									
20	08		0.00	0.30	0.30	11.0	CL		150				1972	50	1972		90	1982										
																	80	1998		9.6	9.0	5.8	9.0		2008	SAI	220	1580
20	08		0.30	7.15	6.85	11.0	CL		150				1972	50	1972		90	1982	1984	4.6	5.5	4.7	4.6	7	1998	PQI	220	1580
20	08		7.15	12.13	4.98	11.0	CL-CI		150			50	1971	100	1974				1976	3.8	5.2	2.8	4.5	7	1996	PQI	220	1580
20	08		12.13	16.70	4.57	10.2	CL-CI		150			50	1971	100	1974		80	1995		7.7	7.2	5.8	8.4		2008	PQI	220	1580
20	08		16.70	26.58	9.88	10.2	CL-CI		150			50	1971	100	1974		90	1995		7.6	7.1	5.7	8.5		2008	PQI	269	1735
Total Length (km): 26.58																												
Paved Length (km): 26.58																												
20A	04		UND JCT 53 TO JCT 20																									
20A	04		0.00	0.81	0.81		TOWN OF RIMBEY (91)																					
20A	04		0.81	1.62	0.81	11.5	CL	250				50	1964	50	1969													
														60	1971				1976	4.0	5.8	2.1	5.5	4	1995	PQI	182	2880
Total Length (km): 1.62																												
Paved Length (km): 0.81																												
21	12		UND JCT 1 TO JCT 9																									
21	12		0.00	5.00	5.00	11.0	SF-CL		150			50	1966	50	1970		80	1993	1998	7.6	6.9	5.7	8.9	3	2007	RCI	204	1460
			5.00	6.00	1.00	10.8	SF-CL		150			50	1966	50	1970		100	1993	1998	7.6	7.0	5.7	8.9	3	2008	PQI	204	1460
			6.00	12.85	6.85	11.0	SF-CL		150			50	1966	50	1970		80	1993	1998	7.6	7.0	5.7	8.9	2	2008	PQI	204	1460
			12.85	17.00	4.15	10.8	SF-CL		150			50	1966	50	1970		100	1993	1998	7.4	6.9	5.6	8.6	2	2007	PQI	245	1649
			17.00	19.53	2.53	11.0	SF-CL		150			50	1966	50	1970		80	1993	1998	7.6	6.9	5.6	8.9	2	2007	RCI	209	1400
21	12		19.53	35.41	15.88	11.0	CL-CI		150			50	1967	50	1970		70	1991	1998	7.2	6.7	6.8	7.7	3	2006	RCI	209	1400
21	12		35.41	39.06	3.65	11.0	CI-CH		150			50	1967	80	1970		80	1991	1998	7.3	6.7	6.5	8.1	4	2006	RCI	209	1400
21	12		39.06	39.30	0.24	11.0	CI-CH		150			50	1967	80	1970		60	1982	1998	4.8	4.9	6.5	5.0	8	1996	RCI	209	1395
Total Length (km): 39.30																												
Paved Length (km): 39.30																												
21	14		UND JCT 9 TO JCT 27 WEST																									
21	14		0.00	12.60	12.60	11.0	CI-CH		150			50	1960	50	1961		80	1973	1979	4.5	5.5	4.9	4.1	5	1998	PQI	318	1610
21	14		12.60	13.30	0.70	13.6	CL-CI		150			50	1960	50	1961		80	1973										
																	50	1990		5.5	5.7	5.6	6.3	3	2000	RCI	318	1610
21	14		13.30	19.88	6.58	11.0	CL-CI		150			50	1960	50	1961		80	1973	1979	4.3	5.3	4.6	4.1	5	1996	RCI	337	1925
21	14		19.88	23.34	3.46	11.0	CL-CI	180				50	1959	100	1961		50	1973	1979	3.7	4.0	4.5	5.0	5	1996	PQI	339	1960
21	14		23.34	24.14	0.80	11.0	CL-CI	180				50	1959	100	1961		50	1966										
																	50	1973	1979	3.8	3.7	5.3	5.6	5	1996	PQI	339	1960
21	14		24.14	28.32	4.18	11.0	CI-CH	180				50	1959	100	1961		60	1966										
																	80	1973										
																	60	1981	1986	4.8	4.5	6.2	6.4	5	1996	RCI	339	1960
21	14		28.32	29.93	1.61	10.4	CI-CH	180				50	1959	100	1961		60	1966										
																	60	1981	1986	5.3	5.0	6.4	6.9	4	1996	RCI	332	1996
21	14		29.93	35.41	5.48	11.0	CL-CI	180				50	1959	100	1961		40	1966										
																	80	1990	1992	6.1	5.9	7.0	6.6	5	2002	RCI	286	2230
21	14		35.41	36.30	0.89	11.0	CL-CI	180				50	1959	100	1961		80	1990	1992	6.0	5.8	7.0	6.7	6	2001	RCI	282	2242

Appendix (5.b)

An Example of Inventory Data after Modification

HWY	CS	Dirction	from	To	Yr of Constr	Yr of Rehab	Age	Pavement	Soil	Clim Region
9	2	UND	0	12.85	1966	1992	7	1	5	3
9	2	UND	12.85	13.07	1966	1992	7	1	5	3
9	2	UND	13.07	19.1	1966	1992	7	1	5	3
9	2	UND	19.1	19.71	1982	1992	7	1	5	3
9	2	UND	19.71	32.11	1967	1992	7	1	5	3
9	2	UND	32.11	36.96	1966	1992	7	1	5	3
9	2	UND	36.96	37.29	1966	1986	13	1	5	3
9	2	UND	37.29	38.59	1966	1986	13	1	5	3
9	2	UND	38.59	38.91	1966	1986	13	1	5	3
9	2	UND	38.91	39.51	1966	1992	7	1	5	3
9	2	UND	39.51	44.1	1967	1992	7	1	5	3
9	2	UND	44.1	44.33	1967	1988	11	1	5	3
9	2	UND	44.33	45.61	1967	1988	11	1	5	3
9	2	UND	45.61	47.65	1967	1982	17	1	5	3
9	2	UND	47.65	54.91	1972	1982	17	1	5	3
9	2	UND	54.91	59.26	1967	1982	17	1	5	3
9	2	UND	59.26	61.62	1972	1982	17	1	5	3
9	2	UND	61.62	64.87	1953	1982	17	1	5	3
9	4	UND	0	0.39	1953	1982	17	1	5	3
9	4	UND	0.39	11.81	1953	1975	24	1	5	3
9	4	UND	11.81	13.42	1960	1975	24	1	3	3
9	4	UND	13.42	13.74	1960	1975	24	1	2	3
9	4	UND	13.74	25	1960	1975	24	1	2	3
9	4	UND	25	27.75	1960	1975	24	1	2	3
9	4	UND	27.75	39.82	1960	1975	24	1	2	3
9	4	UND	39.82	42.06	1978	1988	11	1	2	3
9	4	UND	42.06	42.81	1978	1988	11	1	2	3
9	4	UND	42.81	43.18	1978	1988	11	1	2	3
9	4	UND	43.18	44	1978	1988	11	1	2	3
9	6	UND	0	0.42	1978	1988	11	1	2	3

ESAL	AADT
463	1870
463	1870
557	2330
456	2231
329	2110
307	2466
296	2640
296	2640
296	2640
296	2640
296	2640
296	2640
296	2640
235	2380
235	2380
235	2380
235	2380
235	2379
229	1830
227	1833
192	1920
192	1920
186	2041
182	2150
192	2284
212	2550
212	2550
212	2548
212	2548
212	2548

Appendix (6)

An Example of the Final Database for the Prototype DSS

HWY	CS	From	To	IRI	Age	Pavement	Soil	Clim Region	ESAL	AADT
9	2	0	0.1	2.81	7	1	5	3	463	1870
9	2	0.1	0.2	2.635	7	1	5	3	463	1870
9	2	0.2	0.3	1.905	7	1	5	3	463	1870
9	2	0.3	0.4	1.89	7	1	5	3	463	1870
9	2	0.4	0.5	1.94	7	1	5	3	463	1870
9	2	0.5	0.6	1.905	7	1	5	3	463	1870
9	2	0.6	0.7	2.055	7	1	5	3	463	1870
9	2	0.7	0.8	1.925	7	1	5	3	463	1870
9	2	0.8	0.9	2.11	7	1	5	3	463	1870
9	2	0.9	1	1.95	7	1	5	3	463	1870
9	2	1	1.1	2.07	7	1	5	3	463	1870
9	2	1.1	1.2	1.965	7	1	5	3	463	1870
9	2	1.2	1.3	2.535	7	1	5	3	463	1870
9	2	1.3	1.4	2.2	7	1	5	3	463	1870
9	2	1.4	1.5	2.09	7	1	5	3	463	1870
9	2	1.5	1.6	2.015	7	1	5	3	463	1870
9	2	1.6	1.7	2.26	7	1	5	3	463	1870
9	2	1.7	1.8	2.165	7	1	5	3	463	1870
9	2	1.8	1.9	2.285	7	1	5	3	463	1870
9	2	1.9	2	1.485	7	1	5	3	463	1870
9	2	2	2.1	2.635	7	1	5	3	463	1870
9	2	2.1	2.2	1.37	7	1	5	3	463	1870
9	2	2.2	2.3	1.46	7	1	5	3	463	1870
9	2	2.3	2.4	1.775	7	1	5	3	463	1870
9	2	2.4	2.5	1.51	7	1	5	3	463	1870
9	2	2.5	2.6	1.265	7	1	5	3	463	1870
9	2	2.6	2.7	1.405	7	1	5	3	463	1870
9	2	2.7	2.8	1.455	7	1	5	3	463	1870
9	2	2.8	2.9	1.885	7	1	5	3	463	1870
9	2	2.9	3	1.58	7	1	5	3	463	1870

Rutt Score	TCrack Score	Crack Score	Distortion Score	Bleeding Score	Loss of Aggregate Score	Pothole Score	SCI
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64
0	0	0	8	0	0	0	64

Appendix (7)

Copy of North American SCR Practices Survey

1. How often do you check your primary highway network for surface condition rating?

☐ - Annually

☐ - Every second year

☐ - Every three years

☐ - Every ___ years

☐ - Others, please specify ______________________________

____

2. How much of the network do you measure each time?

☐ - The whole network

☐ - A percentage of the network = ___ %

☐ - Random / Fixed cycle

☐ - Others, please specify

____

3. How do you segment your primary highway network for surface condition rating?

☐ - A segment built on similar surface conditions

☐ - Constant segment length = ___ ___

☐ - Segments built on pavement characteristics

☐ - Others, please specify ______________

____

____

4. How do you represent the surface condition within the selected segment?

☐ - Measure the surface condition distresses within the whole segment

☐ - A gauging length built on segment length equals ___ (m. / feet) per (Km. / Mile)

☐ - Constant gauging length for all segments equals ___ (m. / feet)

☐ - Others, please specify ______________________________

____

**5. Which of these distresses do you measure and what is the measuring unit ?
(e.g. using total length, total area, or total number)**

- ☐ - **Longitudinal Wheel-Track Cracking** ____________________
- ☐ - **Longitudinal Mid-Lane Cracking** ____________________
- ☐ - **Center Line Crack** ____________________
- ☐ - **Edge Crack** ____________________
- ☐ - **Transverse Cracking Deterioration** ____________________
- ☐ - **Transverse Cracking Depression** ____________________
- ☐ - **Alligator, Map, and Block Cracking** ____________________
- ☐ - **Rutting** ____________________
- ☐ - **Ravelling** ____________________
- ☐ - **Bleeding** ____________________
- ☐ - **Rippling and Shoving** ____________________
- ☐ - **Pot Holes** ____________________
- ☐ - **Shoulder Conditions** ____________________
- ☐ - **Patches / Pavement Repairs** ____________________

____________ ____________________

____________ ____________________

____________ ____________________

____________ ____________________

6. How do you scale the severity and density for each type of surface distresses?
(e.g. on a scale of 1:10 for severity and density or combine them on one scale)

	Severity Scale:	Density Scale:	Combined Scale:
☐ - Longitudinal Cracking			
☐ - Transverse Cracking			
☐ - Rutting			
☐ - Local defects			
☐ - Pot Holes			
☐ - Others, please specify			

___

___

___

7. - Do you combine all the surface condition distresses' scales in one composite index?

☐ Yes ☐ No

If yes to the previous question, please briefly describe how do you combine them
(e.g. using specific weight for each type and apply these weights into an equation)

___

___

___

___

8. Is there a special computer software that your organization uses for managing surface condition data? Is it developed in house or commercially available? Please describe its main features.

____

____

____

____

____

9. How do you use surface condition data in your pavement management system ? (e.g. do you use any decision making support tool to assign the appropriate maintenance alternative to the segment built on the surface condition data), please explain.

____

____

____

____

____

10. Do you have technical manuals or any other references which could be helpful in the following five areas? Please tell us about them, and if it is possible to get a hard or electronic copy of each, we are also willing to share our information with your organization.

1- - Segmentation and gauging length _______________

2- - Surface distresses measurement _______________

3- - Surface condition scaling and composite index _______________

4- - Assigning maintenance alternatives _______________

5- - Others, please specify

11. Do you use the surface condition data for predicting future needs of the primary highway network? Is it part of your current pavement management system or do you plan to add it in the future? Please explain briefly.

____

____

____

____

12. General comments and / or questions.

____

____

____

____

____

____

Would you like to receive a copy of the survey results?

☐ No ☐ Yes Send to:

____

____

____

Thank you for your co-operation. We would like to continue networking with you.

Appendix (8)

Members of AT&U Pavement Experts Committee

COMMITTEE MEMBERS

Name	Title
Darrell Camplin, RET	Regional Director, Lethbridge District.
Terry Carter, RET	Operations Manager, Edson District.
Vijay Ghai, P. Eng.	Surfacing Standards Specialist.
Ted Harrison, P. Eng.	Materials Engineer, Technical Standards.
Les Hempsey, P. Eng.	Project Director, N-S Trail Corridor.
Rick Kowalik, RET	Infrastructure Systems Technologist.
Moh Lali, P. Eng.	Director, Maintenance, Specifications, and Traffic Operations.
Steve Otto, P. Eng.	Roadway Preservation Engineer.
Jane Stoeck, P. Eng.	Infrastructure Management System (IMS) Project Manager.
Terry Willis, P. Eng.	Director, Materials and Technical Services.

Appendix (9)

The Knowledge Capturing Questionnaire

A. Distress definitions

Do you agree with these definitions for each type of pavement surface distresses? If not, please write your suggested definition.

1 **Longitudinal Wheel Track Cracking**
Cracks, which follow a path, parallel to the pavement centerline and located at one of the wheel-tracks.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

2 **Non-wheel Track Longitudinal Cracking**
Cracks, which follow a path, parallel to the pavement centerline and are located out of the wheel tracks. They can be construction joint cracking, center line cracking, or shoulder line cracking

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

3 **Meander Cracking**
Cracks which cross the highway randomly. They are usually short cracks up to 5.0 m long.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

4 **Pavement Edge Cracking**

Cracks which occur parallel to and within 60 cm of the pavement edge. They appear only in roads with unpaved shoulders.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

5 **Block or Map Cracking**

Cracks that divide the pavement into rectangular blocks. The blocks can vary in size from 0.1 sq. m to 10 sq. m.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

6 **Transverse Cracking**

Cracks that are perpendicular to the pavement centerline.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

7 **Fatigue or Alligator Cracking**

Cracks usually occur in the wheel path areas that are subjected to repeated traffic loads. They start as a series of interconnected longitudinal cracks and develop into a chicken wire or alligator pattern later on.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

8 **Bleeding or Flushing**

The appearance of excess bituminous binder on the pavement surface. Usually first seen in the wheel paths.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

9 **Ravelling or Loss of Coarse Aggregate**

The progressive loss of pavement materials from the surface downward leaving a rough pavement surface.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

10 Rutting

Longitudinal surface depressions in the wheel paths due to repeated load application.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

11 Rippling or Shoving

A series of ridges and valleys or singular and multiple waves and humps located on the pavement surface. They are usually located on hills, curves, and intersections and first appear in the wheel paths. They usually form ripples higher than the surroundin

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

12 Distortion

Any deviation of the pavement surface from its original shape other than that described before.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

13 **Patching**

Areas of pavement failure from nay cause which has been filled or repaired. Patching has been included among surface distresses because it is a modification of the surface structure, which affects future pavement performance.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

14 **Potholes**

They are usually bowl-shaped holes of various sizes appear in the pavement surface.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

15 **Shoulder Conditions**

The condition, in general, of the pavement shoulder including Cracking, Edge separation and shoulder distortion.

☐ Yes, I agree.

☐ No, I prefer ______________________________

____

B. Distresses Assessment

Flexible pavement surface distresses might affect each of these factors. Rank the importance of these factors, in your opinion, on a scale of 1 : 3 (1 = the least important, 3 = the most important)

Driving Safety	☐
Riding Comfort	☐
Pavement Deterioration	☐

Rank the effect of the following types of distresses on the previously mentioned factors (1 = almost no effect, 10 = very effective).

Surface Distress	Driving Safety	Riding Comfort	Pave. Deterioration
1. Wheel Track Longitudinal Cracking			
2. Non-Wheel Track Longitudinal Cracking			
3. Meander Cracking			
4. Pavement Edge Cracking			
5. Transverse Cracking			
6. Block or Map Cracking			
7. Fatigue or Alligator Cracking			
8. Bleeding or Flushing			
9. Ravelling or Loss of Coarse Aggregate			
10. Rutting			
11. Rippling or Shoving			
12. Distortion			
13. Patching			
14. Potholes			
15. Shoulder Conditions			

C. Probable Causes

For each of the following distresses, select the most probable causes starting with the predominant one. You can use the causes mentioned below or write your own suggestions.

1 Wheel Track Longitudinal Cracking

a ______________________

b ______________________

c ______________________

2 Non-Wheel Track Longitudinal Cracking

a ______________________

b ______________________

c ______________________

3 Meander Cracking

a ______________________

b ______________________

c ______________________

Some of the Possible Causes:

1. **Traffic Loads.**
2. **Environmental & Climatic Factors (Freeze & Thaw, High & Low Temperatures, etc.).**
3. **Poor Drainage Conditions.**
4. **Base Type related (e.g. Soil Cement cracks).**
5. **Subgrade Type related (e.g. CH clay Problems).**
6. **Asphalt Concrete attributes.**
7. **Poor Construction technique.**

C. Probable Causes (Continued)

For each of the following distresses, select the most probable causes starting with the predominant one. You can use the causes mentioned below or write your own suggestions.

4 Transverse Cracking

a ______________________________

b ______________________________

c ______________________________

5 Block or Map Cracking

a ______________________________

b ______________________________

c ______________________________

6 Pavement Edge Cracking

a ______________________________

b ______________________________

c ______________________________

Some of the Possible Causes:

1. Traffic Loads.
2. Environmental & Climatic Factors (Freeze & Thaw, High & Low Temperatures, etc.).
3. Poor Drainage Conditions.
4. Base Type related (e.g. Soil Cement cracks).
5. Subgrade Type related (e.g. CH clay Problems).
6. Asphalt Concrete attributes.
7. Poor Construction technique.

C. Probable Causes (Continued)

For each of the following distresses, select the most probable causes starting with the predominant one. You can use the causes mentioned below or write your own suggestions.

7 Fatigue or Alligator Cracking

a ______________________________

b ______________________________

c ______________________________

8 Bleeding or Flushing

a ______________________________

b ______________________________

c ______________________________

9 Ravelling or Loss of Coarse Aggregate

a ______________________________

b ______________________________

c ______________________________

Some of the Possible Causes:

1. Traffic Loads.
2. Environmental & Climatic Factors (Freeze & Thaw, High & Low Temperatures, etc.).
3. Poor Drainage Conditions.
4. Base Type related (e.g. Soil Cement cracks).
5. Subgrade Type related (e.g. CH clay Problems).
6. Asphalt Concrete attributes.
7. Poor Construction technique.

C. Probable Causes (Continued)

For each of the following distresses, select the most probable causes starting with the predominant one. You can use the causes mentioned below or write your own suggestions.

10 Rutting

a ______________________________

b ______________________________

c ______________________________

11 Rippling or Shoving

a ______________________________

b ______________________________

c ______________________________

12 Distortion

a ______________________________

b ______________________________

c ______________________________

Some of the Possible Causes:

1. Traffic Loads.
2. Environmental & Climatic Factors (Freeze & Thaw, High & Low Temperatures, etc.).
3. Poor Drainage Conditions.
4. Base Type related (e.g. Soil Cement cracks).
5. Subgrade Type related (e.g. CH clay Problems).
6. Asphalt Concrete attributes.
7. Poor Construction technique.

C. Probable Causes (Continued)

For each of the following distresses, select the most probable causes starting with the predominant one. You can use the causes mentioned below or write your own suggestions.

13 Patching

a ______________________________

b ______________________________

c ______________________________

14 Potholes

a ______________________________

b ______________________________

c ______________________________

15 Shoulder Conditions

a ______________________________

b ______________________________

c ______________________________

Some of the Possible Causes:

1. Traffic Loads.
2. Environmental & Climatic Factors (Freeze & Thaw, High & Low Temperatures, etc.).
3. Poor Drainage Conditions.
4. Base Type related (e.g. Soil Cement cracks).
5. Subgrade Type related (e.g. CH clay Problems).
6. Asphalt Concrete attributes.
7. Poor Construction technique.

D. Distresses Measurement

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

1 Wheel Track Longitudinal Cracking

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ____________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

2 Non-Wheel Track Longitudinal Cracking

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ____________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

D. Distresses Measurement (Continued)

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

3 Meander Cracking

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

4 Pavement Edge Cracking

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

D. Distresses Measurement (Continued)

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

5 Transverse Cracking

a) Measurement Method

☐ - Total Length

☐ - Number per Test Section

☐ - Total Area

☐ - Others, please specify ____________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

6 Block or Map Cracking

a) Measurement Method

☐ - Total Length

☐ - Number per Test Section

☐ - Total Area

☐ - Others, please specify ____________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

D. Distresses Measurement (Continued)

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

7 Fatigue or Alligator Cracking

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

8 Bleeding or Flushing

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

D. Distresses Measurement (Continued)

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

9 Ravelling or Loss of Coarse Aggregate

a) Measurement Method

☐ - Total Length

☐ - Number per Test Section

☐ - Total Area

☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

10 Rutting

a) Measurement Method

☐ - Total Length

☐ - Number per Test Section

☐ - Total Area

☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

D. Distresses Measurement (Continued)

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

11 Rippling or Shoving

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ____________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

12 Distortion

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ____________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

D. Distresses Measurement (Continued)

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

13 Patching

a) Measurement Method

- ☐ - Total Length
- ☐ - Total Area
- ☐ - Number per Test Section
- ☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

14 Potholes

a) Measurement Method

- ☐ - Total Length
- ☐ - Total Area
- ☐ - Number per Test Section
- ☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

D. Distresses Measurement (Continued)

For each of the following distresses; Select the most appropriate measuring method and define the thresholds for each degree of severity and density.

15 Shoulder Conditions

a) Measurement Method

☐ - Total Length

☐ - Total Area

☐ - Number per Test Section

☐ - Others, please specify ________

b) Thresholds

Severity:

Slight (S)	
Moderate (M)	
Extreme (X)	

Density:

1 (Low)	
2 (Med.)	
3 (High)	

<u>**Appendix (10)**</u>

Visual Basic Code Used for Developing the Prototype DSS

'Form Begin:
'Open form Cost

```
Private Sub Command8_Click()
On Error GoTo Err_Command8_Click
Dim stDocName As String
Dim stLinkCriteria As String
stDocName = "Cost"
DoCmd.OpenForm stDocName, , , stLinkCriteria
Exit_Command8_Click:
Exit Sub
Err_Command8_Click:
MsgBox Err.Description
Resume Exit_Command8_Click
End Sub
```

'Close form Begin

```
Private Sub Command12_Click()
On Error GoTo Err_Command12_Click
DoCmd.Close
Exit_Command12_Click:
Exit Sub
Err_Command12_Click:
MsgBox Err.Description
Resume Exit_Command12_Click
End Sub
```

'Form Cost
'Close form Cost

```
Private Sub Command11_Click()
On Error GoTo Err_Command11_Click
DoCmd.Close
Exit_Command11_Click:
Exit Sub
Err_Command11_Click:
MsgBox Err.Description
Resume Exit_Command11_Click
End Sub
```

'Go to Previous record

```
Private Sub Command12_Click()
On Error GoTo Err_Command12_Click
DoCmd.GoToRecord , , acPrevious
Exit_Command12_Click:
Exit Sub
Err_Command12_Click:
MsgBox Err.Description
Resume Exit_Command12_Click
End Sub
```

```
'Go to next Record
        Private Sub Command13_Click()
        On Error GoTo Err_Command13_Click
        DoCmd.GoToRecord , , acNext
        Exit_Command13_Click:
        Exit Sub
        Err_Command13_Click:
        MsgBox Err.Description
        Resume Exit_Command13_Click
        End Sub
'Open form Start
        Private Sub Command14_Click()
        On Error GoTo Err_Command14_Click
        Dim stDocName As String
        Dim stLinkCriteria As String
        stDocName = "Start"
        DoCmd.OpenForm stDocName, , , stLinkCriteria
'Fill Table Treatments:
'Clear Table
        CurrentDb.Execute ("Delete * from Treatment")
'Define Variables
        Dim SourceRS As Recordset
        Dim TargetRS As Recordset
        Dim Highway As Long
        Dim ContSec As Long
        Dim Start As Double
        Dim Finish As Double
        Dim CrackTreat1 As String
        Dim CrackTreat2 As String
        Dim CrackTreat3 As String
        Dim CrackPriority1 As Double
        Dim CrackPriority2 As Double
        Dim CrackPriority3 As Double
        Dim TCrackTreat1 As String
        Dim TCrackTreat2 As String
        Dim TCrackTreat3 As String
        Dim TCrackPriority1 As Double
        Dim TCrackPriority2 As Double
        Dim TCrackPriority3 As Double
        Dim DTCrackTreat1 As String
        Dim DTCrackTreat2 As String
        Dim DTCrackTreat3 As String
        Dim DTCrackPriority1 As Double
        Dim DTCrackPriority2 As Double
        Dim DTCrackPriority3 As Double
        Dim LossofAggT1 As String
```

```
        Dim LossofAggT2 As String
        Dim LossofAggT3 As String
        Dim LossofAggP1 As Double
        Dim LossofAggP2 As Double
        Dim LossofAggP3 As Double
        Dim Bleeding As String
        Dim Potholes As String
        Dim Alligator As String
        Dim Distortion As String
        Dim Rutting As String
'Identify priority calculation variables
        Dim Criteria(3) As Double
        Dim Exp(4, 4) As Double
        Dim Dis(4, 4) As Double
        Dim Cost(4, 4) As Double
        Dim NormExp(4, 4) As Double
        Dim NormDis(4, 4) As Double
        Dim NormCost(4, 4) As Double
        Dim TotExp(4) As Double
        Dim TotDis(4) As Double
        Dim TotCost(4) As Double
        Dim VecExp(4) As Double
        Dim VecDis(4) As Double
        Dim VecCost(4) As Double
        Dim Priority(4) As Double
        Dim Yearlycost(4) As Double
        Dim I As Integer
        Dim J As Integer
'Define Criterieria Weights
          Criteria(1) = 0.167
          Criteria(2) = 0.333
          Criteria(3) = 0.5
'Start adding records
        Set SourceRS = CurrentDb.TableDefs("SCRdata").OpenRecordset
        Set TargetRS = CurrentDb.TableDefs("Treatment").OpenRecordset
        Do Until SourceRS.EOF
        Highway = SourceRS!Hwy
        ContSec = SourceRS!CS
        Start = SourceRS!From
        Finish = SourceRS!To
'Calculate Priorities
'Case 1 (Slight Cracks)
        If SourceRS!CrackScore < 5 Then
        CrackTreat1 = "No Action"
        CrackTreat2 = "No Action"
        CrackTreat3 = "No Action"
```

```
        CrackPriority1 = 0
        CrackPriority2 = 0
        CrackPriority3 = 0
        End If
'Case 2 (Moderate Cracks)
        If SourceRS!CrackScore > 4 And SourceRS!CrackScore < 8 Then
'1. Identify Comparison Matrix For Previous Experience
            Exp(1, 1) = 1
            Exp(1, 2) = 2
            Exp(1, 3) = 0.25
            Exp(2, 1) = 0.5
            Exp(2, 2) = 1
            Exp(2, 3) = 0.17
            Exp(3, 1) = 4
            Exp(3, 2) = 6
            Exp(3, 3) = 1
'Identify Comparison Matrix For Disruption
            Dis(1, 1) = 1
            Dis(1, 2) = 0.67
            Dis(1, 3) = 4
            Dis(2, 1) = 1.5
            Dis(2, 2) = 1
            Dis(2, 3) = 6
            Dis(3, 1) = 0.25
            Dis(3, 2) = 0.17
            Dis(3, 3) = 1
'Identify comparison matrix for Cost per Year
        Yearlycost(1) = DLookup("[unitprice]", "cost", "[ID] = 1") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 1")
        Yearlycost(2) = DLookup("[unitprice]", "cost", "[ID] = 2") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 2")
        Yearlycost(3) = DLookup("[unitprice]", "cost", "[ID] = 3") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 3")
        For I = 1 To 3
            For J = 1 To 3
              Cost(I, J) = Yearlycost(J) / Yearlycost(I)
            Next J
        Next I
        Calculate
'Show Results
        CrackTreat1 = DLookup("[treatment]", "cost", "[ID] = 1")
        CrackTreat2 = DLookup("[treatment]", "cost", "[ID] = 2")
        CrackTreat3 = DLookup("[treatment]", "cost", "[ID] = 3")
        CrackPriority1 = Priority(1)
        CrackPriority2 = Priority(2)
        CrackPriority3 = Priority(3)
```

```
        End If
'Case 3 Severe Cracks.
        If SourceRS!CrackScore > 7 Then
'1. Identify Comparison Matrix For Previous Experience
            Exp(1, 1) = 1
            Exp(1, 2) = 0.33
            Exp(1, 3) = 1.5
            Exp(2, 1) = 3
            Exp(2, 2) = 1
            Exp(2, 3) = 3
            Exp(3, 1) = 0.67
            Exp(3, 2) = 0.33
            Exp(3, 3) = 1
'Identify Comparison Matrix For Disruption
            Dis(1, 1) = 1
            Dis(1, 2) = 2
            Dis(1, 3) = 0.67
            Dis(2, 1) = 0.5
            Dis(2, 2) = 1
            Dis(2, 3) = 0.33
            Dis(3, 1) = 1.5
            Dis(3, 2) = 3
            Dis(3, 3) = 1
'Calculate cost / year
        Yearlycost(1) = DLookup("[unitprice]", "cost", "[ID] = 1") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 1")
        Yearlycost(2) = DLookup("[unitprice]", "cost", "[ID] = 4") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 4")
        Yearlycost(3) = DLookup("[unitprice]", "cost", "[ID] = 2") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 2")
'Identify Comparison Matrix For Cost/Year
            For I = 1 To 3
              For J = 1 To 3
                Cost(I, J) = Yearlycost(J) / Yearlycost(I)
              Next J
            Next I
        Calculate
'Show Results
        CrackTreat1 = DLookup("[treatment]", "cost", "[ID] = 1")
        CrackTreat2 = DLookup("[treatment]", "cost", "[ID] = 4")
        CrackTreat3 = DLookup("[treatment]", "cost", "[ID] = 2")
        CrackPriority1 = Priority(1)
        CrackPriority2 = Priority(2)
        CrackPriority3 = Priority(3)
        End If
```

```
'Case 4 No Transverse Cracks
        If SourceRS!TCrackScore = 0 Then
        'Show Results
        TCrackTreat1 = "No Action"
        TCrackTreat2 = "No Action"
        TCrackTreat3 = "No Action"
        TCrackPriority1 = 0
        TCrackPriority2 = 0
        TCrackPriority3 = 0
        End If
'Case 5 Slight and Moderate Transverse Cracks
        If SourceRS!TCrackScore > 0 And SourceRS!TCrackScore < 8 Then
'1. Identify Comparison Matrix For Previous Experience
        Exp(1, 1) = 1
        Exp(1, 2) = 2
        Exp(1, 3) = 0.25
        Exp(2, 1) = 0.5
        Exp(2, 2) = 1
        Exp(2, 3) = 0.17
        Exp(3, 1) = 4
        Exp(3, 2) = 6
        Exp(3, 3) = 1

'Identify Comparison Matrix For Disruption
        Dis(1, 1) = 1
        Dis(1, 2) = 0.67
        Dis(1, 3) = 4
        Dis(2, 1) = 1.5
        Dis(2, 2) = 1
        Dis(2, 3) = 6
        Dis(3, 1) = 0.25
        Dis(3, 2) = 0.17
        Dis(3, 3) = 1
'Calculate cost / year
        Yearlycost(1) = DLookup("[unitprice]", "cost", "[ID] = 1") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 1")
        Yearlycost(2) = DLookup("[unitprice]", "cost", "[ID] = 2") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 2")
        Yearlycost(3) = DLookup("[unitprice]", "cost", "[ID] = 3") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 3")
'Identify Comparison Matrix For Cost/Year
            For I = 1 To 3
              For J = 1 To 3
                Cost(I, J) = Yearlycost(J) / Yearlycost(I)
              Next J
            Next I
```

```
        Calculate
'Show Results
        TCrackTreat1 = DLookup("[treatment]", "cost", "[ID] = 1")
        TCrackTreat2 = DLookup("[treatment]", "cost", "[ID] = 2")
        TCrackTreat3 = DLookup("[treatment]", "cost", "[ID] = 3")
        TCrackPriority1 = Priority(1)
        TCrackPriority2 = Priority(2)
        TCrackPriority3 = Priority(3)
        End If
'Case 6 Extreme Transverse Cracks
        If SourceRS!TCrackScore > 7 Then
'1. Identify Comparison Matrix For Previous Experience
          Exp(1, 1) = 1
          Exp(1, 2) = 0.33
          Exp(1, 3) = 3
          Exp(2, 1) = 3
          Exp(2, 2) = 1
          Exp(2, 3) = 9
          Exp(3, 1) = 0.33
          Exp(3, 2) = 0.11
          Exp(3, 3) = 1
'Identify Comparison Matrix For Disruption
          Dis(1, 1) = 1
          Dis(1, 2) = 3
          Dis(1, 3) = 9
          Dis(2, 1) = 0.33
          Dis(2, 2) = 1
          Dis(2, 3) = 3
          Dis(3, 1) = 0.11
          Dis(3, 2) = 0.33
          Dis(3, 3) = 1
'Calculate cost / year
        Yearlycost(1) = DLookup("[unitprice]", "cost", "[ID] = 1") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 1")
        Yearlycost(2) = DLookup("[unitprice]", "cost", "[ID] = 4") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 4")
        Yearlycost(3) = DLookup("[unitprice]", "cost", "[ID] = 5") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 5")
'Identify Comparison Matrix For Cost/Year
          For I = 1 To 3
            For J = 1 To 3
              Cost(I, J) = Yearlycost(J) / Yearlycost(I)
            Next J
          Next I
         Calculate
        'Show Results
```

```
        TCrackTreat1 = DLookup("[treatment]", "cost", "[ID] = 1")
        TCrackTreat2 = DLookup("[treatment]", "cost", "[ID] = 4")
        TCrackTreat3 = DLookup("[treatment]", "cost", "[ID] = 5")
        TCrackPriority1 = Priority(1)
        TCrackPriority2 = Priority(2)
        TCrackPriority3 = Priority(3)
        End If
'Case 7 No Depressed Transverse Cracks
        If SourceRS!DTCrackScore < 2 Then
        'Show Results
          DTCrackTreat1 = "No Action"
          DTCrackTreat2 = "No Action"
          DTCrackTreat3 = "No Action"
          DTCrackPriority1 = 0
          DTCrackPriority2 = 0
          DTCrackPriority3 = 0
        End If
'Case 8 Slight Depressed Transverse Cracks
        If SourceRS!DTCrackScore > 1 And SourceRS!DTCrackScore < 5 Then
'1. Identify Comparison Matrix For Previous Experience
          Exp(1, 1) = 1
          Exp(1, 2) = 2
          Exp(1, 3) = 0.25
          Exp(2, 1) = 0.5
          Exp(2, 2) = 1
          Exp(2, 3) = 0.17
          Exp(3, 1) = 4
          Exp(3, 2) = 6
          Exp(3, 3) = 1
'Identify Comparison Matrix For Disruption
          Dis(1, 1) = 1
          Dis(1, 2) = 0.67
          Dis(1, 3) = 4
          Dis(2, 1) = 1.5
          Dis(2, 2) = 1
          Dis(2, 3) = 6
          Dis(3, 1) = 0.25
          Dis(3, 2) = 0.17
          Dis(3, 3) = 1
'Calculate cost / year
        Yearlycost(1) = DLookup("[unitprice]", "cost", "[ID] = 1") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 1")
        Yearlycost(2) = DLookup("[unitprice]", "cost", "[ID] = 2") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 2")
        Yearlycost(3) = DLookup("[unitprice]", "cost", "[ID] = 3") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 3")
```

```
'Identify Comparison Matrix For Cost/Year
        For I = 1 To 3
          For J = 1 To 3
            Cost(I, J) = Yearlycost(J) / Yearlycost(I)
          Next J
        Next I
      Calculate
      'Show Results
      DTCrackTreat1 = DLookup("[treatment]", "cost", "[ID] = 1")
      DTCrackTreat2 = DLookup("[treatment]", "cost", "[ID] = 2")
      DTCrackTreat3 = DLookup("[treatment]", "cost", "[ID] = 3")
      DTCrackPriority1 = Priority(1)
      DTCrackPriority2 = Priority(2)
      DTCrackPriority3 = Priority(3)
      End If
'Case 9 Moderate and Extreme Depressed Transverse Cracks
      If SourceRS!DTCrackScore > 4 Then
'1. Identify Comparison Matrix For Previous Experience
        Exp(1, 1) = 1
        Exp(1, 2) = 0.25
        Exp(1, 3) = 0.2
        Exp(2, 1) = 4
        Exp(2, 2) = 1
        Exp(2, 3) = 0.67
        Exp(3, 1) = 5
        Exp(3, 2) = 1.5
        Exp(3, 3) = 1
'Identify Comparison Matrix For Disruption
        Dis(1, 1) = 1
        Dis(1, 2) = 0.2
        Dis(1, 3) = 0.5
        Dis(2, 1) = 5
        Dis(2, 2) = 1
        Dis(2, 3) = 2.5
        Dis(3, 1) = 2
        Dis(3, 2) = 4
        Dis(3, 3) = 1
'Calculate cost / year
      Yearlycost(1)   =   DLookup("[unitprice]",   "cost",   "[ID]   =   5")   /
      DLookup("[expectedservicelife]", "cost", "[ID] = 5")
      Yearlycost(2)   =   DLookup("[unitprice]",   "cost",   "[ID]   =   4")   /
      DLookup("[expectedservicelife]", "cost", "[ID] = 4")
      Yearlycost(3)   =   DLookup("[unitprice]",   "cost",   "[ID]   =   6")   /
      DLookup("[expectedservicelife]", "cost", "[ID] = 6")
'Identify Comparison Matrix For Cost/Year
        For I = 1 To 3
```

```
      For J = 1 To 3
        Cost(I, J) = Yearlycost(J) / Yearlycost(I)
      Next J
    Next I
  Calculate
  'Show Results
  DTCrackTreat1 = DLookup("[treatment]", "cost", "[ID] = 5")
  DTCrackTreat2 = DLookup("[treatment]", "cost", "[ID] = 4")
  DTCrackTreat3 = DLookup("[treatment]", "cost", "[ID] = 6")
  DTCrackPriority1 = Priority(1)
  DTCrackPriority1 = Priority(2)
  DTCrackPriority1 = Priority(3)
  End If
'Case 10 Potholes
  If SourceRS!PotholeScore < 8 Then
  Potholes = "No Action"
  Else
  Potholes = "You can Apply (Manual Throw and Roll)or Spray Patch to Fill the
  Potholes"
  End If
'Case 11 Bleeding
  If SourceRS!BleedingScore < 8 Then
  Bleeding = "No Action"
  Else
  Bleeding = "You Need to Apply (Skid Resistance Test) to the Segment"
  End If
'Case 12 Alligator Cracks
  If SourceRS!AlligatorCrackScore < 8 Then
  Alligator = "No Action"
  Else
  Alligator = "You Need to Apply Structural Adequacy Test (FWD) to the
  Segment"
  End If
'Case 13 Distortion
  If SourceRS!DistortionScore < 8 Then
  Distortion = "No Action"
  Else
  Distortion = "You Need to Apply Soil Investigation Test to the Segment"
  End If
'Case 14 Rutting
  If SourceRS!RuttScore < 5 Then
  Rutting = "No Action"
  Else
  Rutting = "You Need to Apply Structural Adequacy Test (FWD) to the Segment"
  End If
'Case 15(Loss of Aggregate with Slight Severity)
```

```
        If SourceRS!LossofAggregateScore < 5 Then
        'Show Results
        LossofAggT1 = "No Action"
        LossofAggT2 = "No Action"
        LossofAggT3 = "No Action"
        End If
'Case 16(Loss of Aggregate with Moderate and Extreme Severity)
        If SourceRS!LossofAggregateScore > 4 Then
'1. Identify Comparison Matrix For Previous Experience
            Exp(1, 1) = 1
            Exp(1, 2) = 0.14
            Exp(1, 3) = 0.11
            Exp(2, 1) = 7
            Exp(2, 2) = 1
            Exp(2, 3) = 0.8
            Exp(3, 1) = 9
            Exp(3, 2) = 1.25
            Exp(3, 3) = 1
'Identify Comparison Matrix For Disruption
            Dis(1, 1) = 1
            Dis(1, 2) = 9
            Dis(1, 3) = 9
            Dis(2, 1) = 0.11
            Dis(2, 2) = 1
            Dis(2, 3) = 1
            Dis(3, 1) = 0.11
            Dis(3, 2) = 1
            Dis(3, 3) = 1
'Calculate cost / year
        Yearlycost(1) = DLookup("[unitprice]", "cost", "[ID] = 7") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 7")
        Yearlycost(2) = DLookup("[unitprice]", "cost", "[ID] = 8") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 8")
        Yearlycost(3) = DLookup("[unitprice]", "cost", "[ID] = 9") /
        DLookup("[expectedservicelife]", "cost", "[ID] = 9")
'Identify Comparison Matrix For Cost/Year
            For I = 1 To 3
              For J = 1 To 3
                Cost(I, J) = Yearlycost(J) / Yearlycost(I)
              Next J
            Next I
        Calclate
'Show Results
        LossofAggT1 = DLookup("[treatment]", "cost", "[ID] = 7")
        LossofAggT2 = DLookup("[treatment]", "cost", "[ID] = 8")
        LossofAggT3 = DLookup("[treatment]", "cost", "[ID] = 9")
```

```
        LossofAggP1 = Priority(1)
        LossofAggP2 = Priority(2)
        LossofAggP3 = Priority(3)
        End If
'Add Records to the Table
        TargetRS.AddNew
        TargetRS!Hwy = Highway
        TargetRS!CS = ContSec
        TargetRS!From = Start
        TargetRS!To = Finish
        TargetRS!CrackT1 = CrackTreat1
        TargetRS!CrackT2 = CrackTreat2
        TargetRS!CrackT3 = CrackTreat3
        TargetRS!CrackP1 = CrackPriority1
        TargetRS!CrackP2 = CrackPriority2
        TargetRS!CrackP3 = CrackPriority3
        TargetRS!TCrackT1 = TCrackTreat1
        TargetRS!TCrackT2 = TCrackTreat2
        TargetRS!TCrackT3 = TCrackTreat3
        TargetRS!TCrackP1 = TCrackPriority1
        TargetRS!TCrackP2 = TCrackPriority2
        TargetRS!TCrackP3 = TCrackPriority3
        TargetRS!DTCrackT1 = DTCrackTreat1
        TargetRS!DTCrackT2 = DTCrackTreat2
        TargetRS!DTCrackT3 = DTCrackTreat3
        TargetRS!DTCrackP1 = DTCrackPriority1
        TargetRS!DTCrackP2 = DTCrackPriority2
        TargetRS!DTCrackP3 = DTCrackPriority3
        TargetRS!LoAGGT1 = LossofAggT1
        TargetRS!LoAGGT2 = LossofAggT2
        TargetRS!LoAGGT3 = LossofAggT3
        TargetRS!LoAGGP1 = LossofAggP1
        TargetRS!LoAGGP2 = LossofAggP2
        TargetRS!LoAGGP3 = LossofAggP3
        TargetRS!BleedingTreat = Bleeding
        TargetRS!PotholesTreat = Potholes
        TargetRS!AlligatorTreat = Alligator
        TargetRS!DistortionTreat = Distortion
        TargetRS!RuttingTreat = Rutting
'Update the Table
        TargetRS.UPdate
        TargetRS.AddNew
        SourceRS.MoveNext
        Loop
        Exit_Command14_Click:
           Exit Sub
```

```
        Err_Command14_Click:
            MsgBox Err.Description
            Resume Exit_Command14_Click
        End Sub
```

Module Calculate

```
Public Sub Calculate
'Calculate Summation of Columns for Experience criteria
            For I = 1 To 3
                TotExp(I) = Exp(1, I) + Exp(2, I) + Exp(3, I)
            Next I
'Calculate Normalized Matrix
            For J = 1 To 3
                For I = 1 To 3
                    NormExp(I, J) = Exp(I, J) / TotExp(J)
                Next I
            Next J
'Calculate Experience Eigenvector
            For I = 1 To 3
            VecExp(I) = (NormExp(I, 1) + NormExp(I, 2) + NormExp(I, 3)) / 3
    Next I
'Calculate Summation of Columns for Disruption Criteria
            For I = 1 To 3
                TotDis(I) = Dis(1, I) + Dis(2, I) + Dis(3, I)
            Next I
'Calculate Normalized Matrix
            For J = 1 To 3
                For I = 1 To 3
                    NormDis(I, J) = Dis(I, J) / TotDis(J)
                Next I
            Next J
'Calculate Disruption Eigenvector
            For I = 1 To 3
            VecDis(I) = (NormDis(I, 1) + NormDis(I, 2) + NormDis(I, 3)) / 3
            Next I
'Calculate Summation of Columns for cost / year criteria
            For I = 1 To 3
                TotCost(I) = Cost(1, I) + Cost(2, I) + Cost(3, I)
            Next I
'Calculate Normalized Matrix
            For J = 1 To 3
                For I = 1 To 3
                    NormCost(I, J) = Cost(I, J) / TotCost(J)
                Next I
            Next J
```

```
'Calculate Cost / Year Eigenvector
        For I = 1 To 3
        VecCost(I) = (NormCost(I, 1) + NormCost(I, 2) + NormCost(I, 3)) / 3
        Next I
'Calculate Final Priority
        For I = 1 To 3
          Priority(I) = (Criteria(3) * VecExp(I) + Criteria(1) * VecDis(I) + Criteria(2)
* VecCost(I))
        Next I
      End Sub
```

'Form Segment Surface Condition

```
'Calculate Average IRI
      Private Sub Form_Open(Cancel As Integer)
      'If Count("[AverageIRIforSegment]") > 1 Then
            AveIRI.Caption = DLookup("[AverageIRI]","[AverageIRIforSegment]")
      End If
'Identify segment surface condition based on SCI
      SCI.SetFocus
      If SCI.Text <= 36 Then
            Cond.Caption = "Excellent Condition"
      Else
      If SCI.Text > 36 And SCI.Text <= 244 Then
            Cond.Caption = "Acceptable Condition"
      Else
      If SCI.Text > 244 Then
            Cond.Caption = "Poor Condition"
            MsgBox "The specified segment is a Rehabilitation Candidate. You might
            count for General Treatment", vbExclamation, "Warning"
            General.Visible = True
      End If
      End If
      End If
      Treatments.SetFocus
      End Sub
```

'Form Reports

```
Private Sub Command1_Click()
      On Error GoTo Err_Command1_Click
      Dim stDocName As String
      stDocName = "ESAL"
      DoCmd.OpenReport stDocName, acPreview
      Exit_Command1_Click:
      Exit Sub
      Err_Command1_Click:
      MsgBox Err.Description
      Resume Exit_Command1_Click
```

```
End Sub
Private Sub Command7_Click()
        On Error GoTo Err_Command7_Click
        Dim stDocName As String
        stDocName = "Seg Surf Cond"
        DoCmd.OpenReport stDocName, acPreview
        Exit_Command7_Click:
        Exit Sub
        Err_Command7_Click:
        MsgBox Err.Description
        Resume Exit_Command7_Click
End Sub
Private Sub Command8_Click()
        On Error GoTo Err_Command8_Click
        Dim stDocName As String
        stDocName = "SegTreat"
        DoCmd.OpenReport stDocName, acPreview
        Exit_Command8_Click:
        Exit Sub
        Err_Command8_Click:
        MsgBox Err.Description
        Resume Exit_Command8_Click
        End Sub

Private Sub Command11_Click()
        On Error GoTo Err_Command11_Click
        DoCmd.Close
        Exit_Command11_Click:
        Exit Sub
        Err_Command11_Click:
        MsgBox Err.Description
        Resume Exit_Command11_Click
End Sub
Private Sub Command12_Click()
        On Error GoTo Err_Command12_Click
        Dim stDocName As String
        Dim stLinkCriteria As String
        stDocName = "Start"
        DoCmd.OpenForm stDocName, , , stLinkCriteria
        Exit_Command12_Click:
        Exit Sub
        Err_Command12_Click:
        MsgBox Err.Description
        Resume Exit_Command12_Click
End Sub
```

Appendix (11)

The SQL Statements used for Developing the Prototype DSS

1) Prepare the DSS Database

```
SELECT [IRI data].HWY, [IRI data].CS, [IRI data].From, [IRI data].To, [IRI
data].IRI, [Inventory data].Age, [Inventory data].Pavement, [Inventory data].Soil,
[Inventory data].[Clim Region], [Inventory data].ESAL, [Inventory data].AADT INTO
First
FROM [Inventory data], [IRI data]
WHERE ((([IRI data].HWY)=[Inventory data]![HWY]) AND (([IRI
data].CS)=[Inventory data]![CS]) AND (([IRI data].From)>=[Inventory data]![from])
AND (([IRI data].To)<=[Inventory data]![To]))
ORDER BY [IRI data].HWY, [IRI data].CS, [IRI data].From, [IRI data].To;
```

```
SELECT First.HWY, First.CS, First.From, First.To, First.IRI, First.Age,
First.Pavement, First.Soil, First.[Clim Region], First.ESAL, First.AADT, [SCR
data].[Rutt Score], [SCR data].[TCrack Score], [SCR data].[Crack Score], [SCR
data].[Distortion Score], [SCR data].[Bleeding Score], [SCR data].[Loss of Aggregate
Score], [SCR data].[Pothole Score], [SCR data].SCI INTO DSS
FROM First, [SCR data]
WHERE (((First.HWY)=[SCR data]![Hwy]) AND ((First.CS)=[SCR data]![CS]) AND
((First.From)>=[SCR data]![From]) AND ((First.To)<=[SCR data]![To]));
```

2) Calculate Age for All Segments

```
SELECT [Inventory data].HWY, [Inventory data].CS, [Inventory data].Dirction,
[Inventory data].from, [Inventory data].To, [Inventory data].[Yr of Constr], [Inventory
data].[Yr of Rehab], 1999-[Inventory data]![Yr of Rehab] AS Age, [Inventory
data].Pavement, [Inventory data].Soil, [Inventory data].[Clim Region], [Inventory
data].ESAL, [Inventory data].AADT INTO Inventory
FROM [Inventory data];
```

3) Calculate Average IRI for One Segment

```
SELECT DSS.HWY, DSS.CS, DSS.From, DSS.To, DSS.IRI, DSS.Age,
DSS.Pavement, DSS.Soil, DSS.[Clim Region], DSS.ESAL, DSS.[Rutt Score],
DSS.[TCrack Score], DSS.[Crack Score], DSS.[Distortion Score], DSS.[Bleeding
Score], DSS.[Loss of Aggregate Score], DSS.[Pothole Score], DSS.SCI
    FROM DSS
    WHERE (((DSS.HWY)=[Forms]![SegSurfCond]![Hwy]) AND
((DSS.CS)=[Forms]![SegSurfCond]![CS]) AND
((DSS.From)>[Forms]![SegSurfCond]![From]) AND
((DSS.To)<[Forms]![SegSurfCond]![To]));
```

```
SELECT Avg([Segment Attributes]![IRI]) AS AverageIRI
FROM [SCR data], [Segment Attributes];
```

4) Assign Segment Treatments

```
SELECT Treatment.Hwy, Treatment.CS, Treatment.From, Treatment.To,
Treatment.CrackT1, Treatment.CrackT2, Treatment.CrackT3, Treatment.CrackP1,
Treatment.CrackP2, Treatment.CrackP3, Treatment.TCrackT1, Treatment.TCrackT2,
Treatment.TCrackT3, Treatment.TCrackP1, Treatment.TCrackP2,
Treatment.TCrackP3, Treatment.DTCrackT1, Treatment.DTCrackT2,
Treatment.DTCrackT3, Treatment.DTCrackP1, Treatment.DTCrackP2,
Treatment.LoAggT1, Treatment.DTCrackP3, Treatment.LoAggT2,
Treatment.LoAggT3, Treatment.LoAggP1, Treatment.LoAggP2, Treatment.LoAggP3,
Treatment.BleedingTreat, Treatment.PotholesTreat, Treatment.AlligatorTreat,
Treatment.DistortionTreat, Treatment.RuttingTreat
FROM Treatment
WHERE (((Treatment.Hwy)=[Forms]![SegSurfCond]![Hwy]) AND
((Treatment.CS)=[Forms]![SegSurfCond]![CS]) AND
((Treatment.From)=[Forms]![SegSurfCond]![From]) AND
((Treatment.To)=[Forms]![SegSurfCond]![To]));
```

5) Select Segments within One Control Section

```
SELECT [SCR data].ID, [SCR data].Hwy, [SCR data].CS, [SCR data].From,
[SCR data].To
FROM [SCR data]
WHERE ((([SCR data].Hwy)=[Forms]![Start]![Hwy]) AND
(([SCR data].CS)=[Forms]![Start]![CS]))
```

6) Identify Segment Surface Condition Based on SCI

```
SELECT [SCR data].Hwy, [SCR data].CS, [SCR data].From, [SCR data].To,
[SCR data].Length, [SCR data].[Seg Area], [SCR data].SCI, IIf([SCR
data]![SCI]>244,"Poor",IIf([SCR data]![SCI]>36,"Good","Excellent")) AS Condition
FROM [SCR data];
```

Appendix (12)

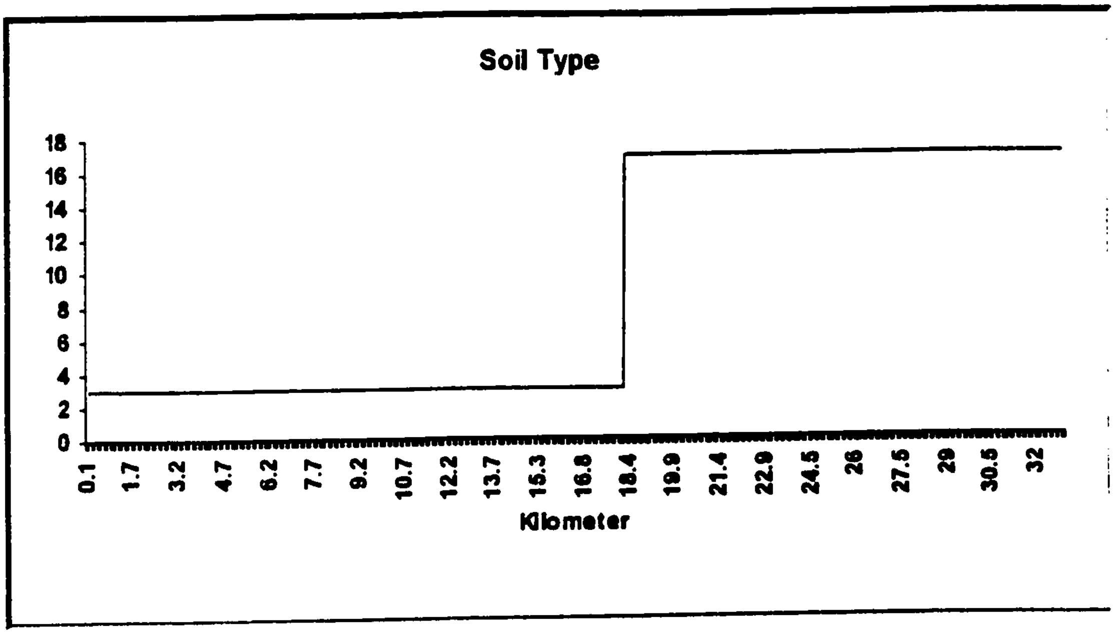
The Segment Attributes Reports

Segment Soil Type Report

Segment Data:

Highway	9	*Control Section*	14		
From (Km)	0	*To (Km)*	33.02	*Segment Length =*	33.02 *Km*

Segment Soil Type Plot:



1 = BO

2 = CH

3 = CI

4 = CI-CH

5 = CL

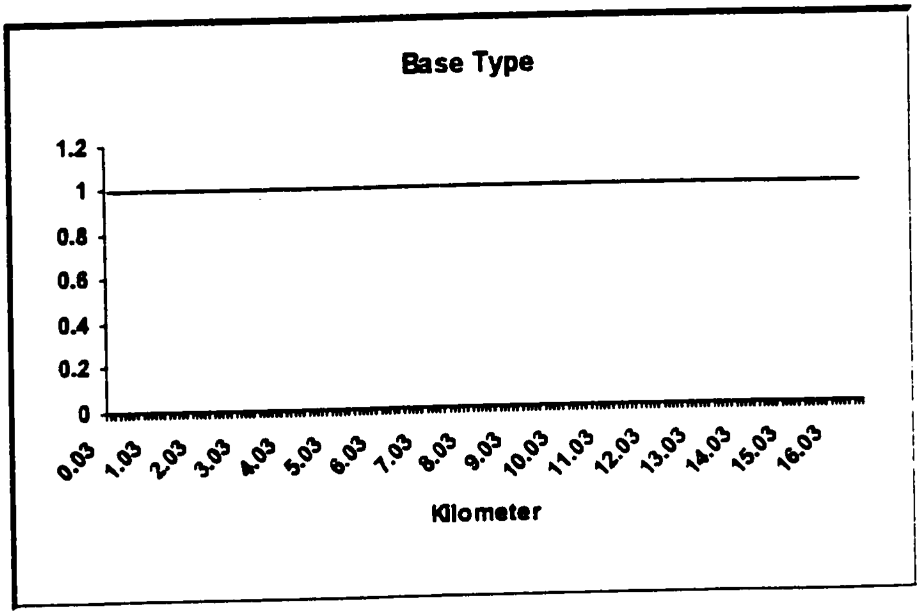
6 = CL-CI

Segment Base-type Report

Segment Data:

Highway	**14**	***Control Section***	**10**		
From (Km)	**0**	***To (Km)***	**16.78**	***Segment Length =***	**16.78** ***Km***

Segment Base-type Plot:



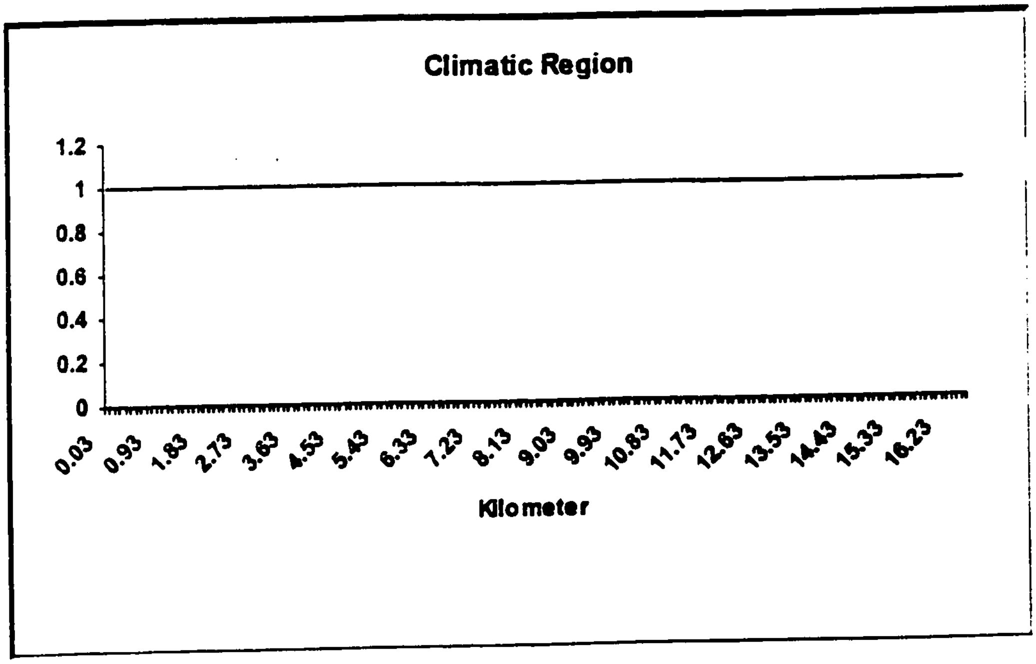
1 = GB **2 = FD** **3 = SC** **4 = CMS**

Segment Climatic-regionReport

Segment Data:

Highway	14	*Control Section*	10		
From (Km)	0	*To (Km)*	16.78	*Segment Length =*	16.78 *Km*

Segment Climatic-region Plot:



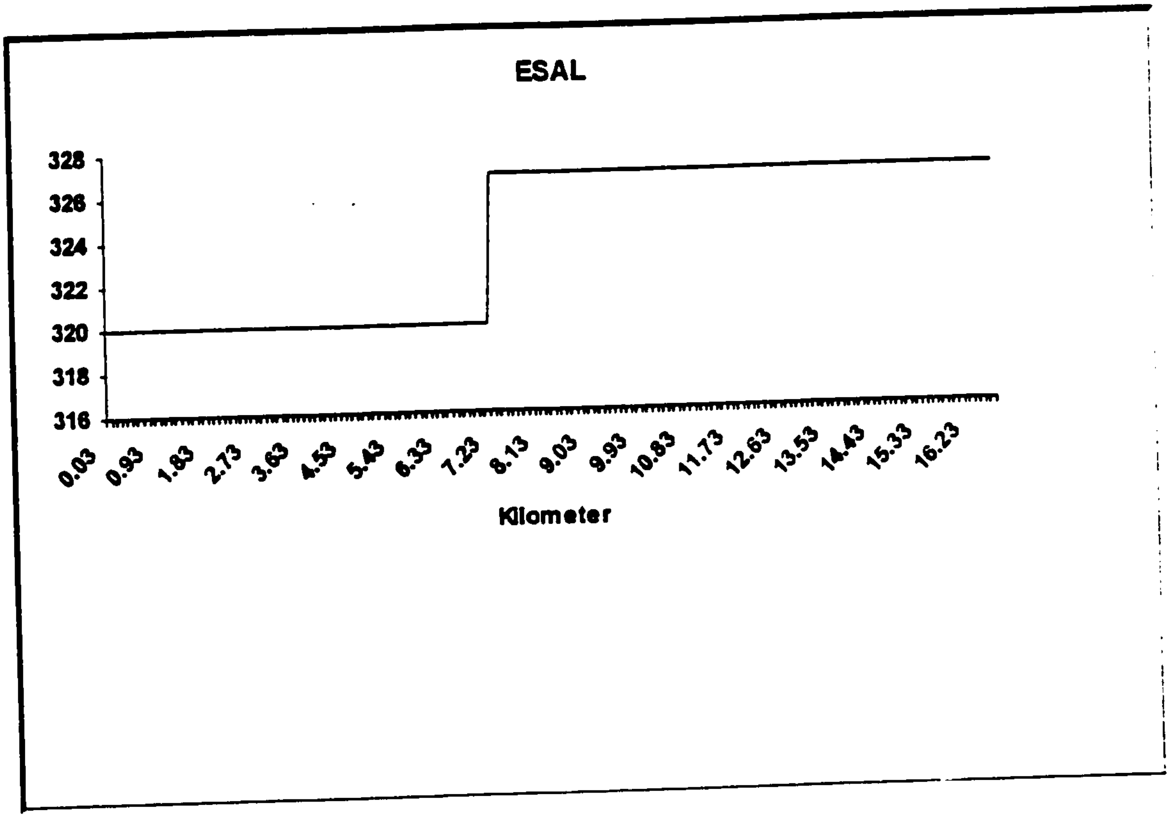
1 = Central 2 = North 3 = South

Segment ESAL Report

Segment Data:

Highway	14	Control Section	10		
From (Km)	0	To (Km)	16.78	Segment Length =	16.78 Km

Segment ESAL Plot:



Segment Age (at 1999) Report

Segment Data:

Highway	14	*Control Section*	10		
From (Km)	0	*To (Km)*	16.78	*Segment Length =*	16.78 *Km*

Segment Roughness Plot: