The Thesis Committee for JEAWON HWANG
Certifies that this is the approved version of the following thesis:

The Development of a Conceptual Framework for a District 4-Year Pavement Management Plan

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor:

____
Zhanmin Zhang

____
Michael R. Murphy

The Development of a Conceptual Framework for a District 4-Year Pavement Management Plan

by

JEAWON HWANG, B.E.

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Dedication

I would like to dedicate my thesis to my parents. Because of their love and support, I have been able to focus all of my efforts and energy into completing my thesis. I would also thank my brother, his wife, and my adorable nieces for their love and encouragement. Thank you for always being there for me. Love you always.

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Abstract

The Development of a Conceptual Framework for a District 4-Year Pavement Management Plan

Jaewon Hwang, M.S.E.

The University of Texas at Austin, 2011

Supervisor: Zhanmin Zhang

The Texas Department of Transportation (TxDOT) is concerned about the widening gap between preservation needs and available funding. Funding levels are not adequate to meet the preservation needs of the roadway network; therefore projects listed in the 4-Year Pavement Management Plan must be ranked to determine which projects should be funded now and which can be postponed until a later year. Currently, each district uses locally developed methods to rank and prioritize projects. These ranking methods have relied on less formal qualitative assessments based on engineers' subjective judgment. It is important for TxDOT to have a rational 4-Year Pavement Management Plan. The objective of this study is to develop a conceptual framework that describes the development of the 4-Year Pavement Management Plan and a proposed ranking process. It can be largely divided into three steps; (1) Network-Level preliminary project screening process, (2) Project-Level project ranking process, and (3) Economic

Analysis. A rational pavement management procedure and a project ranking method that are accepted by districts and the TxDOT administration will maximize efficiency in budget allocations and help improve pavement condition.

As a part of this study, based on the data provided by the Austin District Pavement Engineer, the Network-Level Project Screening (NLPS) tool, including the candidate project selection algorithm and the preliminary project screening matrix, is developed. The NLSP tool has been used by the Austin District Pavement Engineer (DPE) to evaluate the PMIS (Pavement Management Information System) data and to prepare a preliminary list of candidate projects for further evaluation. The automated tool will help TxDOT engineers easily incorporate the developed mathematical algorithm into their daily pavement maintenance management.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background

The Texas Transportation Commission (TTC) set a 10-year statewide goal specifying that 90 percent or more of pavements in Texas should be in good or better condition by FY 2012. District engineers and their staff are responsible for the annual condition goals set for their districts by TxDOT administration and are committed to manage pavement conditions within their budget allocation. However, the current funding for pavement preservation is insufficient to achieve the pavement condition at their goal levels. A recent study indicated that pavement revenue from FY 2010 to FY 2035 predicted by TxDOT is much less than pavement needs estimated by the 2030 Committee. Based on funding projections and the same methodology and assumptions used in the 2030 Committee's Pavement Needs study conducted by Zhang, the 90 percent "good or better" goal cannot be achieved, and pavement network conditions will deteriorate to unacceptable levels as shown in Figure 1.1 [Zhang 2009]. The TxDOT PMIS Annual Report of Condition of Texas Pavement in FY 2009 indicated the percentage of Texas pavements in good or better condition has been decreasing since FY 2005. Therefore, there is a need for an enhanced, rational pavement management plan to maintain and improve pavement conditions and extend pavement life under a given budget.

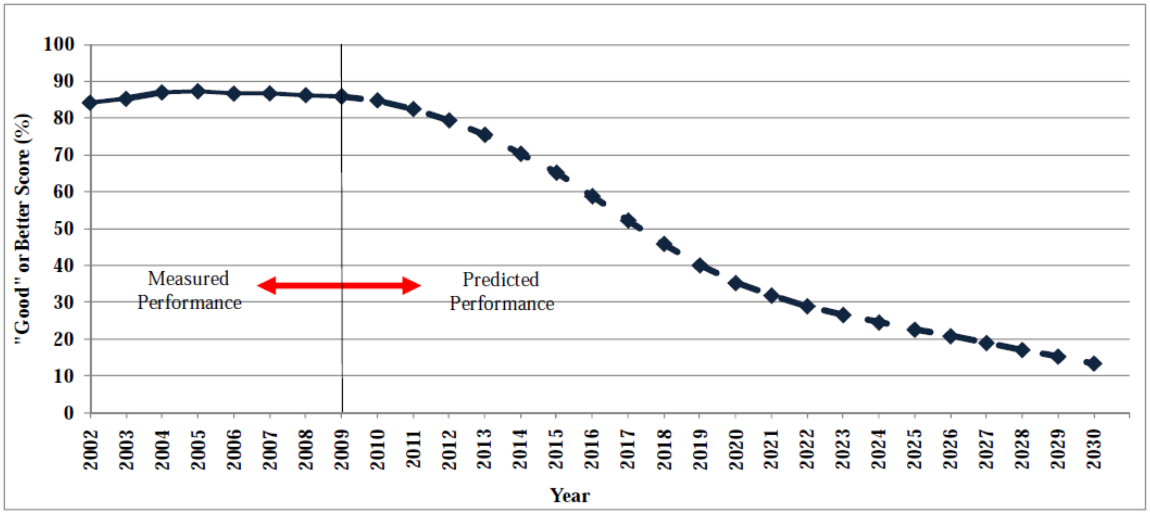


Figure 1.1: Predicted Pavement Performance Trend for FY 2009-2030 [Zhang et al. 2009]

Currently, each district must develop a 4-Year Pavement Management Plan that documents project expenditures and maintenance activities based on an allocated budget. The 25 individual district plans are combined to create the statewide 4-Year Pavement Management Plan [Gao 2011]. The plan is then reviewed, modified and approved by TxDOT administration based on district and statewide pavement network and performance goals, as well as the budget allocation.

When the developing a 4-Year Pavement Management Plan, TxDOT is concerned about the widening gap between preservation needs and available funding. Funding levels are inadequate to meet the preservation needs of the roadway network; therefore, projects listed in the 4-Year Pavement Management Plan must be ranked to determine which should be funded now and which can be postponed until a later year. Currently, each district uses locally developed methods to rank and prioritize projects. These ranking methods incorporate both quantitative and less formal, qualitative assessments based on engineers' subjective judgment. It is essential for TxDOT to have a rational pavement management procedure and a project ranking method. The objective of this study is to develop a conceptual framework that describes the development of the 4-Year Pavement Management Plan and a proposed project ranking process. The 4-Year Pavement Management Plan is evaluated at all levels from lower management to upper management. In other words, project ranking decisions require input from all organizational levels within TxDOT: by area engineers and district pavement engineers (DPEs), district engineers and their staff and TxDOT administration. Considering the flexibility for adjusting project rankings at each management level in the TxDOT organization, this study presents the 4-Year Pavement Management Plan and a ranking process developed for the Austin District that can potentially be implemented statewide. The procedure developed in this study will help engineers evaluate system conditions and prioritize pavement maintenance needs, potentially achieving the stated TTC goal.

1.2 Problem Description

TxDOT is concerned about the widening gap between preservation needs and available funding. Funding levels are not adequate to meet the preservation needs of the roadway network; therefore, projects listed in the 4-Year Pavement Management Plan must be ranked to determine which should be funded now and which can be postponed. Currently, each district uses locally developed methods to rank and prioritize projects. These ranking methods incorporate both quantitative and less formal qualitative assessments based on engineers' subjective opinions; therefore, it is important for TxDOT to have a rational pavement management procedure and a project ranking method in place. To develop a pavement management procedure that can be used statewide, a ranking method should take into account local factors that may vary with local environmental and climatic conditions within a district, from one district to another and across the state. In addition, the method should permit project rankings to be adjusted by each management level in TxDOT. This flexibility is necessary to develop a rational pavement management process.

1.3 Research Objective

The objective of this study is to develop a conceptual framework that describes the development of the 4-Year Pavement Management Plan and a proposed ranking process for candidate projects. The framework is divided into three steps: 1) a network-level preliminary project screening process; 2) a project-level project ranking process; and 3) an economic analysis. A rational pavement management procedure and a candidate project ranking method acceptable to districts and TxDOT maximizes efficiency in budget allocations and improves pavement condition. Based on data provided by the Austin DPE, a Network-Level Project Screening Tool (NLPS), including the candidate project selection algorithm and a preliminary project screening matrix, was developed for this study. The automated NLPS will help Austin District engineers to easily incorporate the developed mathematical algorithm into daily pavement maintenance management.

1.4 Scope of Work

This study provides a conceptual framework for the TxDOT Pavement Management Plan. Based on the conceptual framework, a methodology for the network-level project screening process was developed, including the candidate project selection algorithm and the preliminary project screening matrix. An implementation case study is presented. Although the development of a project-level ranking process and economic analysis is not included in this study, these components will be address in future studies.

Based on the methodologies of the candidate project selection algorithm and the preliminary project screening matrix, a Network-Level Project Screening (NLPS) tool is developed in this study. The NLPS tool is designed for implementation in the Austin District; however, the developed tool can potentially be expanded for use by other districts.

Once preliminary project lists are determined by the NLPS tool, the DPE can decide if each project is a candidate for Preventive Maintenance (PM) or Rehabilitation (Rehab) based on visual distress type and extent, structural condition and other factors. The visual distress type and extent helps determine if a project primarily has functional (candidate for PM treatment) or structural (candidate for Rehab treatment) issues.

Routine Maintenance (RM) projects are identified during the ranking process. RM projects typically consist of localized distress conditions that can be addressed by spot repairs. RM projects are identified during the candidate selection process and are further evaluated during a site visit to determine if temporary repairs are sufficient until a more intensive treatment application is planned. However, the associated ranking process and methodology for RM projects is not provided in this study.

Safety-related projects and the associated ranking process are outside the scope of this study. Safety-related projects are evaluated and ranked by TxDOT using a separate process that considers factors and decision criteria that may differ from factors associated with non-safety projects. The ranking process and the associated factors and decision criteria developed in this study are only for projects with no safety issues.

1.5 Research Organization

This study consists of Six Chapters. Chapter One introduces the background knowledge of the gap between preservation needs and available funding that TxDOT is currently experiencing. Chapter One also provides a statement of the problem in reference to developing TxDOT's 4-Year Pavement Management Plan. Chapter Two includes a literature review of general pavement maintenance management methodologies and the state of the art in developing indices for project ranking, including methods and techniques employed by other state DOTs. Chapter Three includes a discussion of developing a procedure of the 4-Year Pavement Plan based on the results of the literature review and communication with the Austin DPE. The development of a conceptual frame work for a 4-Year Pavement Plan follows in Chapter Four and includes implementation of the NLPS tool. Chapter Four discusses methodologies for developing algorithms for the candidate project selection process and preliminary project screening matrix embedded in the NLPS tool. Chapter Five validates the functionality of the NLPS tool using Bastrop County FY 2010-11 PMIS data. A concluding statement and reference to future works is in Chapter Six.

Chapter 2: Literature Review

2.1 The Current State of Pavement Maintenance Management System

Currently, maintenance management systems are undergoing significant changes due to advances in technology, especially the development of effective computational methods and applications. Many agencies have attempted to update their management system capabilities to keep pace with technological innovations. Despite these efforts, the state-of-the practice of management system still continues to lag behind the actual state of the art [Zhang 2010]. Although numerous studies of such data management and analysis techniques and related methodologies exist in literature, it is difficult to implement them in practice due to the lack of applicable data that reflects pavement performance. Although an agency may collect data using many different methods, documentation is sparse. Data may not be transferable or analyzed in an organized fashion [Moulthrop 2000]. Although many options and tools may be available in theory, they may not lead to more efficient and effective decisions than anticipated in practice. Therefore, a systematic pavement maintenance management using integrated data obtained from various systems should be implemented. The rational decision support system improves the objectiveness of decisions made and ensures the consistency of decisions made at various levels within an organization. Lytton proved that the process of systematically and objectively selecting pavement projects brings great financial benefits to agencies. Lytton found that ranking procedures can provide an agency with 20 to 40 percent more benefit than manual and subjective ranking approaches. Furthermore, an optimized ranking procedure that incorporates information from other management systems can bring another 10 to 20 percent benefit to the agencies [Zimmerman 1995] [Lytton 1994].

2.2 The Current Project Ranking Methods and Technique by Other DOTs

Most agencies use their own pavement management methodologies to select projects and decide which projects to include in their maintenance plans. Some information on ranking methodologies currently used by other DOTs is summarized as follows:

Colorado DOT uses the Surface Treatment Program (STP) based on Incremental Benefit Cost (IBC) analysis to determine project recommendations. In the STP, a network model is used to determine current pavement conditions and long-range (20- and 30-year) projections of system conditions based on variable constrained budget scenarios. The network model is then used to determine regional allocation of fund percentages. The DOT regions then use the budget allocation to perform their own optimization and project recommendations using region-specific variables. This is based on information provided in an email dated June 21, 2011 from Mr. Steve Olson, Colorado Department of Transportation.

Kansas DOT (KDOT) uses a tiered project selection method that incorporates separate prioritization and optimization processes. The prioritization process is based on a "worst first" formula that incorporates various factors including route tier classification. Prioritization of projects within tiers is followed by project optimization across tiers. Pavement data is collected annually and used to determine route location and limits for preventive maintenance and light and medium rehabilitation. Available preservation funds are allocated based on maximizing benefits from a statewide perspective. The optimization process considers three future years. Cutoff probabilities are established for each year, and candidate projects that exceed the cutoff probabilities in a given year are assigned a recommended action based on established treatment policies. This is based on information provided in an email dated June 21, 2011 from Mr. Rick Miller, Kansas Department of Transportation.

New York State DOT (NYSDOT) uses a preservation model based on pavement condition information for each roadway segment. The model assigns each pavement segment a recommended treatment based on:

- pavement type;
- Annual Average Daily Traffic (AADT);
- surface rating;
- International Roughness Index (IRI);
- dominant distress type;
- consideration of prior treatments;
- condition deterioration rate; and
- presence of curb.

The model calculates project cost, which is divided by the Vehicle Miles of Travel (VMT) to produce the cost effectiveness measure “$/VMT.” Projects are then sorted by increasing $/VMT to create a prioritized list of candidate projects. This approach pushes project selection first to low cost preservation treatments on high volume roads, then to more expensive projects on progressively lower volume roads. The running sum of total project costs is used to define the limit of what can be done working within the available budget. This is based on information provided in an email dated June 18, 2011 from the New York State Department of Transportation.

Illinois DOT (IDOT) does not have a defined, written project selection and prioritization method. For pavement treatment selection, a backlog mileage concept is used that combines a pavement distress index (Condition Rating System [CRS]), roadway type and Average Daily Traffic (ADT). Based on these criteria, all state maintained highways in Illinois are classified every year as follows:

- Backlog: repair is needed now and a significant delay will probably result in higher cost repairs being needed.
- Accruing: the pavement is not in backlog condition yet but is expected to deteriorate to that condition in five years or less.
- Adequate: the pavement needs little or no repair and will not become backlog in the next five years.

Based on this information and other criteria, each district locally evaluates and prioritizes projects. Some criteria considered include rutting, roughness, geometrics, and safety issues. A formal prioritization model is not used. A cost-benefit analysis is also not conducted; however, the department’s strategic goals are considered when developing the maintenance plan. This is based on information provided in an email dated June 21, 2011 from Jeffrey M. South, Illinois Department of Transportation.

North Carolina DOT (NCDOT) releases the State Transportation Improvement Program (STIP) for project prioritization based on a combination of quantitative data, local input and multi-modal characteristics. This process includes NCDOT's planning partners: metropolitan planning organizations (MPOs) and rural planning organizations (RPOs) and internal staff, specifically NCDOT's division (or field) offices. Quantitative data includes volume-to-capacity ratios, crash rates and pavement condition ratings. Local input is based on the top 25 priorities determined by each respective MPO, RPO and division. Multi-model characteristics address if the project benefits more than one mode of transportation such as highway, bicycling, walking, rail, ferry, aviation, or transit. The process also reflects the department's emphasis on improving system performance with respect to three goals (safety, mobility and infrastructure health) and across three system tiers (statewide, regional and sub-regional) on its 79,000-mile network. Each project is subsequently categorized and scored through a matrix weighted by goal and tier and ultimately used to rank individual projects [NCDOT 2010].

Washington State DOT (WSDOT) has fully implemented the Washington State Pavement Management System (WSPMS), a tool that not only helps identify the present needs of the state highway system but also forecasts future needs and evaluates the project selection decision. The WSPMS uses pavement structural condition (PSC) as a trigger value to identify candidate pavement projects. The PSC ranges from 0 (extensive distress) to 100 (no distress). WSDOT attempts to apply rehabilitation for pavement segments when they are projected to reach a PSC of 50. To develop a prioritized list of projects, each pavement section is applied to the pavement condition and performance curves so the WSPMS can forecast the expected time to the next rehabilitation for each section. Each candidate project is assigned to a priority group based on the expected due date. It should be noted that WSDOT considers the importance of the candidate project on AADT, so the WSPMS attempts to rehabilitate high volume routes when they are “due” and prevents them from reaching “past due” status. The WSPMS focuses on pavement preservation. One hundred percent of chip seal project that are due are programmed first. Typically, the segment has low volume with less than 2000 AADT and receives a bituminous surface treatment on a six- to eight-year cycle. The remaining funds are allocated to rehabilitation projects with PSC values between 40 and 60; nearly 90 percent of rehabilitation projects receive a two-inch overlay [FHWA 2008].

Most DOTs identified for this literature review have developed their own pavement management procedure. Only a few, such as KDOT and WSDOT, have developed a fully systematic, automated program for selecting and ranking candidate projects. Many DOTs have no defined project selection and prioritization method incorporated into their management system, nor do they have a fully developed project ranking procedure. Each ranking procedure reviewed was developed based on statewide factors and does not consider local circumstances, such as traffic level, climate, drainage, and geological/geotechnical conditions. Each procedure discussed above does not provide the flexibility for adjusting project rankings at each management level in the organization (e.g., lower management level, pavement management level and upper management level) except in the case of KDOT, which is centrally organized. At KDOT, project decisions are made in the central office rather than by regions or districts. Because it is possible that the final project rankings may be adjusted at each management level in decentralized organizations, the ranking procedure should include the flexibility to make these changes. Lastly, some DOTs require an optimization process based on benefit and cost analysis, although approaches vary. Agencies are required to have an optimization process in their pavement management program to develop a long term maintenance plan.

2.3 The 4-Year Plan Pavement Maintenance Plan -Organizational Overview

Rider 55[1] of TxDOT's Legislative Appropriation Bill requires TxDOT to provide the Legislative Budget Board (LBB) and governor a detailed plan outlining how state transportation funds are used [Gao et al. 2011]. Based on anticipated funds for the four following fiscal years, each district has developed a 4-Year Pavement Management Plan that provides a central point for comparing projects; evaluates current pavement conditions; reviews priorities; and eliminates project overlap [Gao et al. 2011]. The districts' plans are combined to create the statewide 4-Year Pavement Management Plan.

When developing the final statewide 4-Year Pavement Management Plan, input from all levels within TxDOT, including the local or lower management level, the district or pavement management level and the statewide or upper management level are required. Area engineers, maintenance supervisors and DPEs in the lower management level make the earliest determination of needs. The lower management level exerts the most effort to perform testing and conduct field surveys to determine specific pavement treatment solutions. The lower management level also prepares the draft District Pavement Management plan based on factors that address local conditions such as traffic levels; pavement type; distress types, extent and severity; maintenance costs; and drainage and geological/geotechnical conditions. The district engineer and his/her administrative staff at the pavement management level may consider many of these factors when reviewing project rankings but may include additional factors, such as cost-

[1] Rider 55 projects are planned to go contract. These projects will bring the benefits and impacts to the economy, safety, pavement quality and connectivity to the state transportation network [TxDOT 2009]

benefit impacts, project timing and public or political issues to support funding allocation. TxDOT administration then reviews and possibly modifies finalized project rankings based on funding allocations and statewide pavement network and performance goals [Gao et al. 2011].

TxDOT is decentralized, having 25 district offices. Each district selects and ranks projects based on its priority factors. For example, the Austin District begins development of the 4-Year Pavement Management Plan each year in January when the most current PMIS data is received. General direction is given to area engineers and maintenance supervisors to review roadways and submit candidate projects for the updated 4-Year Pavement Management Plan. The director of construction discusses needs such as trends and contractual issues with area engineers, and the director of maintenance discusses specific needs such as pavement preservation strategies with maintenance supervisors. Then all committees, including the director of construction, director of maintenance and the DPEs review the PMIS data and previous PM project performance data and discuss the overall district strategy along with their specific concerns. The committees use a matrix for selecting and ranking projects based on pavement age, condition score, skid score, and ADT when developing the 4-Year Pavement Management Plan that's submitted to TxDOT. Based on discussions with committee members, the matrix is a sufficient way to prioritize pavement projects, but there is concern that the matrix does not fully characterize pavement conditions or diagnose treatments.

TxDOT has no recommended standard procedure for selecting and ranking projects. Each district has its own prioritization procedure with less formal assessments based on engineers' subjective opinions and experience. To develop a rational, transparent, effective, statewide 4-Year Pavement Management Plan, it is important for districts to have a logical and systematic procedure in place to maximize efficiency given budget constraints. The 4-Year Pavement Management Plan ranking process should also incorporate the ability for input, adjustment, and documentation of project rankings at each level of management. This flexibility is necessary in the decision-making process regarding both individual projects and the entire pavement network. This study acknowledges the importance of the ability to adjust project rankings based on additional information or factors brought into the decision process at each level of TxDOT management. The enhanced ranking process developed in this study can be used by all management levels within TxDOT. Therefore, it can help engineers evaluate and prioritize projects and can also potentially be used to assist in allocating funds.

Chapter 3: Research Methodology

3.1 The 4-Year Plan Pavement Maintenance Plan – Organizational Overview

Each district has developed a 4-Year plan based on analysis of pavement conditions within its area. The 25 individual district plans are then combined to create a statewide 4-Year Pavement Management Plan for review by TxDOT administration. It is essential for pavement managers and decision makers at every level in TxDOT to understand this process. It is also important that the project ranking procedure be easy to explain and supported by subject matter experts and the public.

The pavement management plan proposed in this thesis is developed based on a comprehensive ranking process that can be used by at different management levels. The plan development process ranking tool allows engineers to select different factors to be considered when ranking projects, as well as the ability to adjust the weight of each factor given local circumstances.

The systematically developed 4-Year Pavement Management Plan helps pavement engineers easily incorporate a comprehensive ranking procedure into their daily pavement maintenance management. It will also help TxDOT administration allocate funds to districts more efficiently.

3.2 Development of a Conceptual Framework for a Pavement Management Plan

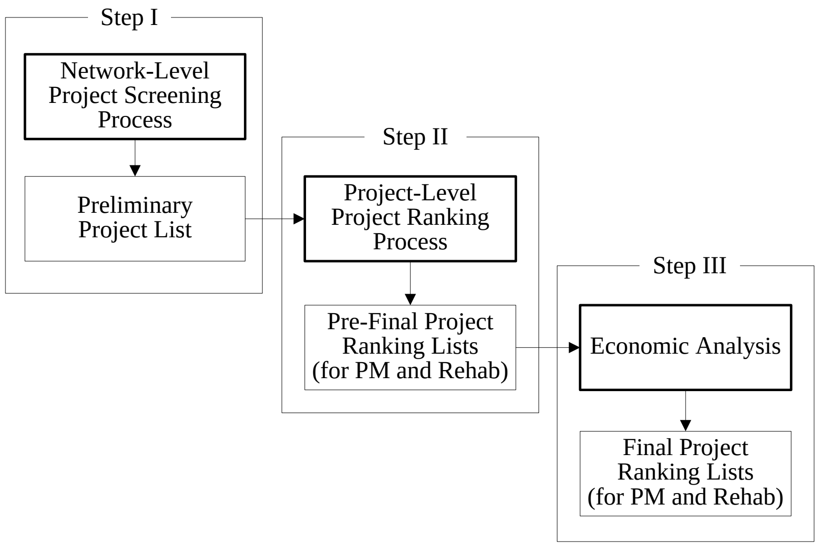


Figure 3.1: An Overall Conceptual Pavement Management Procedure

The 4-Year Pavement Management Plan should be developed based on a thorough analysis of inventory data in PMIS and other systems, as well as project level field data that evaluates conditions, predicts performance and optimizes cost and benefits. This study proposes that the 4-Year Pavement Management Plan process be divided into three steps:

1. A network-level project screening process;
2. A project-level project ranking process; and
3. An economic analysis.

Figure 3.1 shows the proposed overall conceptual pavement management system. In Step I, the project screening process is based on analysis of network-level PMIS data. In this step, the status and trends in pavement conditions are primary factors used to identify and prioritize candidate pavement projects for further evaluation. Once preliminary candidate ranking lists for PM and Rehab projects are developed, DPEs collect project-level data in Step II by conducting a field survey on each candidate project and project level tests such as FWD, GPR, cores, and laboratory tests on selected projects. The project level data provides engineers with the current structural, distress and ride quality conditions in detail. In this step, project level data and other factors that reflect pavement performance are considered to create a pre-final project ranking list. In Step III, an economic analysis is performed to evaluate the project cost and benefits received by constructing the project in terms of improved safety, extended pavement life and increased structural capacity. The final ranking list is developed based on a cost and benefit analysis considering the given budget.

This approach develops more precise indices for evaluating and ranking pavement projects, thereby allowing engineers to make informed decisions when developing the pavement management plan and selecting maintenance treatments. Figure 3.2 illustrates the detail of a conceptual framework for development of the 4-Year Pavement Management Plan.

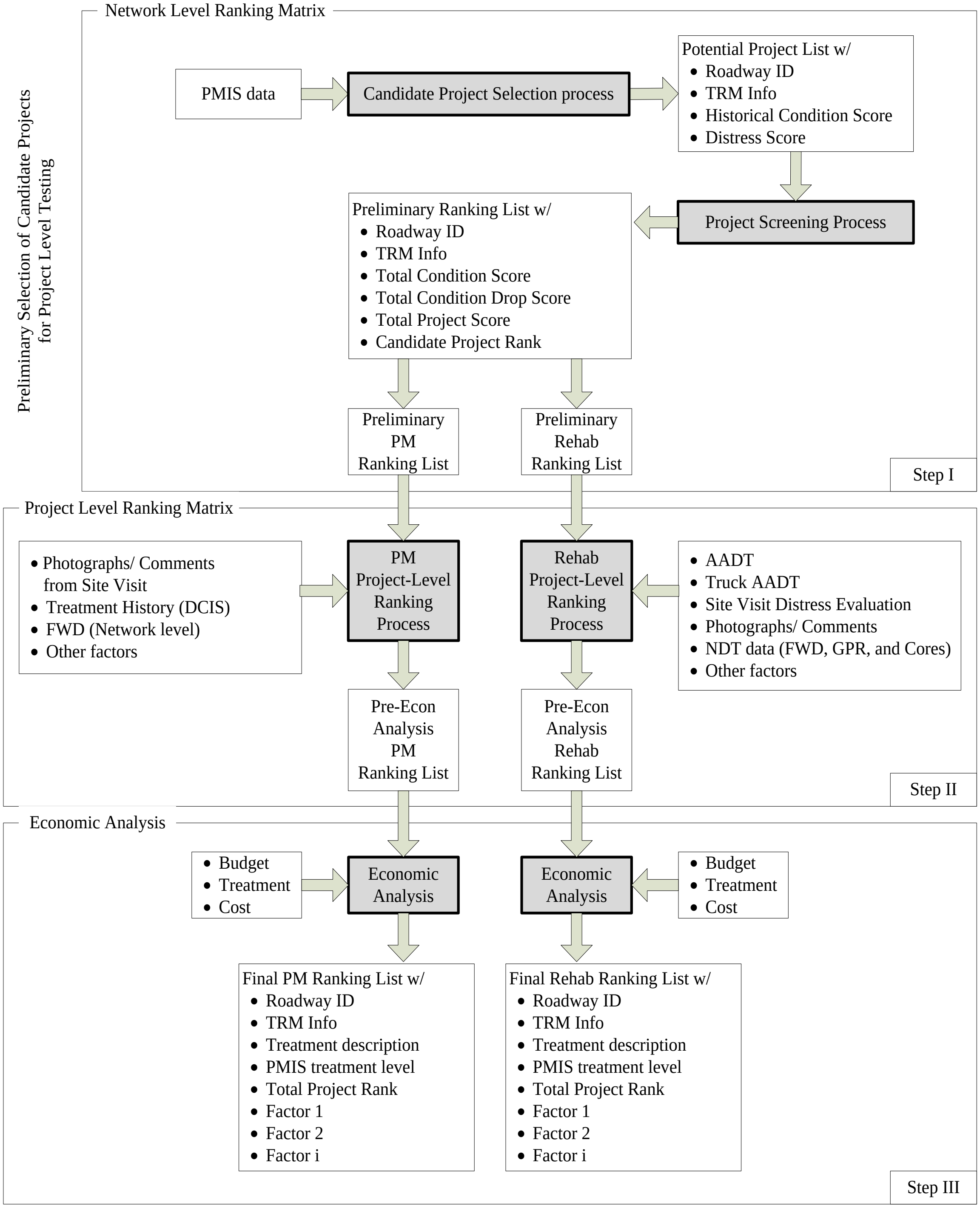


Figure 3.2: A Conceptual Framework-The development of 4-Year Pavement Management Plan

3.2.1 Step I: Network-Level Project Screening Process

The PMIS database contains information on overall conditions of each 0.5-mile pavement management section using various scores based on visual distress and ride quality surveys as follows:

1. Distress Score: a combined score based on the amount and types of visible surface deterioration (pavement distress).
2. Ride Score: a description of pavement ride quality based on Present Serviceability Index (PSI) as a function of IRI.
3. Condition Score: a description of overall pavement condition that combines distress, ride and site factors such as posted speed and traffic.

The network-level project screening process is based on network-level measurements that describe pavement conditions in PMIS. As a result, the network-level process utilizes information about trends in pavement condition. The following sections describe the process of developing the network-level project screening process in greater detail.

To prepare PMIS data, both the current fiscal year PMIS and previous year PMIS are required. The TRM information and Condition Score (CS) and the change in CS are required for candidate project selection. The change in CS over time indicates the extent of deterioration in pavement conditions. Based on this information, DPEs can evaluate pavement conditions and develop a list of candidates. The candidates are then evaluated based on the PMIS Distress and Condition Score; the change in Distress and Condition Score; and other factors to rank preliminary candidate projects.

3.2.1.1 Candidate Project Selection Process

The candidate project selection process within the network-level project screening process is created from data contained within the PMIS database. The following three data sets are considered to evaluate pavement conditions:

1. Texas Reference Marker (TRM) information. Contains location data such as District, County, Maintenance section, Highway, Beginning Reference Marker and displacement, Ending Reference Marker and displacement, and roadbed (for divided highways).
2. Condition Score in PMIS. Because CS is calculated using both Distress and Ride measurements, it is considered suitable for evaluating pavement condition at the network level.
3. The change in CS from the previous fiscal year. The change in CS over time indicates the extent of deterioration or improvement in pavement condition.

Depending on the Condition Score, the change in Condition Score from the previous year and other factors, engineers evaluate each section of roadway. Each PMIS section is then evaluated sequentially based on functional and/or structural issues, and sections are linked together to form projects. Depending on the conditions, engineers can identify candidate projects, including potential projects to monitor that are included in years two through four of the 4 Year Plan. Routine maintenance projects are identified for treatment by in-house or contract maintenance forces. RM projects consist of isolated PMIS sections that meet the selection criteria but are considered too short to be designated construction projects.

3.2.1.2 Preliminary Project Screening Process

Once the DPEs have identified candidate projects, each project is evaluated based on Distress and Condition Score, the change in Distress and Condition scores over time and other factors to rank preliminary candidate projects. The information is quantified, and the total project score is calculated based on score range categories and weighting factors. The weighting factor is assigned based on the contribution of each score category to overall project rank. In this step, candidate projects are roughly ordered highest to lowest in terms of total score. The preliminary list of candidate projects is used to plan field visits with area engineers and maintenance supervisors who review local road conditions and further evaluate the candidate projects. This information helps DPEs determine if the preliminary screened projects should be added to the PM or Rehab project list. The DPEs evaluate information related to pavement structure type, visual distress type and extent, structural condition, and other factors. This information helps DPEs decide if a project primarily has functional (candidate for PM treatment) or structural (candidate for Rehab treatment) issues.

3.2.2 Step II: Project-Level Ranking Process

Once the preliminary ranked list of candidate projects for PM and Rehab is developed, DPEs conduct a field survey for further project evaluation in Step II. DPEs conduct a review of office records for each project, such as construction plans, past field test records, geologic and soil maps, and PMIS data regarding the number of lanes, pavement types, traffic, and intersecting routes. Because PMIS raters are trained to rate the most distressed roadbeds, network-level data may not reflect the overall condition of each lane or travel direction. Maintenance is not recorded in PMIS, so pavement type and/or conditions may have changed since the PMIS rating was performed during the previous fall. Current pavement conditions or even pavement type might therefore be different from what was initially recorded. The information for each project is adjusted based on the reality of what actually exists in the field in this step.

A DPE performs a visual inspection of the pavement while driving along the road for PM projects. Additional information such as photos and notes are also prepared to document particular points of interest. For Rehab projects, the DPE conducts a thorough field survey of distress conditions regarding functional and structural distress type, density and severity. The DPE may also conduct NDT, such as ground penetrating radar (GPR), falling weight deflectometer (FWD) and dynamic cone penetrometer (DCP) on selected Rehab projects. Results of these tests are used to establish the cause(s) of the distress, locate sub-surface moisture damage, verify layer thickness and material types, and determine the structural condition of the pavement.

A separate ranking criteria and methodology has not been developed for PM and Rehab projects at this time. The list of candidate projects for PM will potentially be ranked based on field survey information in conjunction with treatment performance history, engineering judgment and network-level FWD data if necessary. Rehab candidate projects will potentially be ranked based on thorough field survey distress data in conjunction with traffic data including truck ADT, soil conditions obtained from NDT tests and engineers' opinion of each project location.

Once potential factors and preliminary ranking indices are developed, it is necessary to analyze each factor for possible use in PM and Rehab ranking methodologies. Only key points/concepts will be discussed that may be considered when developing a project-level ranking index, as the development of a project-level ranking methodology is outside the scope of this study.

Reliability Concept

Accurate information/data at each management level must be collected and decision criteria determined and quantified to maximize the benefits of the project selection and ranking system. The project ranking algorithm may include several quantifiable indices such as ADT, truck ADT, pavement structural condition, and maintenance treatment costs to determine which project is given higher priority. There are additional factors that should be considered, however, that cannot necessarily be quantified. These can still help establish the reliability of the project ranking score. For example, the project ranking score could consist of a set of several indices that includes a factor to quantify the pavement structural condition. A simple drop-down box in the ranking tool allows the user to select the appropriate Structural Condition Index based on the ranges shown in Figure 3.3.

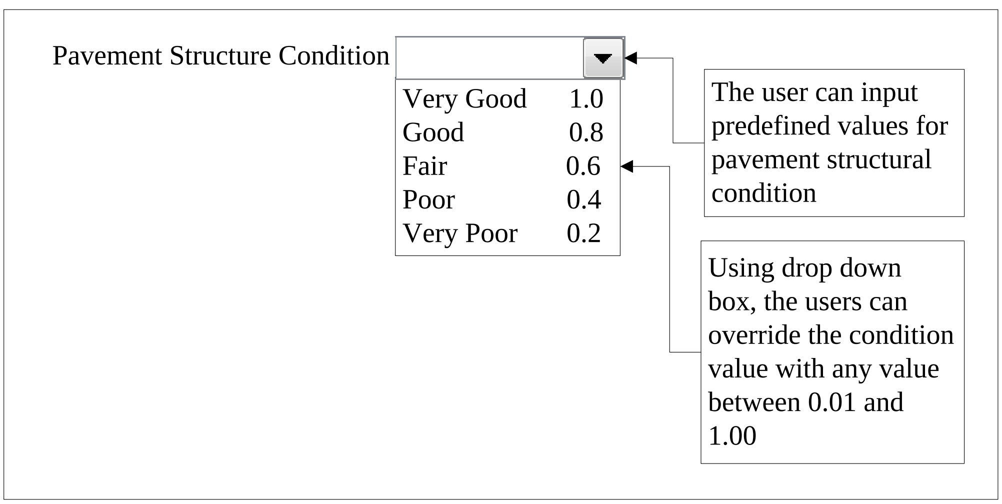


Figure 3.3: A Conceptual Pavement Structural Condition Score Drop Down Box

The pavement structural condition may be selected by the user based solely on engineering judgment. Alternately, the index may be selected based on a site visit. This would increase the reliability of the index value. The index may also be selected based on a site visit and NDT testing, including FWD, GPR, DCP, cores and lab testing. These additional factors allow the user to adjust value of the pavement structural condition and increase the reliability of the selected value. This suggests that the pavement structural condition index value — if based solely on engineering judgment with no site visit — would have a lower reliability than an index value based on a site visit and some or all of the NDTs and lab testing methods available to TxDOT pavement managers.

The same concept could be applied to indices based on ADT, truck ADT, maintenance cost, soil conditions, and many other environmental factors incorporated into project ranking as individual indices. Each district may consider different factors and/or different factor weights based on local conditions. For example, a ranking index factor based on ADT or truck ADT may be weighted differently in metro and rural districts. A rural district may consider 10,000 ADT a high traffic level, while a metro district may consider 10,000 ADT moderate. To address these issues, potential indices to consider local circumstances should be identified. It is envisioned that although pre-selected, default values are established for each index value, the user will have the option to override default settings and input a higher or lower value based on local conditions.

Furthermore, the reliability factors could be used to adjust the final ranking either positively or negatively depending on the amount of preparatory testing and analysis performed for each project. The incorporation of reliability factors encourages utilization of the NDT or other project-level testing methods available to all districts for sound pavement management practices.

Flexibility Concept

A comprehensive project ranking methodology should be developed to perform a thorough evaluation of pavement projects. The method will be designed so it can be used at each organizational level to evaluate, assign and adjust project rankings. It is envisioned that a series of quantitative and qualitative index values can be adjusted by users and then summed to obtain the total project ranking. Figure 3 depicts a preliminary concept for a flexible ranking tool that provides individual indices, including index categories, weighting factors and the contribution of each index value to the overall project ranking. Figure 3 is presented for illustrative purposes only.

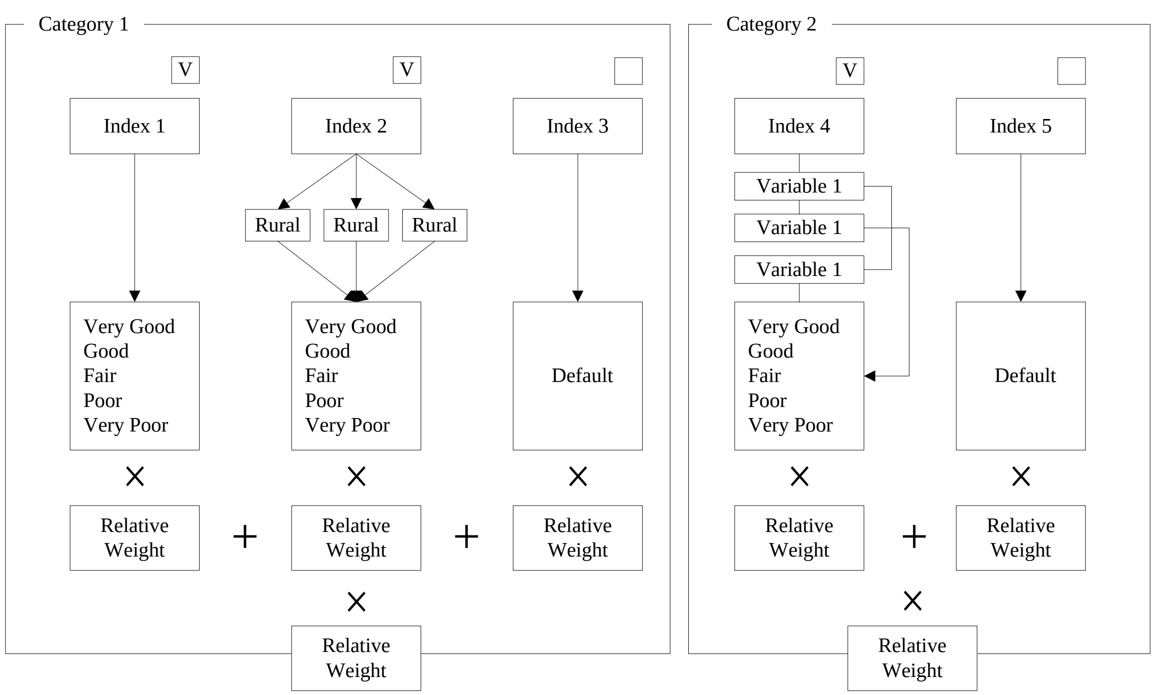


Figure 3.4: A Preliminary Concept for a Flexible Ranking Tool in Project-Level Ranking Process (Step II)

In Step II, the appropriate treatment application for each project will be designed and selected based on past treatments of similar routes, pavement design methods and information obtained using pavement analysis tools. After each project site is visited and specific treatments determined, the projects are summarized with TRM locations, a physical location description, the specific treatment type recommendation, and related information. Candidate projects are ranked using criteria and weighting factors determined by engineers, and the ranked list is presented to the upper management level. Two lists are prepared at the end of Step II. One list contains proposed PM projects, and the other contains proposed Rehab projects.

3.2.3 Step III: Economic Analysis

A final list of projects for the 4-Year Pavement Management Plan is developed in Step III based on an economic analysis. Once two pre-final project lists are prepared in Step II, each project budget is evaluated to ensure that the proposed scope of work meets requirements. An economic analysis is then performed to evaluate project cost and benefits received in terms of improved safety, extended pavement life, increased structural capacity, reduced vehicle operating costs, and better serviceability levels.

Further adjustment of project rankings may occur as a result of the economic analysis. Some projects may be postponed due to lack of funds or shifted in priority after considering costs, ADT and other factors.

Once an economic analysis is performed for each project, the PM and Rehab project ranking lists are presented to the district engineer and his/her administrative staff. The district engineer may adjust project rankings based on recommendations from his/her staff, as well as other economic, political and local considerations. The local considerations may include funding allocations to each area office respective of staffing and work load, project timing in relation to ongoing construction projects and other factors.

The final project list for the current fiscal year of the 4-Year Pavement Management Plan is developed based on available funding after each project budget is evaluated to ensure that the proposed scope of work meets requirements. Projects that cannot be funded in the current fiscal year may be relegated to year 2, 3, or 4 Plan. The district engineer submits the plan to the 4-Year Pavement Management Plan Committee and may subsequently meet with senior TxDOT staff to discuss project selections and expenditures. The combined individual district 4-Year plan is then reviewed, modified and approved by TxDOT based on district and statewide pavement network performance goals, as well as budget allocations.

3.3 Development of Decision Making Procedure in Ranking Process

As the result of a more thorough evaluation of a project based on a site visit, the project may shift from PM to Rehab or vice-versa depending on actual road condition. Therefore, decision-making flexibility should be considered when developing a ranking process. Figure 3.5 illustrates a flow chart of decision making in the ranking process. Safety-related projects are typically evaluated by TxDOT using a separate process from non-safety-related PM and Rehab projects. TxDOT performs an evaluation of project locations based on the Wet Weather Accident Reduction Program (WWARP) and uses Crash Record Information System (CRIS) reports to evaluate safety issues. Safety-related projects with high accident rates, especially sites where severe injuries or fatalities are incurred, are given high priority and not ranked using the same process as non-safety-related projects. It is anticipated that safety-related projects that warrant treatment will be placed at the top of the final ranked list and funded before non-safety-related projects. Safety-related projects and the associated ranking process is considered outside the scope of this study for this reason.

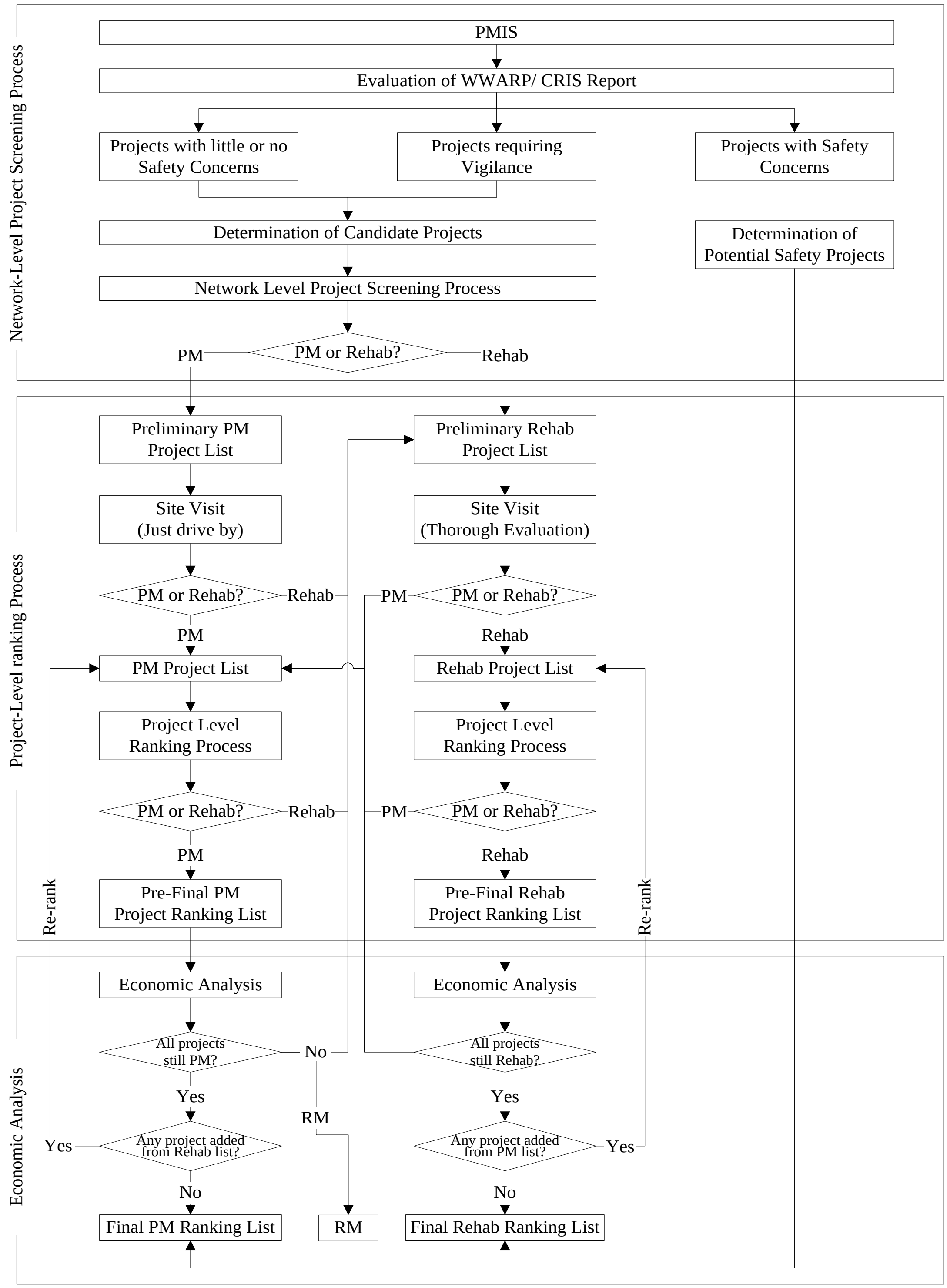


Figure 3.5: A Flow Chart of the Decision-Making Process in the Proposed 4-Year Pavement Management Plan

Once safety-related projects are isolated, non-safety-related projects are roughly ordered from lowest to highest pavement condition using a network-level ranking process. Engineers then evaluate distress data of each project such as distress type, density, and overall distress pattern to find evidence of functional and structural problem. This helps them categorize projects for PM or Rehab.

Once the preliminary ranked list of candidate projects for PM and Rehab is developed, DPEs conduct a field survey for further project evaluation. However, during a site visit, individual projects may be shifted from PM to Rehab or vice-versa depending on actual field conditions. The reality of what actually exists in the field may be quite different from what they expected in the office. During a thorough examination of each project in the project-level ranking process, DPEs may shift their determination again depending on the cause(s) of the distress, sub-surface damage or layer thickness and material type.

An economic analysis is performed to evaluate project cost and benefits after DPEs finalize pre-final PM and Rehab project lists. Depending on each project budget, the total available budget for PM and Rehab and the project cost benefits, the project may once again shift from PM to Rehab or vice-versa. During this process, PM projects may be moved to the RM list and flagged to receive temporary repairs until a more intensive treatment application is planned. The candidate projects are then summarized in the draft plan according to three categories: 1) construction projects that will receive PM treatment; 2) construction projects that will receive Rehab treatment; and 3) RM projects that will be performed using in-house forces or a routine maintenance contract.

3.4 Summary

This chapter presented a conceptual framework of a pavement management plan consisting of a network-level project screening process, project-level ranking process and economic analysis. The ranking criteria and key concepts considered in each process were described in this chapter. Based on the understanding of the conceptual framework, the next chapter will provide a more detailed discussion of the network-level project screening process, including candidate project selection methodology and the preliminary project screening matrix. Development of in-depth, comprehensive ranking methodologies for the project-level ranking process and economic analysis is outside the scope of this study.

Chapter 4: Implementation of a Network-Level Project Screening Tool

4.1 Overview of Network-Level Project Screening Tool

Previously, the Austin DPE evaluated the large pavement data set manually to select candidate projects. Based on plots of pavement performance, each roadway was evaluated based on PMIS distress, ride and condition scores to select candidate projects. However, manually analyzing the entire Austin District pavement network took several weeks and may have yielded misleading results. Once the DPE developed a list of candidate projects, a matrix method was used to determine the priority of each candidate. The matrix does not fully characterize the condition of the project, so it was uncertain whether the pavement maintenance plan would achieve the desired goals.

This study developed the automated NLPS tool to help screen and select candidate projects at the network level. Although the NLPS tool was designed for use in the Austin District, it can potentially be used by other districts. The NLSP tool reduces the amount of time necessary to review the district PMIS data to identify candidate projects from a matter of weeks to a few hours. The NLSP tool also helps reduce the possibility of human error. It helps DPEs to easily incorporate the developed mathematical network ranking algorithm into their pavement maintenance management processes.

The focus of this study is to develop methodologies for the current fiscal year's candidate projects to include PM and Rehab treatments only; however, the candidate projects generated by the ranking methodologies for the current year but not selected due to limited funding or that currently have a low priority could be assigned to years 2 or 3 of the plan based on the DPE's judgment. Because this process is performed each year, when year 2 of the plan becomes the current year, new candidate projects will be identified, and previously unfunded projects will be re-ranked to determine if they should be funded. The network-level project screening process is adaptable and interactive; it provides a way to rank candidate projects to ensure optimal project selection and plan flexibility from year to year.

4.2 Development of Candidate Project Selection Algorithm

Previously, the Austin DPE manually analyzed pavement performance graphs of each roadway to determine candidate projects as shown in Figure 4.1. The graph depicts the overall pavement condition of roadway SH 95 located in Williamson County. The solid line blue indicates the Condition Score (CS) of the current year and the dashed line shows the CS of the previous year. Based on the analysis of both scores, engineers can identify candidate roadway sections. These are depicted as rectangles in Figure 4.1. The tool that creates these graphs and the manual selection process that allows project identification were developed at the Center for Transportation Research (CTR) by Dr. Seokho Chi and the author.

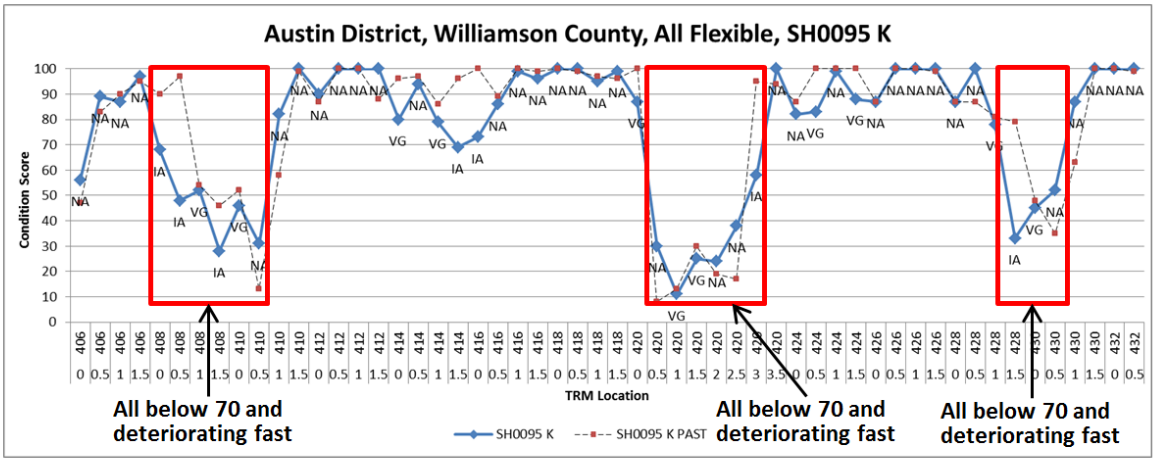


Figure 4.1: An Example of Performance Graph Analysis for Project Selection

To help develop an automated system to identify candidate projects for his study, Mike Arellano, the Austin DPE, provided pavement performance graphs indicating candidate projects he selected along 12 routes (a total of 443 PMIS sections) in Williamson County. The graphs were used by the DPE to identify 26 candidate projects and included the engineers' rationale (decision criteria) in choosing these particular projects. Based on the analysis of this data, the criteria considered by the Austin DPE for selecting candidate projects is as follows:

1. The current Condition Score;
2. Condition Score deterioration from the previous year (called the Condition Score Drop or CSD); and
3. The condition of the adjacent sections.

An algorithm for project selection was developed using these criteria. The algorithm consists of the following separate models:

1. The first model identifies project possibility of each roadway section; and
2. The second model determines project length.

Figure 4.2 illustrates the conceptual development of Models 1 and 2 for the candidate project selection algorithm. In the first model, each pavement section of a given roadway route (e.g., FM 141, SH 95, etc.) is evaluated to determine if it is considered a project based on one of three options: Y (Yes), N (NO) or P (a Potential project for Year 2-3 plan. These options were determined based on both Condition Score and Condition Score Drop. In the second model, the length of a project is determined. A series of PMIS sections with a resulting option response of ‘Y’ or ‘P’ are grouped together and considered a project.

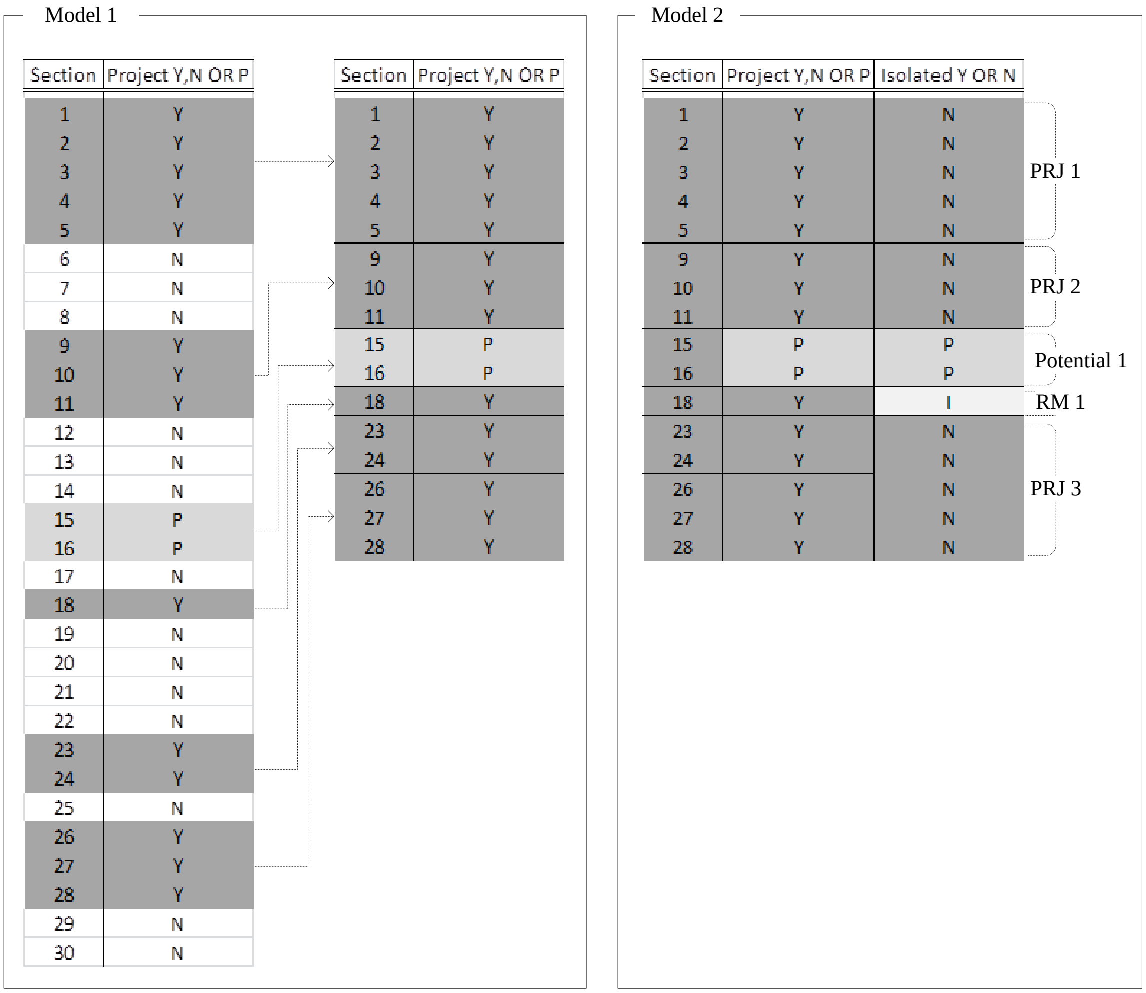


Figure 4.2: A Conceptual Development of Candidate Project Selection Algorithm

The following subchapters will describe the process of developing Models 1 and 2 in more detail.

4.2.1 Development of Model 1

To develop Model 1 for identification as a possible project, the 443 roadway sections provided by the DPEs were listed with the following information: FY2010 Condition Score (CS2010); Condition Score Drop (CSD) obtained by subtracting the

FY2009 Condition Score from the FY 2010 Condition Score; and the engineers' determination if the section was selected as a project (Y= Project, N= Non-Project and P= a Potential project Year 2-3 Plan).

Based on the dataset of the roadway sections, Model 1 was developed using decision tree approaches. A decision tree provides a model form depicting "how a decision should be performed" or "how a decision was made" [Duda et al. 2001]. For this study, Weka 3.6, a collection of machine algorithms for data mining tasks, was selected. Weka provides users with tools to determine which method is most suitable for the given data based on analysis of each accuracy rate [Witten and Frank 2005]. Weka contains many decision tree algorithms. For this study, J48, J48graft, LADTree, RandomTree, and REPTree were selected and a comparative analysis performed. Table 4.1 depicts these decision tree algorithms.

Decision Tree algorithms	Summary
J48	Class for generating a pruned or unpruned C4.5 decision tree.
J48 graft	Class for generating a grafted (pruned or unpruned) C4.5 decision tree.
LADTree	Class for generating a multi-class alternating decision tree using the LogitBoost.
RandomTree	Class for constructing a tree that considers K randomly chosen attributes at each node. Performs no pruning.
REPTree	Fast decision tree learner. Builds a decision/ regression tree using information gain/ variance and prunes it using reduced-error pruning (with backfitting).

Table 4.1: The Short Introduction of Decision Tree Algorithms Contained in Weka [Hall et al. 2009]

Model 1, a decision tree algorithm, was developed to provide a snapshot of the criteria that ”branches” to each selected node. The goal was to develop a transparent and relatively understandable decision tree process with a high degree of accuracy in candidate project selection compared to the project selected manually by the DPE. The accuracy of each decision tree algorithm model was measured by counting the proportion of correctly predicted examples in the test dataset not included in the algorithm development. This approach provides a measure for the overall accuracy of the classifier [Andrew 2005]:

$$\text{accuracy} = \frac{\text{number of correctly classified instances}}{\text{number of instances}}$$

The developed dataset was analyzed by the five algorithms mentioned, and a comparative analysis was performed based on accuracy rate. Table 4.2 shows the results of the accuracy rate of each algorithm.

	J48	J48graft	LADTree	RandomTree	REPTree
Original Dataset	85.10%	85.10%	83.30%	80.36%	84.20%

Table 4.2: The Comparative Results of Accuracy of Five Decision Tree Algorithms

As shown in Table 4.2, the overall accuracy values are about 84 percent. The J48 and J48graft are the algorithms with the highest accuracy rate: 85.10 percent.

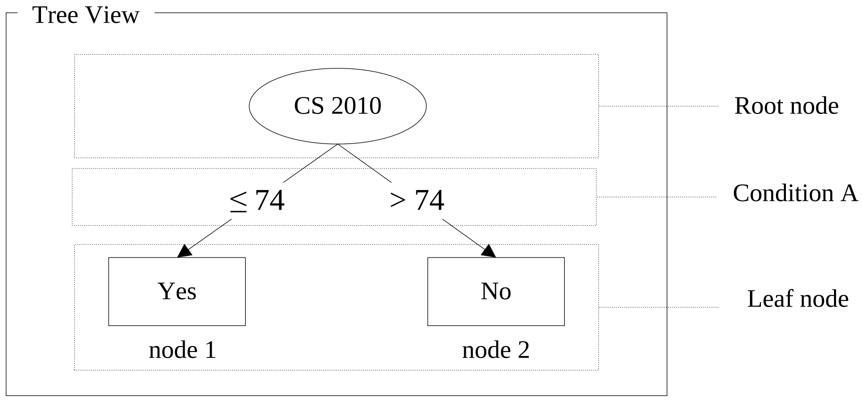


Figure 4.3: An Example of Weka's Visualization of a Decision Tree

Figure 4.3 shows an example of WEKA's visualization of one decision tree. The decision tree starts at the root node 'CS2010' and applies Condition A to split the input. If the input data in Condition A is larger than or equal to Condition Score '74', it is classified to node 1; otherwise, the input data is classified to node 2. The threshold value '74' was computed in the decision tree based on the training samples associates with the node. In the first attempt, the attribute 'CS2010' was categorized based on a Condition Score number '74' as shown in Figure 4.3. When categories are established, small differences in CS can result in branching to one node or the other, yielding quite different conclusion. However, small differences in CS are not sufficient to make such a distinction due to the inherent variability in the ratings and measurements used to compute the CS. To address this issue, this study proposes to use a data classification method. The classification class values of CS and CSD were defined based on the values actually used by the DPE when identifying candidate projects; however, weighting factors can be provided so the user can adjust the impact of the CS or CSD before running the tool. For both of these attributes, three performance levels have been defined in Table 4.3. The concept of using slow, medium, and fast rates in CSD as decision criteria was developed at the University of Texas – Austin by Dr. Zhanmin Zhang and his colleagues and has been used in Web-based System for Pavement Performance & Maintenance Management (PPMM) [Zhang 2008].

Classified Level	Condition Score (CS2010)
Good	80 ~ 100
Fair	60 ~ 80
Bad	< 60

Classified Level	Drop Score (DS)
Slow	> -10
Medium	-10 ~ -20
Fast	< -20

Table 4.3: The Classification Class for Condition Score and Drop Condition Score

When developing the algorithm for Model 1, it was discovered that the training sample might lead to incorrect results if the user does not select an individual 0.5-mile-long PMIS section as a construction project. Because project lengths typically exceed 0.5 miles, it was determined that these should be categorized as RM projects. However, RM projects should theoretically be categorized as construction projects in Model 1 and then re-categorized as RM projects in Model 2 based on the length of the project.

Some sections were categorized as construction projects in the training sample, although they are in good or fair condition. Surrounding sections in bad condition may cause them to deteriorate rapidly in the near future, so it was determined that these should be categorized as projects. However, these could theoretically be categorized as non-projects in Model 1 and then re-categorized as projects in Model 2.

Based on the analysis, the training sample was refined. It resulted in an improvement in all the classifier's accuracy. The results presented in Table 4.4 indicate that accuracy in all of cases increased by at least 4 percent but up to 10 percent. The algorithm with the highest accuracy rate was LADTree and Random Tree.

	J48	J48graft	LADTree	RandomTree	REPTree
Original Dataset	85.10%	85.10%	83.30%	80.36%	84.20%
Refined Dataset	89.39%	89.39%	90.29%	90.29%	89.62%

Table 4.4: The Comparative Results of Accuracy of Five Decision Tree Algorithms with Refined Dataset

When developing the algorithm that best matched the engineers' decision making process, it was discovered that the classification class level values of CS2010 and CSD were not consistent with values actually used by the DPE, resulting in lower accuracy. For example, if sections with a Condition Score of less than 70 were considered projects, sections with a Condition Score of more than 70 were excluded as projects. However, because a CS classification level of "fair" was defined as between 60 and 80, this resulted in problems clarifying the decision-making sequence. To address these issues, the classified class of Condition Score and Condition Score Drop were redefined based on values actually used by DPEs when they determined candidate projects as shown in Table 4.5.

Classified Level	Condition Score (CS2010)
Good	80 ~ 100
Fair	70 ~ 80
Bad	< 70

Classified Level	Drop Score (DS)
Slow	> -5
Medium	-5 ~ -15
Fast	< -15

Table 4.5: The Redefined Classification Class Levels of Condition Score and Drop Score

	J48	J48graft	LADTree	RandomTree	REPTree
Original Dataset	85.10%	85.10%	83.30%	80.36%	84.20%
Refined Dataset	89.39%	89.39%	90.29%	90.29%	89.62%
Dataset based on the re-defined classification class level	92.55%	92.33%	92.33%	92.55%	91.20%

Table 4.6: The Comparative Results of Accuracy of Five Decision Tree Algorithms with Each Different Dataset.

Use of the redefined classification class level resulted in increased accuracy rates in all cases. It can be seen in Table 4.6 that in 80 percent of cases, accuracy was increased to more than 92 percent. It can be also noted that nearly 7 percent of accuracy rate was increased compared to when the original dataset was used. The algorithms that generated the highest accuracy rate are J48 and RandomTree. In this study, the J48 algorithm was selected for Model 1 to provide an illustration of the decision branching process compared to Random Tree. Figure 4.4 depicts a decision tree generated by J48 and shows the steps required to arrive at a final classification. The decision classifies sections as Y= 'Project', N= 'Non-Project', or P= 'Potential project for Year 2-3 plan' based on CS2010 and DS. In this case, the CS2010 value is in the root node. The degrees of the node are the attribute (CS2010) values. The child nodes are tests of DS classification (slow, medium and fast) and lead to the leaf nodes, which are the actual classifications. Based on the clarified sequence of decision making for project selection generated by J48, Model 1 identifies a project possibility (Y, N or P) of each section and picks sections with Y and P. The selected sections are sorted by Roadway ID and TRM information.

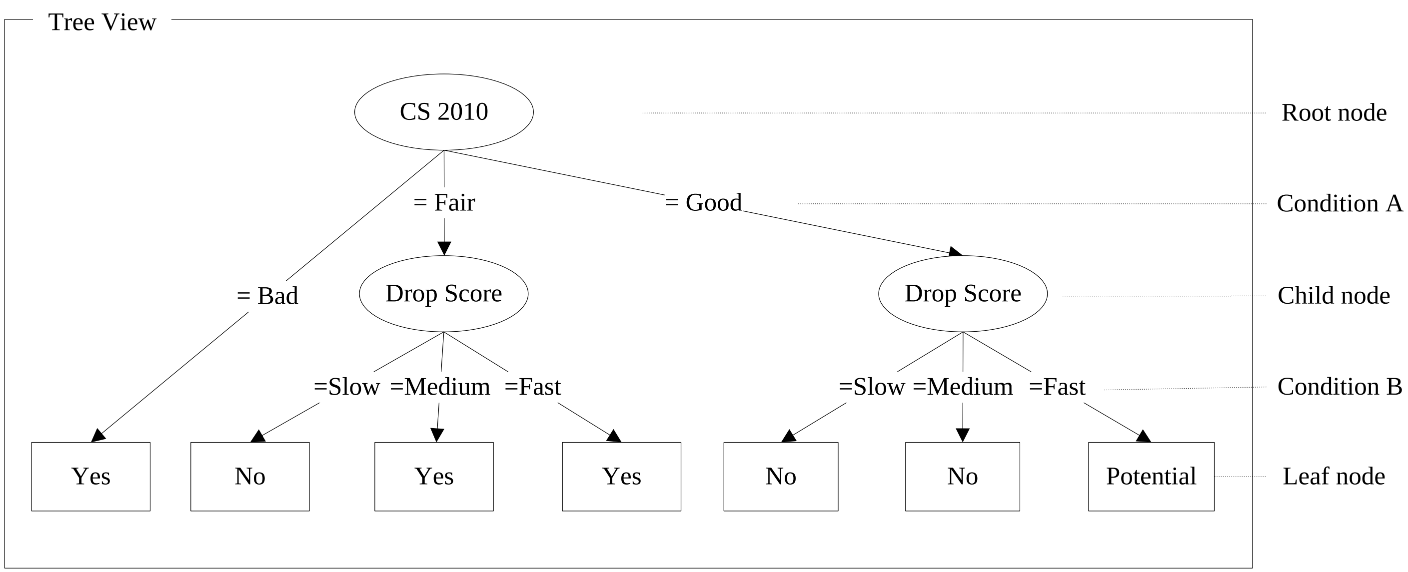


Figure 4.4: A Visualization of the Decision Tree Generated by J48

4.2.2 Development of Model 2

After candidate sections sorted by Roadway ID and TRM are obtained, Model 2 determines how long the project length will be. The candidate sections with sequential Roadway ID and TRM information are combined and created as a candidate project. It is possible for a particular roadway route to have no serial PMIS sections designated ‘Y’ or ‘P’ that can be combined; only one section is poor condition while the surrounding sections are in good condition. These routes are considered isolated sections and categorized as RM projects, because it is not cost effective to treat one section as a project. An additional criterion that is considered regards whether the distance between two projects is less than one mile; these two projects should be combined together and considered as a one project. This rule defers to engineers’ judgment: the condition of each section can be easily affected by surrounding sections. Even if a section is in good condition, it can deteriorate rapidly in the near future if its surrounding sections have bad performance.

4.2 Development of Preliminary Project Screening Process

The preliminary project screening process provides the Austin DPE with information about each candidate project related to the pavement distress and ride condition, change in CS over time, and other factors considered during preliminary candidate project ranking. Each project’s information is viewed in a matrix for easy comparison.

Development of Preliminary Project Screening Matrix

The candidate project selection algorithm includes a function that accesses PMIS data in the required format, including data elements such as Roadway ID, TRM information, Condition Score (CS), and Condition Score Drop (CSD) so that analysis can be performed. The project screening matrix was developed for the analysis so that engineers can evaluate each factor's contribution to the overall candidate ranking. Table 4.7 depicts a preliminary project screening matrix at the network level.

In this matrix, factors such as CS and CSD are assigned a weighting factor, and each factor is subdivided into score ranges that are also assigned weighting factors based on their contribution to project prioritization. The user can adjust the weighting factors. The contribution of each factor is calculated separately depending on the assigned weighting factor and then summed so that the impact of each factors can be reviewed and considered independently.

The matrix determines how many PMIS sections within a project fit into each of the CS and CSD categories. Based on these values and the weighting value listed for each category of CS and CSD, the weighted CS and weighted CSD are calculated. It should be noticed that to calculate the weighted CS and weighted CSD, PMIS sections in the each category is converted into a percentage based on the total number of PMIS sections of a project. Based on the weighted CS and the weighted CSD and the weighting factor for each, the Total Score is calculated to rank candidate projects from highest to lowest.

Project		Condition Score (CS)				Condition Score Drop (CSD)				Weighted CS	Weighted CSD	Total Score	Rank	Visual Distress Summation							
	Weighting factor	0.6*				0.4*								Shallow Rut	Deep Rut	Patching	Failure	Block	Alligator	Longitudinal Cracking	Transverse Cracking
		0.4*	0.4*	0.3*	0.2*	0.1*	0.2*	0.3*	0.4*												
	Score Range	0≦CS<30	30≦CS<50	50≦CS<70	70≦CS	0≦CS<-10	-10≦CS<-20	-20≦CS<-30	-30≦CS												
1	# of Sections																				
2	# of Sections																				
3	# of Sections																				
4	# of Sections																				
5	# of Sections																				

*can be adjusted by the users

Table 4.7: The Network-Level Project Screening Matrix

The matrix provides a Total Condition Score along with a summation of each raw visual distress type and rating so engineers can identify what types of visual distress occur within a project. This information helps engineers make a rough 'first cut' decision when designating a project for PM or Rehab. The DPE indicated that the distress summation information helps to determine if a project primarily has functional issues that require to PM treatment or structural issues that need Rehab treatment.

4.4 SUMMARY

The development of the NLPS tool was described in Chapter Four. The methodologies for selecting and ranking candidate projects were developed based on data provided by Austin DPEs. The automated candidate project selection algorithm saves time and reduces error in developing a list of candidate projects. The preliminary project screening matrix provides engineers with necessary information to evaluate each project so they can develop a preliminary ranking list. The preliminary project list assists engineers in planning field visits for further evaluation. Chapter Five will present the implementation of the NLPS tool for a country in the Austin District.

Chapter 5: A Case Study and Results

5.1 Raw Data Preparation

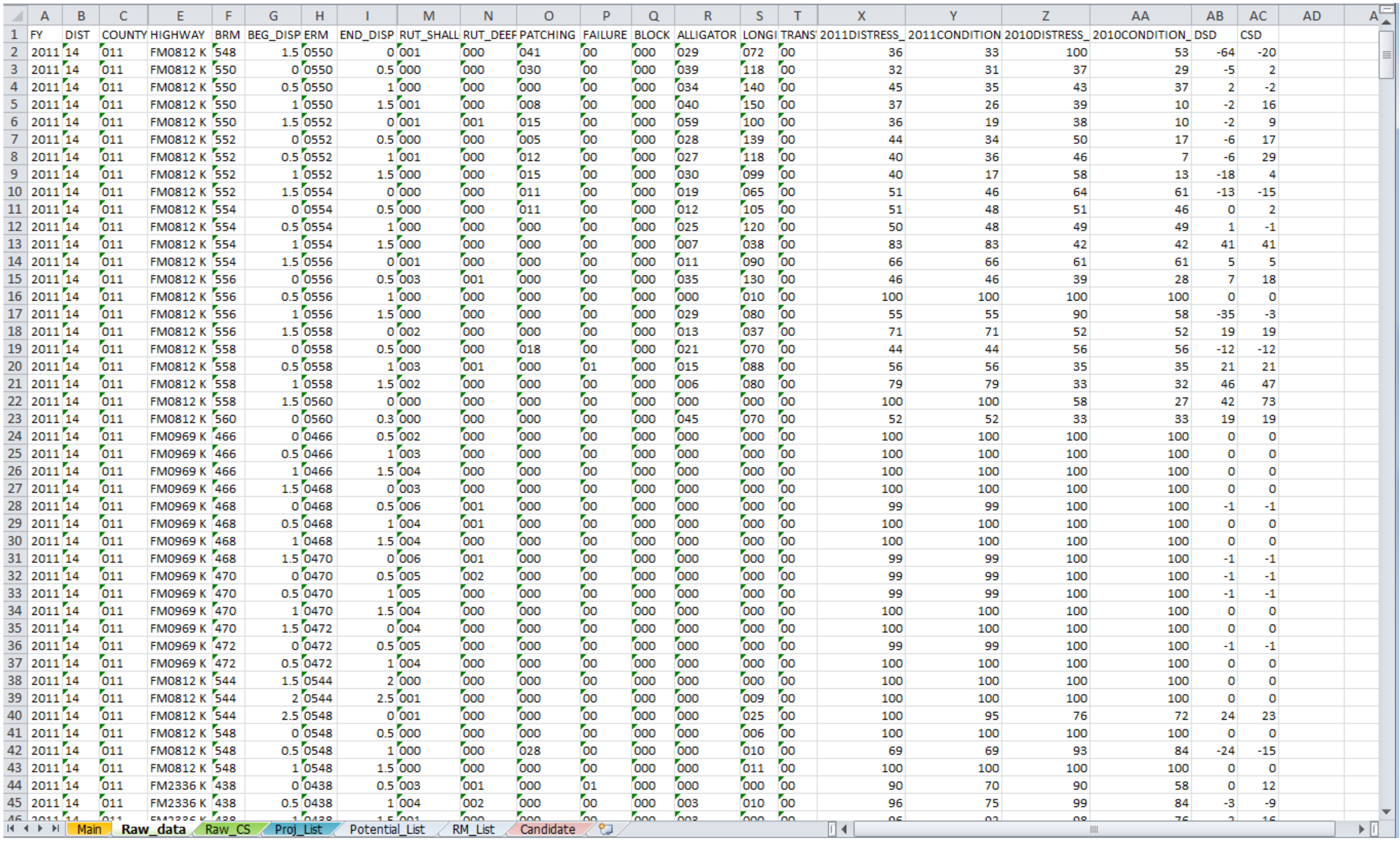
A case study was conducted to verify that the developed NLPS tool functions properly and produces accurate results based on the DPE's judgment. The case study was conducted using FY 2010-2011 PMIS data of all flexible pavement types for Bastrop County in the Austin District.

Figure 5.1 shows a portion of a raw data worksheet sorted by county number. The county number is a unique identifier assigned to each county in Texas. There are 254 counties in Texas, so county number ranges from 1 to 254. County Number 11 is assigned to Bastrop County. The raw data worksheet is composed of numerous rows and columns. Each row, or record, represents a particular PMIS data collection pavement section (typically 0.5 mile). Each column in a row, or field, describes one attribute of a pavement section. Each pavement section includes a number of attributes such as Current Fiscal Year, Responsible District. County Number, Signed Highway ID, TRM information, individual visual distress, and FY 2010-2011 Condition Score among others. The individual visual distress is stored as percentage of a section length or total quantity within a section. PMIS does not automatically calculate Condition Score Drop (CSD), or the change in Condition Score from the previous year. Therefore, both FY 2010 and FY 2011 PMIS data should be considered simultaneously. There are a few issues to consider when developing the raw data based on PMIS:

- The PMIS includes a number of missing values (e.g., zero Distress Score and/or Condition Score). To obtain better output, the user is advised to filter zero values before running this tool. Otherwise, the section with a zero value may receive highest priority. According to DPEs, sections with a zero may not be critical to consider. Engineers assume that sections with zero value were under construction during PMIS data collection or closed due to other testing so raters could not collect data for those sections.

- The NLPS tool allows only a numerical value for TRM information. Some PMIS sections include a letter in TRM information (e.g., 420A, 435B). These should be modified to delete the letter designations before being included in the ranking process.
- The order of column and the cell formats in the raw data worksheet must be in the same format as that in the NLPS tool.

The details of raw data development and each attribute format are explained in Appendix A, The NLPS Tool User's Manual.



	A	B	C	E	F	G	H	I	M	N	O	P	Q	R	S	T	X	Y	Z	AA	AB	AC	AD
1	FY	DIST	COUNTY	HIGHWAY	BRM	BEG_DISP	ERM	END_DISP	RUT_SHALL	RUT_DEEF	PATCHING	FAILURE	BLOCK	ALLIGATOR	LONGI	TRANS	2011DISTRESS_	2011CONDITION	2010DISTRESS_	2010CONDITION_	DSD	CSD	
2	2011	14	011	FM0812 K	548	1.5	0550	0	001	000	041	00	000	029	072	00	36	33	100	53	-64	-20	
3	2011	14	011	FM0812 K	550	0	0550	0.5	000	000	030	00	000	039	118	00	32	31	37	29	-5	2	
4	2011	14	011	FM0812 K	550	0.5	0550	1	000	000	000	00	000	034	140	00	45	35	43	37	2	-2	
5	2011	14	011	FM0812 K	550	1	0550	1.5	001	000	008	00	000	040	150	00	37	26	39	10	-2	16	
6	2011	14	011	FM0812 K	550	1.5	0552	0	001	001	015	00	000	059	100	00	36	19	38	10	-2	9	
7	2011	14	011	FM0812 K	552	0	0552	0.5	000	000	005	00	000	028	139	00	44	34	50	17	-6	17	
8	2011	14	011	FM0812 K	552	0.5	0552	1	001	000	012	00	000	027	118	00	40	36	46	7	-6	29	
9	2011	14	011	FM0812 K	552	1	0552	1.5	000	000	015	00	000	030	099	00	40	17	58	13	-18	4	
10	2011	14	011	FM0812 K	552	1.5	0554	0	000	000	011	00	000	019	065	00	51	46	64	61	-13	-15	
11	2011	14	011	FM0812 K	554	0	0554	0.5	000	000	011	00	000	012	105	00	51	48	51	46	0	2	
12	2011	14	011	FM0812 K	554	0.5	0554	1	000	000	000	00	000	025	120	00	50	48	49	49	1	-1	
13	2011	14	011	FM0812 K	554	1	0554	1.5	000	000	000	00	000	007	038	00	83	83	42	42	41	41	
14	2011	14	011	FM0812 K	554	1.5	0556	0	001	000	000	00	000	011	090	00	66	66	61	61	5	5	
15	2011	14	011	FM0812 K	556	0	0556	0.5	003	001	000	00	000	035	130	00	46	46	39	28	7	18	
16	2011	14	011	FM0812 K	556	0.5	0556	1	000	000	000	00	000	000	010	00	100	100	100	100	0	0	
17	2011	14	011	FM0812 K	556	1	0556	1.5	000	000	000	00	000	029	080	00	55	55	90	58	-35	-3	
18	2011	14	011	FM0812 K	556	1.5	0558	0	002	000	000	00	000	013	037	00	71	71	52	52	19	19	
19	2011	14	011	FM0812 K	558	0	0558	0.5	000	000	018	00	000	021	070	00	44	44	56	56	-12	-12	
20	2011	14	011	FM0812 K	558	0.5	0558	1	003	001	000	01	000	015	088	00	56	56	35	35	21	21	
21	2011	14	011	FM0812 K	558	1	0558	1.5	002	000	000	00	000	006	080	00	79	79	33	32	46	47	
22	2011	14	011	FM0812 K	558	1.5	0560	0	000	000	000	00	000	000	000	00	100	100	58	27	42	73	
23	2011	14	011	FM0812 K	560	0	0560	0.3	000	000	000	00	000	045	070	00	52	52	33	33	19	19	
24	2011	14	011	FM0969 K	466	0	0466	0.5	002	000	000	00	000	000	000	00	100	100	100	100	0	0	
25	2011	14	011	FM0969 K	466	0.5	0466	1	003	000	000	00	000	000	000	00	100	100	100	100	0	0	
26	2011	14	011	FM0969 K	466	1	0466	1.5	004	000	000	00	000	000	000	00	100	100	100	100	0	0	
27	2011	14	011	FM0969 K	466	1.5	0468	0	003	000	000	00	000	000	000	00	100	100	100	100	0	0	
28	2011	14	011	FM0969 K	468	0	0468	0.5	006	001	000	00	000	000	000	00	99	99	100	100	-1	-1	
29	2011	14	011	FM0969 K	468	0.5	0468	1	004	001	000	00	000	000	000	00	100	100	100	100	0	0	
30	2011	14	011	FM0969 K	468	1	0468	1.5	004	000	000	00	000	000	000	00	100	100	100	100	0	0	
31	2011	14	011	FM0969 K	468	1.5	0470	0	006	001	000	00	000	000	000	00	99	99	100	100	-1	-1	
32	2011	14	011	FM0969 K	470	0	0470	0.5	005	002	000	00	000	000	000	00	99	99	100	100	-1	-1	
33	2011	14	011	FM0969 K	470	0.5	0470	1	005	000	000	00	000	000	000	00	99	99	100	100	-1	-1	
34	2011	14	011	FM0969 K	470	1	0470	1.5	004	000	000	00	000	000	000	00	100	100	100	100	0	0	
35	2011	14	011	FM0969 K	470	1.5	0472	0	004	000	000	00	000	000	000	00	100	100	100	100	0	0	
36	2011	14	011	FM0969 K	472	0	0472	0.5	005	000	000	00	000	000	000	00	99	99	100	100	-1	-1	
37	2011	14	011	FM0969 K	472	0.5	0472	1	004	000	000	00	000	000	000	00	100	100	100	100	0	0	
38	2011	14	011	FM0812 K	544	1.5	0544	2	000	000	000	00	000	000	000	00	100	100	100	100	0	0	
39	2011	14	011	FM0812 K	544	2	0544	2.5	001	000	000	00	000	000	009	00	100	100	100	100	0	0	
40	2011	14	011	FM0812 K	544	2.5	0548	0	001	000	000	00	000	000	025	00	100	95	76	72	24	23	
41	2011	14	011	FM0812 K	548	0	0548	0.5	000	000	000	00	000	000	006	00	100	100	100	100	0	0	
42	2011	14	011	FM0812 K	548	0.5	0548	1	000	000	028	00	000	000	010	00	69	69	93	84	-24	-15	
43	2011	14	011	FM0812 K	548	1	0548	1.5	000	000	000	00	000	000	011	00	100	100	100	100	0	0	
44	2011	14	011	FM2336 K	438	0	0438	0.5	003	001	000	01	000	000	000	00	90	70	90	58	0	12	
45	2011	14	011	FM2336 K	438	0.5	0438	1	004	002	000	00	000	003	010	00	96	75	99	84	-3	-9	

Figure 5.1: A Screen Capture of the Raw Data in the NLPS tool

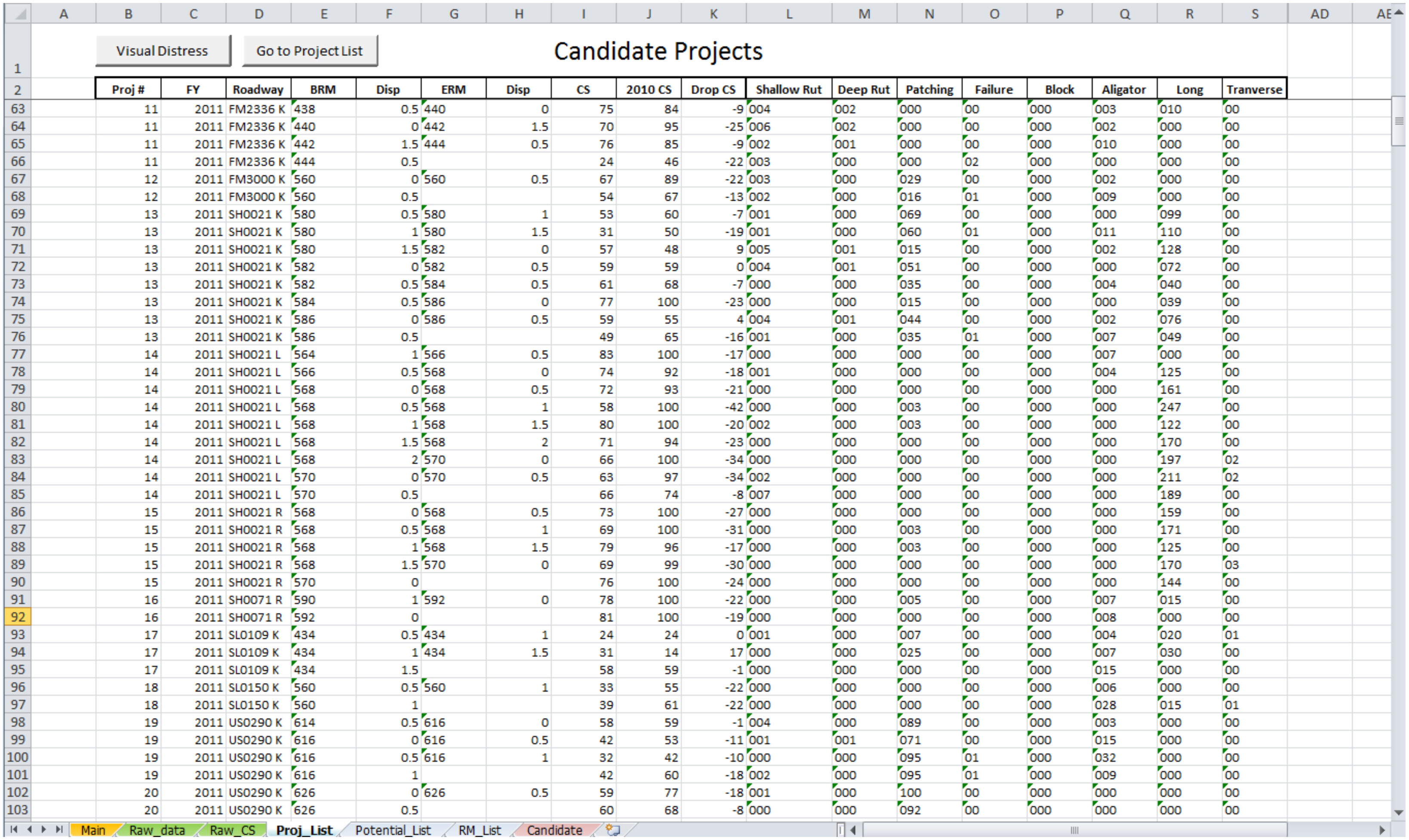
5.2 RESULTS

Using the PMIS data, which included a total of 712 pavement sections within Bastrop County, the NLPS tool produced 20 candidate projects to be further evaluated in the current year. As seen in Figure 5.2, each section was assigned a Project ID number based on Highway ID and TRM information. Based on the Project ID number, the user can identify the number of sections included within a project and gauge the total length of the project. Additionally, the raw visual distress information was imported from the PMIS database. The raw data will help engineers understand what types of distress have occurred on each pavement section and assist them in determining if the section primarily has structural or functional condition issues. In addition to the 20 candidate projects, the NLPS tool also generated three potential projects for years 2 and 3 of the Plan and six RM projects that are automatically stored in separate tabs shown Figures 5.3 and 5.4. These lists contain the same information as the 20 candidate projects designated for the current year.

Once the list of candidate project sections for the current year was developed, the list was summarized by assigning Project ID numbers as shown in Figure 5.5. The project screening matrix was applied. The matrix determines how many sections within a project fit into each of the CS and CSD range categories and then calculates the percentage of sections depending on the projects' total length. The contribution of each CS or CSD index category and its potential weight are calculated separately and summed to get weighted CS and weighted CSD. The weighted CS and CSD and the weighting factors given for each are calculated to obtain a Total Score.

Figure 5.5 shows the summarized candidate project list ranked by the weighted Total CS. The projects are rank-ordered and the highest-priority project listed first.

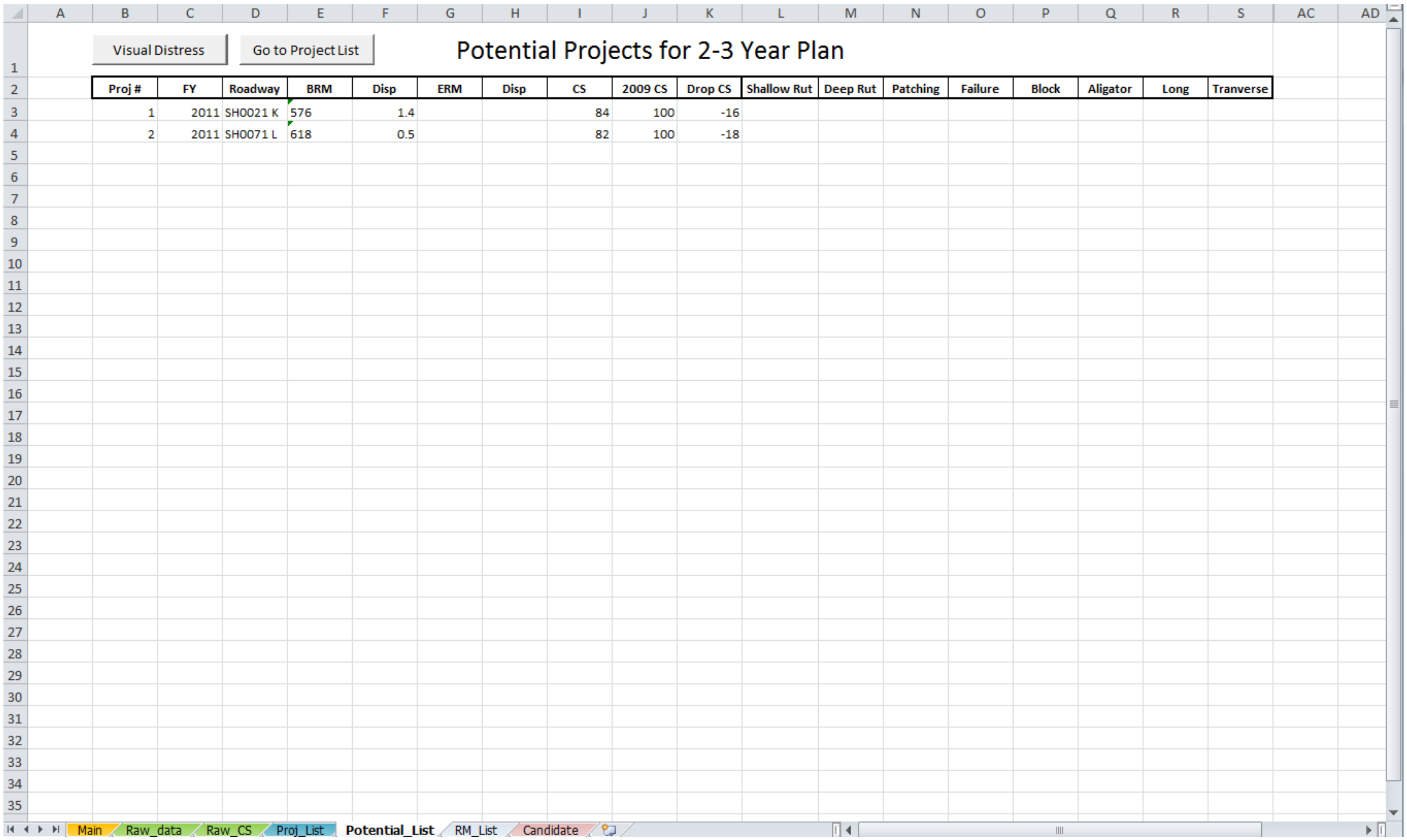
Project 18 has highest priority because all the sections are in critical condition and deteriorating fast; most sections show the largest drop in Condition Score over a year. Project 7, ranked second, has 17 sections, most of which are in critical condition but deteriorating slowly. Lower priority projects are in relatively good condition and deteriorating gradually. The NLPS tool provides not only section counts assigned to each CS and CSD category but also a summation of the raw data score for each visual distress that exists within project limits. The summation of each raw visual distress score indicates if a project has functional or structural problems. This information helps engineers determine if a project is a candidate for PM or Rehab treatment.



Candidate Projects

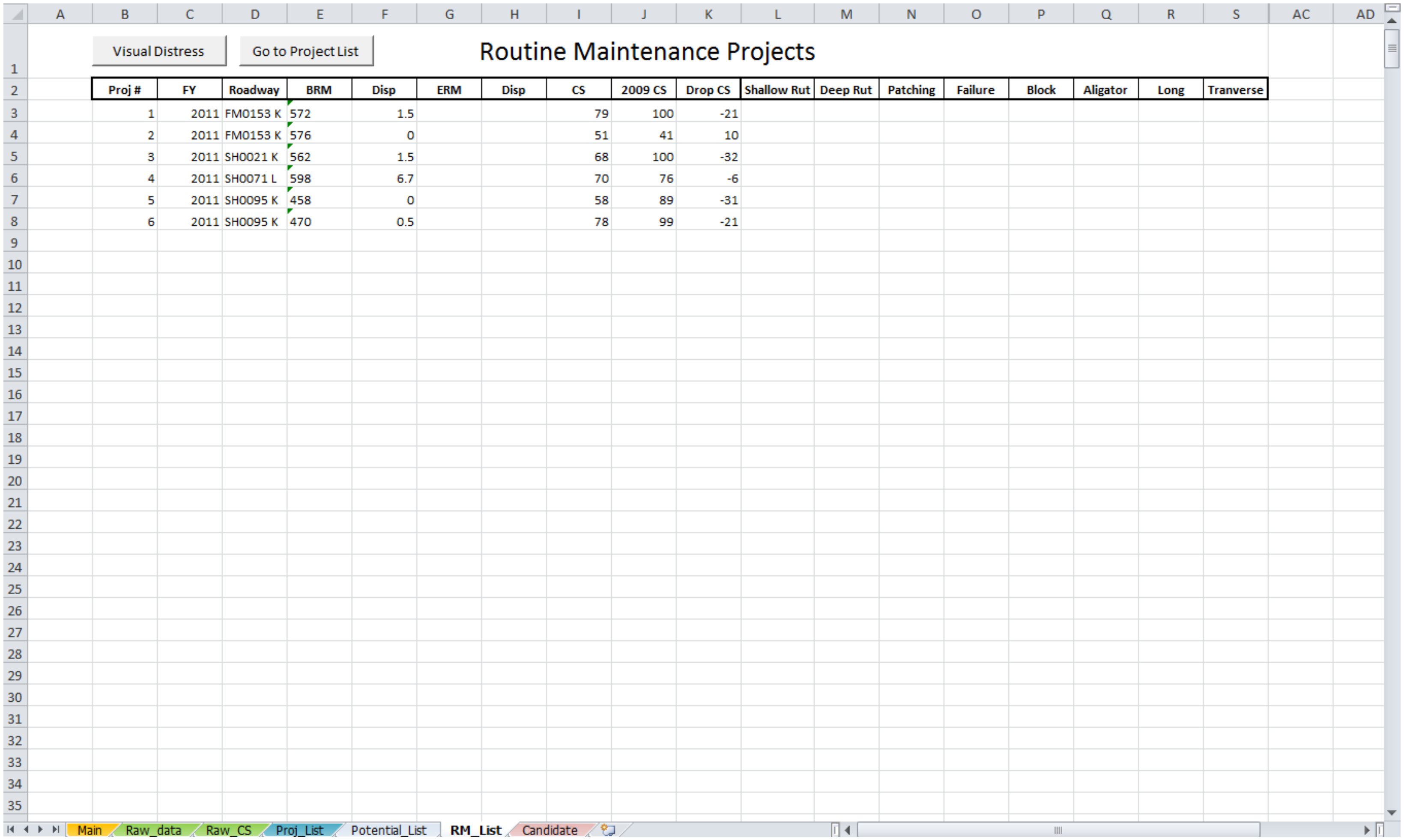
	Proj #	FY	Roadway	BRM	Disp	ERM	Disp	CS	2010 CS	Drop CS	Shallow Rut	Deep Rut	Patching	Failure	Block	Aligator	Long	Tranverse
63	11	2011	FM2336 K	438	0.5	440	0	75	84	-9	004	002	000	00	000	003	010	00
64	11	2011	FM2336 K	440	0	442	1.5	70	95	-25	006	002	000	00	000	002	000	00
65	11	2011	FM2336 K	442	1.5	444	0.5	76	85	-9	002	001	000	00	000	010	000	00
66	11	2011	FM2336 K	444	0.5			24	46	-22	003	000	000	02	000	000	000	00
67	12	2011	FM3000 K	560	0	560	0.5	67	89	-22	003	000	029	00	000	002	000	00
68	12	2011	FM3000 K	560	0.5			54	67	-13	002	000	016	01	000	009	000	00
69	13	2011	SH0021 K	580	0.5	580	1	53	60	-7	001	000	069	00	000	000	099	00
70	13	2011	SH0021 K	580	1	580	1.5	31	50	-19	001	000	060	01	000	011	110	00
71	13	2011	SH0021 K	580	1.5	582	0	57	48	9	005	001	015	00	000	002	128	00
72	13	2011	SH0021 K	582	0	582	0.5	59	59	0	004	001	051	00	000	000	072	00
73	13	2011	SH0021 K	582	0.5	584	0.5	61	68	-7	000	000	035	00	000	004	040	00
74	13	2011	SH0021 K	584	0.5	586	0	77	100	-23	000	000	015	00	000	000	039	00
75	13	2011	SH0021 K	586	0	586	0.5	59	55	4	004	001	044	00	000	002	076	00
76	13	2011	SH0021 K	586	0.5			49	65	-16	001	000	035	01	000	007	049	00
77	14	2011	SH0021 L	564	1	566	0.5	83	100	-17	000	000	000	00	000	007	000	00
78	14	2011	SH0021 L	566	0.5	568	0	74	92	-18	001	000	000	00	000	004	125	00
79	14	2011	SH0021 L	568	0	568	0.5	72	93	-21	000	000	000	00	000	000	161	00
80	14	2011	SH0021 L	568	0.5	568	1	58	100	-42	000	000	003	00	000	000	247	00
81	14	2011	SH0021 L	568	1	568	1.5	80	100	-20	002	000	003	00	000	000	122	00
82	14	2011	SH0021 L	568	1.5	568	2	71	94	-23	000	000	000	00	000	000	170	00
83	14	2011	SH0021 L	568	2	570	0	66	100	-34	000	000	000	00	000	000	197	02
84	14	2011	SH0021 L	570	0	570	0.5	63	97	-34	002	000	000	00	000	000	211	02
85	14	2011	SH0021 L	570	0.5			66	74	-8	007	000	000	00	000	000	189	00
86	15	2011	SH0021 R	568	0	568	0.5	73	100	-27	000	000	000	00	000	000	159	00
87	15	2011	SH0021 R	568	0.5	568	1	69	100	-31	000	000	003	00	000	000	171	00
88	15	2011	SH0021 R	568	1	568	1.5	79	96	-17	000	000	003	00	000	000	125	00
89	15	2011	SH0021 R	568	1.5	570	0	69	99	-30	000	000	000	00	000	000	170	03
90	15	2011	SH0021 R	570	0			76	100	-24	000	000	000	00	000	000	144	00
91	16	2011	SH0071 R	590	1	592	0	78	100	-22	000	000	005	00	000	007	015	00
92	16	2011	SH0071 R	592	0			81	100	-19	000	000	000	00	000	008	000	00
93	17	2011	SL0109 K	434	0.5	434	1	24	24	0	001	000	007	00	000	004	020	01
94	17	2011	SL0109 K	434	1	434	1.5	31	14	17	000	000	025	00	000	007	030	00
95	17	2011	SL0109 K	434	1.5			58	59	-1	000	000	000	00	000	015	000	00
96	18	2011	SL0150 K	560	0.5	560	1	33	55	-22	000	000	000	00	000	006	000	00
97	18	2011	SL0150 K	560	1			39	61	-22	000	000	000	00	000	028	015	01
98	19	2011	US0290 K	614	0.5	616	0	58	59	-1	004	000	089	00	000	003	000	00
99	19	2011	US0290 K	616	0	616	0.5	42	53	-11	001	001	071	00	000	015	000	00
100	19	2011	US0290 K	616	0.5	616	1	32	42	-10	000	000	095	01	000	032	000	00
101	19	2011	US0290 K	616	1			42	60	-18	002	000	095	01	000	009	000	00
102	20	2011	US0290 K	626	0	626	0.5	59	77	-18	001	000	100	00	000	000	000	00
103	20	2011	US0290 K	626	0.5			60	68	-8	000	000	092	00	000	000	000	00

Figure 5.2: A Screen Capture of Sections of Candidates


Visual Distress
Go to Project List
Potential Projects for 2-3 Year Plan

Proj #	FY	Roadway	BRM	Disp	ERM	Disp	CS	2009 CS	Drop CS	Shallow Rut	Deep Rut	Patching	Failure	Block	Aligator	Long	Tranverse
1	2011	SH0021 K	576	1.4			84	100	-16								
2	2011	SH0071 L	618	0.5			82	100	-18								

Figure 5.3: A Screen Capture of Sections of Potential Projects



Visual Distress   Go to Project List

Routine Maintenance Projects

Proj #	FY	Roadway	BRM	Disp	ERM	Disp	CS	2009 CS	Drop CS	Shallow Rut	Deep Rut	Patching	Failure	Block	Aligator	Long	Tranverse
1	2011	FM0153 K	572	1.5			79	100	-21								
2	2011	FM0153 K	576	0			51	41	10								
3	2011	SH0021 K	562	1.5			68	100	-32								
4	2011	SH0071 L	598	6.7			70	76	-6								
5	2011	SH0095 K	458	0			58	89	-31								
6	2011	SH0095 K	470	0.5			78	99	-21								

Figure 5.4: A Screen Capture of Sections of Routine Maintenance Projects

$$Index\ Score = \left\{\left(\frac{Num\ of\ Section\ Poor}{2}\right) + \left(\frac{Num\ of\ Section\ Marginal}{4}\right)\right\} \times \text{Total CS Score} + RS\ Index$$

							Condition Score (CS)				Drop Condition Score (DCS)			
						Weighting factor	0.7				0.3			
Proj #	Roadway	BRM	Disp	ERM	Disp		0.4	0.3	0.2	0.1	0.1	0.2	0.3	0.4
						Score Range	0≦CS<30	30≦CS<50	50≦CS<70	70≦CS	-10≦CSD	-20≦CSD<-10	-30≦CSD<-20	CSD≦-30
18	SL0150 K	560	0.5	560	1	# of Sections	0	2	0	0	0	0	2	0
7	FM0812 K	548	0.5	560	0	# of Sections	3	10	4	0	13	4	0	0
8	FM1100 K	560	0	562	0	# of Sections	1	2	1	0	4	0	0	0
17	SL0109 K	434	0.5	434	1.5	# of Sections	1	1	1	0	3	0	0	0
19	US0290 K	614	0.5	616	1	# of Sections	0	3	1	0	2	2	0	0
1	FM0020 K	568	0.5	578	0.5	# of Sections	3	6	5	1	11	4	0	0
12	FM3000 K	560	0	560	0.5	# of Sections	0	0	2	0	0	1	1	0
6	FM0696 K	566	1.5	566	1.9	# of Sections	0	0	1	1	0	0	1	1
13	SH0021 K	580	0.5	586	0.5	# of Sections	0	2	5	1	5	2	1	0
15	SH0021 R	568	0	570	0	# of Sections	0	0	2	3	0	1	3	1
3	FM0535 K	552	0	564	0	# of Sections	0	3	4	3	7	1	2	0
20	US0290 K	626	0	626	0.5	# of Sections	0	0	2	0	1	1	0	0
5	FM0672 K	556	0	556	0.5	# of Sections	0	0	2	0	1	1	0	0
14	SH0021 L	564	1	570	0.5	# of Sections	0	0	4	5	1	3	2	3
11	FM2336 K	438	0.5	444	0.5	# of Sections	1	0	0	3	2	0	2	0
4	FM0535 K	574	0	574	1	# of Sections	0	0	2	0	2	0	0	0
9	FM2104 K	446	0.5	448	0.5	# of Sections	0	0	2	1	1	2	0	0
2	FM0535 K	546	0	546	0.5	# of Sections	0	0	1	1	0	2	0	0
10	FM2104 K	452	0.5	454	0	# of Sections	0	0	0	3	0	1	2	0
16	SH0071 R	590	1	592	0	# of Sections	0	0	0	2	0	1	1	0

										Distress Summation							
Proj #	Weight CS	Weight DCS	Total CS	Rank by CS	RS Index	No. of Section - Poor	No. of Section - Marginal	Index Score	Rank by Index	SHALLOW RUT	DEEP RUT	PATCHING	FAILURE	BLOCK	ALLIGATOR	LONGITUDE	TRANSVERSE
18	30	30	30	1	-13.5	2	0	16.5	11	0	0	0	0	0	34	15	1
7	29.412	12.353	24.3	2	-1.24	13	4	181	1	10	3	194	1	0	487	1674	0
8	30	10	24	3	-7	3	1	35	7	5	2	48	2	0	41	125	1
17	30	10	24	3	-9.33	2	1	20.67	9	1	0	32	0	0	26	50	1
19	27.5	15	23.8	5	0	3	1	41.56	5	7	1	350	2	0	59	0	0
1	27.333	12.667	22.9	6	-9	9	6	128.6	2	36	5	309	2	0	25	69	0
12	20	25	21.5	7	0	0	2	10.75	14	5	0	45	1	0	11	0	0
6	15	35	21	8	0	0	2	10.5	15	2	0	69	1	0	2	0	0
13	21.25	15	19.4	9	0.38	2	6	48.81	4	16	3	324	2	0	26	613	0
15	14	30	18.8	10	0	0	5	23.5	8	0	0	6	0	0	0	769	3
3	20	15	18.5	11	-4.4	3	7	55.73	3	29	3	129	0	0	30	275	0
20	20	15	18.5	11	0	0	2	9.25	16	1	0	192	0	0	0	0	0
5	20	15	18.5	11	-2	0	2	7.25	18	7	7	10	2	0	7	0	0
14	14.444	27.778	18.4	14	0	0	9	41.5	6	12	0	6	0	0	11	1422	4
11	17.5	20	18.3	15	-5.75	1	3	17.06	10	15	5	0	2	0	15	10	0
4	20	10	17	16	0	0	2	8.5	17	4	0	74	0	0	15	0	0
9	16.667	16.667	16.7	17	0	0	3	12.5	12	8	2	144	0	0	2	0	0
2	15	20	16.5	18	-3.5	0	2	4.75	20	1	0	42	0	0	0	0	0
10	10	26.667	15	19	0	0	3	11.25	13	11	1	48	0	0	0	12	0
16	10	25	14.5	20	0	0	2	7.25	18	0	0	5	0	0	15	15	0

Main | Raw_data | Raw_CS | Proj_List | Potential_List | RM_List | Candidate

Figure 5.5: A Screen Capture of Candidates List with CS and CSD and Raw Visual Distress Information (Ranked by Total Condition Score)

As seen in Figure 5.6, there is a second ranking list based on the Index Score. The Index Score and ranking index equation was developed by the DPE based on CTR methodology. The Index is used when additional funds become available. The Index helps the DPE quickly evaluate which projects should be ranked higher for greater pavement network improvement with the additional funds. The Index Score was calculated based on the ranking index equation as follows:

$$Index\ Score = \left(\frac{Num.of\ section\ \ POOR}{2} + \frac{Num.of\ section\ \ MARGINAL}{4}\right) \times\ Total\ CS + RS\ Index$$

The equation is based on number of sections in poor condition (Condition Score range 0 to 50; number of sections in marginal condition: Condition Score 50 to 100); Total CS obtained from the network-level project screening matrix; and RS index. The RS index is the difference between Total DS and Total CS. Total DS is calculated based on the same methodology used in the calculation of Total CS.

This study performed a comparative analysis of the two ranking results. Figure 5.6 displays these results, and it was determined that although the order is different, 70 percent of projects ranked in the top 10 from each approach matched. There are small differences between the two results. Project 3 was given third highest priority based on the Index Score equation, but it was ranked 11th based on the network-level project screening matrix approach. Because the index equation used by engineers is based on the section count of each category rather than the percentage of sections depending on the total length of a project, it seems that relatively long-length projects would have higher priority and shorter projects would be given lower priority.

$$Index\ Score = \left\{\left(\frac{Num\ of\ Section\ Poor}{2}\right) + \left(\frac{Num\ of\ Section\ Marginal}{4}\right)\right\} \times \text{Total CS Score} + RS\ Index$$

Proj #	Roadway	BRM	Disp	ERM	Disp	Weighting factor	Condition Score (CS) 0.7				Drop Condition Score (DCS) 0.3			
							0.4	0.3	0.2	0.1	0.1	0.2	0.3	0.4
						Score Range	0≦CS<30	30≦CS<50	50≦CS<70	70≦CS	-10≦CSD	-20≦CSD<-10	-30≦CSD<-20	CSD≦-30
7	FM0812 K	548	0.5	560	0	# of Sections	3	10	4	0	13	4	0	0
1	FM0020 K	568	0.5	578	0.5	# of Sections	3	6	5	1	11	4	0	0
3	FM0535 K	552	0	564	0	# of Sections	0	3	4	3	7	1	2	0
13	SH0021 K	580	0.5	586	0.5	# of Sections	0	2	5	1	5	2	1	0
19	US0290 K	614	0.5	616	1	# of Sections	0	3	1	0	2	2	0	0
14	SH0021 L	564	1	570	0.5	# of Sections	0	0	4	5	1	3	2	3
8	FM1100 K	560	0	562	0	# of Sections	1	2	1	0	4	0	0	0
15	SH0021 R	568	0	570	0	# of Sections	0	0	2	3	0	1	3	1
17	SL0109 K	434	0.5	434	1.5	# of Sections	1	1	1	0	3	0	0	0
11	FM2336 K	438	0.5	444	0.5	# of Sections	1	0	0	3	2	0	2	0
18	SL0150 K	560	0.5	560	1	# of Sections	0	2	0	0	0	0	2	0
9	FM2104 K	446	0.5	448	0.5	# of Sections	0	0	2	1	1	2	0	0
10	FM2104 K	452	0.5	454	0	# of Sections	0	0	0	3	0	1	2	0
12	FM3000 K	560	0	560	0.5	# of Sections	0	0	2	0	0	1	1	0
6	FM0696 K	566	1.5	566	1.9	# of Sections	0	0	1	1	0	0	1	1
20	US0290 K	626	0	626	0.5	# of Sections	0	0	2	0	1	1	0	0
4	FM0535 K	574	0	574	1	# of Sections	0	0	2	0	2	0	0	0
5	FM0672 K	556	0	556	0.5	# of Sections	0	0	2	0	1	1	0	0
16	SH0071 R	590	1	592	0	# of Sections	0	0	0	2	0	1	1	0
2	FM0535 K	546	0	546	0.5	# of Sections	0	0	1	1	0	2	0	0

Proj #	Weight CS	Weight DCS	Total CS	Rank by CS	RS Index	No. of Section Poor	No. of Section - Marginal	Index Score	Rank by Index	Distress Summation: SHALLOW RUT	DEEP RUT	PATCHING	FAILURE	BLOCK	ALLIGATOR	LONGITUDE	TRANSVERSE
7	29.412	12.353	24.3	2	-1.24	13	4	181	1	10	3	194	1	0	487	1674	0
1	27.333	12.667	22.9	6	-9	9	6	128.6	2	36	5	309	2	0	25	69	0
3	20	15	18.5	11	-4.4	3	7	55.73	3	29	3	129	0	0	30	275	0
13	21.25	15	19.4	9	0.38	2	6	48.81	4	16	3	324	2	0	26	613	0
19	27.5	15	23.8	5	0	3	1	41.56	5	7	1	350	2	0	59	0	0
14	14.444	27.778	18.4	14	0	0	9	41.5	6	12	0	6	0	0	11	1422	4
8	30	10	24	3	-7	3	1	35	7	5	2	48	2	0	41	125	1
15	14	30	18.8	10	0	0	5	23.5	8	0	0	6	0	0	0	769	3
17	30	10	24	3	-9.33	2	1	20.67	9	1	0	32	0	0	26	50	1
11	17.5	20	18.3	15	-5.75	1	3	17.06	10	15	5	0	2	0	15	10	0
18	30	30	30	1	-13.5	2	0	16.5	11	0	0	0	0	0	34	15	1
9	16.667	16.667	16.7	17	0	0	3	12.5	12	8	2	144	0	0	2	0	0
10	10	26.667	15	19	0	0	3	11.25	13	11	1	48	0	0	0	12	0
12	20	25	21.5	7	0	0	2	10.75	14	5	0	45	1	0	11	0	0
6	15	35	21	8	0	0	2	10.5	15	2	0	69	1	0	2	0	0
20	20	15	18.5	11	0	0	2	9.25	16	1	0	192	0	0	0	0	0
4	20	10	17	16	0	0	2	8.5	17	4	0	74	0	0	15	0	0
5	20	15	18.5	11	-2	0	2	7.25	18	7	7	10	2	0	7	0	0
16	10	25	14.5	20	0	0	2	7.25	18	0	0	5	0	0	15	15	0
2	15	20	16.5	18	-3.5	0	2	4.75	20	1	0	42	0	0	0	0	0

Main / Raw data / Raw CS / Proj List / Potential List / RM List / **Candidate**

Figure 5.6: A Screen Capture of Candidates List with CS and CSD and Raw Visual Distress Information (Ranked by Index Score)

Austin DPEs indicated that they have an additional fund coming in, hence the reason they devised the Index equation. TxDOT administration would like allocate the additional budget on to projects with the most impact on network improvement. Therefore, a longer project may be given higher priority. In a constrained pavement maintenance budget scenario, long length projects can be divided into several small projects due to high construction estimates, even though one long length project could potentially save construction money considering manpower and other mobilization factors. For example, if TxDOT has five two-mile-long projects, it may require five contractors and five inspectors for each project location; however, if these are combined into one project, TxDOT only may need one or two inspectors and one contract. Therefore, the engineers have developed the index equation effected by total project length. The ranking list based on the index equation helps engineers quickly identify the longest construction projects that may have the most impact on the overall network improvement of Condition Score. According to the DPEs, if there is a budget constraint, they prioritize serviceability and AADT over total project length.

The primary function of the NLPS tool is to identify a list of candidate projects and present all necessary information. The tool helps engineers identify each candidate project so they can develop a preliminary list for further evaluation. The DPE does not consider traffic volume or other specific factors at this point; the goal is to identify a preliminary candidate list of projects for review and verification before proceeding to Step II. Once the DPE develops the preliminary candidate project list, he/she visits and discusses the candidate list with area engineers. An area engineer may opt to add candidate project(s) to the list not included based solely on the PMIS data. Because area engineers are familiar with local factors affecting roadways in their area of responsibility, their input improves the preliminary candidate project list. Once the list is updated, the

DPEs must provide the CS and CSD values so that new, additional candidate projects can be evaluated and the expanded candidate list re-ranked. If the area engineer has added one or more candidate projects with a lower ranking score than projects in the original candidate list, but are considered more highly ranked by the area engineers, this information is documented by the DPEs for later evaluation This information is also recorded by researchers for possible inclusion in the candidate ranking algorithm when available.

After a final candidate list is developed by the DPE and area engineers, the projects are evaluated using the raw PMIS distress data to determine which projects are potential candidates for PM or Rehab. This list of candidate projects is later evaluated in Step II (project-level ranking) of the 4-Year Pavement Management Process.

Chapter 6: Conclusion and Future Work

6.1 Conclusion

The primary objectives of this study are: 1) to develop a conceptual framework that describes the development of the 4-year Pavement Management Plan; and 2) to develop and implement Step I of the framework, which is a network-level candidate project ranking process. Conclusions drawn from this study are as follows:

- A literature review was undertaken to identify pavement management procedures implemented by other DOTs. It was found that most DOTs developed their own pavement management methods; however, these may not be appropriate for use statewide. Each district uses locally developed methods to rank and prioritize projects. The literature review found that most DOTs did not consider local district factors or did not provide flexibility for adjusting project ranking at each management level in their respective organizations. It was also recognized that cost and benefit analysis was required in management plans for developing long-term maintenance plans.

- A conceptual framework for 4-Year Pavement Management Plan was developed for this study. The framework can be largely divided into three steps: (1) a network-level preliminary project screening process, (2) a project-level project ranking process, and (3) an economic analysis. The network-level process helps engineers identify pavement needs and candidate projects for network improvement. The pre-screened candidate projects also assists engineers in planning field visits for further evaluation. During the project-level ranking process, the separate ranking approaches for PM and Rehab treatments helps engineers thoroughly evaluate each project and develop candidate project lists. Finally, project cost and benefit analysis ascertained after an economic analysis assists engineers in developing a long-term maintenance plan and finalizing project rankings.

- The proposed conceptual framework of 4-Year Pavement Management in this study can serve as a solid foundation for project prioritization based on thorough analysis of pavement needs and project evaluation. This process can potentially maximize efficiency in budget allocations, resulting in improved in pavement conditions.

- The project ranking algorithm includes several quantifiable variables such as ADT, truck ADT, pavement structural condition, and maintenance treatment costs, etc. Some additional factors, although unquantifiable, are taken into consideration to help improve ranking reliability. If there is more than one factor used to quantify an index, the reliability of that index can be potentially improved. For example, the project ranking score could consist of several indices, including a factor to quantify pavement structural condition. In this case, the user can select the value that best describes the current condition based on data he/she has collected. The reliability of the index value, if based on solely on engineering judgment with no site visit, would be lower than an index value based on a site visit and conducting an additional evaluation. Reliability factors can be used for quick review by district administration for the current fiscal year. Furthermore, it can potentially encourage districts to initiate site visits and conduct additional evaluation for sound pavement management practices.

- The proposed 4-Year Pavement Management Plan is based on a comprehensive ranking methodology that can be used by different management levels (i.e., area engineers, district engineers or senior administration). Flexibility should be incorporated in the ranking process, allowing engineers in each district to adjust the level of index after considering local conditions. Therefore, study of how different users select various factors considered for ranking projects according to local conditions should be conducted in future work.

- The NLPS tool was developed to assist TxDOT in selecting and evaluating candidate projects. The NLSP reduced the time and effort required for project analysis and evaluation and also minimizes human error. A user manual was also developed to provide necessary guidelines for the use of the NLPS tool.

6.2 FUTURE WORK

- It is necessary to analyze the treatment history index for possible use in the PM ranking methodologies in future work. The performance of a section can help identify treatment timing and also suggest required treatment levels. However, it is difficult to determine if a small change in score is result from routine maintenance or variability in the visual distress pavement rater's subjective judgment. Because the frequency of routine maintenance is an important factor for a treatment decision and ranking process, it is necessary to identify an approach that analyzes routine maintenance treatment history data. The amount of funds spent on RM may be a potential new factor to include in the candidate ranking index.

- Typically, treatment history can be inferred from two sources: the Design and Construction Information System (DCIS) and SiteManager. The DCIS is an automated information system TxDOT uses to plan, program and develop projects. It contains project information such as work description, funding requirement and dates for proposed activities [2006 TxDOT]. SiteManager contains project design and construction quality control and assurance (QC/QA) information. These sources can be sound references when inferring what type of treatment has been performed on each roadway. However, the problem with these sources is that the information recorded does not have consistent format; the beginning and ending extents of a project are not recorded with TRM location. It is difficult to establish a link between DCIS and PMIS or SiteManager and PMIS. Therefore, a study of how treatment history data from DCIS and SiteManager could be integrated with the PMIS database should be done before applying the data to the proposed ranking methodology. If this process is automated, the DPEs can spend more of their valuable time making engineering and management decision rather than processing and getting the data into their preferred format for project evaluation.

- Future work is needed to develop the separate Project-Level ranking methodology for PM projects and Rehab projects. Unlike the Network-Level process, for Project-Level ranking process, a comprehensive ranking methodology will be required. PM ranking methodology should be based on the field survey information in conjunction with treatment history, engineering judgment and FWD Network-Level data if necessary. Rehab ranking methodology should be based on thorough field survey and distress data in conjunction with other data such as traffic data, soil conditions obtained from NDT tests, and engineer opinions. Therefore, in the future work, a critical task is to develop methodologies to quantify these variables and develop the evaluation index so that engineers can quickly and accurately evaluate candidate projects.

- In the future work, it is necessary to study how individual indices should be used on the ranking methodology. Each district may consider different factors and/or different factor weights based on their local conditions. In addition, each district has different quality of preparatory work for project ranking. To address these issues, the future study should consider how the local circumstances can be applied to the ranking methodology.

- Future work is required to research and develop an appropriate approach for cost and benefit analysis. In order to develop a method for quantifying benefit, expected performance increase, remaining services life or user cost can be considered.

Appendix A

User Manual of Network-Level Project Screening Tool

The user manual is prepared to assist TxDOT engineers in utilizing the Network-Level Project Screening (NLPS) tool. In order to use the NLPS tool, Microsoft Office version 2007 should be installed in the computer. The algorithm was written as a macro in Microsoft Office Excel using Visual Basic Applications (VBA). VBA is Excel's powerful built-in programming language and allows to you to easily incorporate user-written functions into a spreadsheet.

STEP 1: MAIN TAB

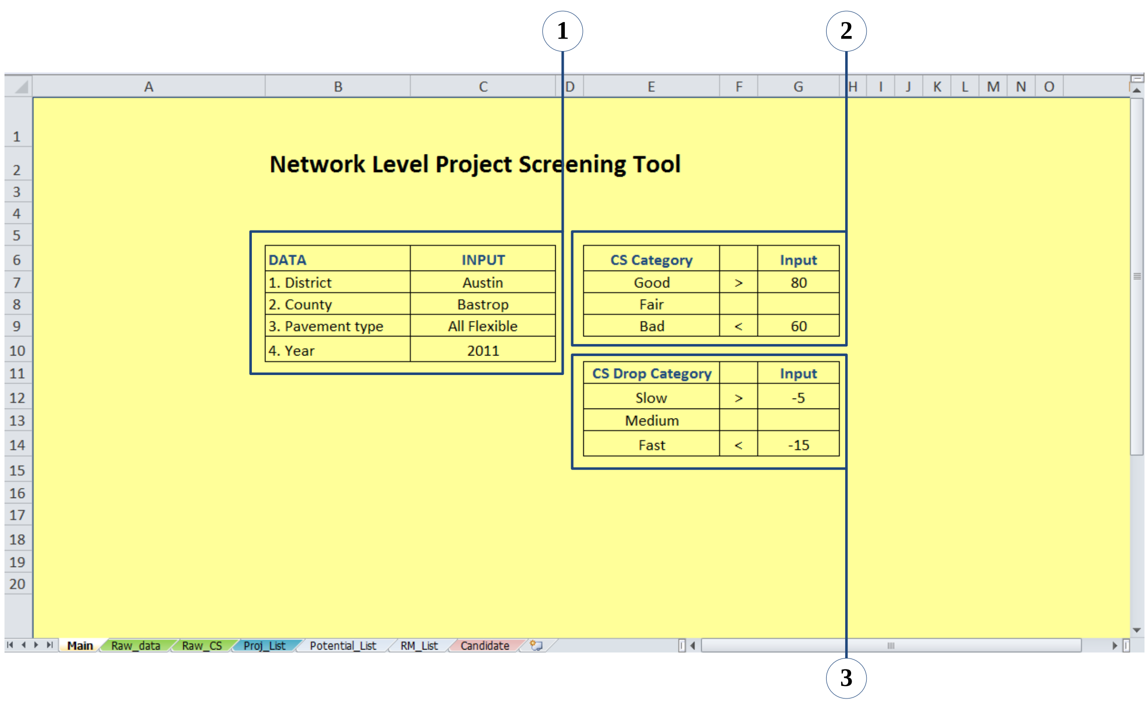


Figure A-1: A Screen Capture of Main Tab.

1. Data information box: User can type the information for a dataset including District, County, Pavement Type, and Fiscal Year. This is optional.
2. Condition Score category box: The user can change the Condition Score range to establish the criteria for the three categories: 'Good', 'Fair' or 'Bad'. For example, the user can select a score for Condition less than 50, and 'Good' greater than 70;
3. Condition Score Drop category box: The user can change the Drop Condition Score range of each class. For example, 'Fast' deterioration 'Fast' is less than -20, 'Slow' deterioration less than -5.

The Condition Score and Condition Score Drop ranges can be selected based on the user's experience or the consensus opinion of a group of experts within the district.

STEP 2: RAW DATA PREPARATION

The 2nd step to developing a preliminary candidate project list is to collect the necessary data from PMIS. The User can download PMIS data from the mainframe of TxDOT MapZapper program (PMIS mapping routine). Two MapZapper tables entitled 1) PMIS_DATA_COLLECTION_SECTION and 2) PMIS_ACP_DISTRESSES must be accessed to download the data.

Each column in the raw data worksheet follows the same format in PMIS so that the user can easily and quickly gather the necessary information from PMIS database.

	A	B	C	E	F	G	H	I	M	N	O	P	Q	R	S	T	X	Y	Z	AA	AB	AC
1	FY	DIST	COUNTY	HIGHWAY	BRM	BEG_DISP	ERM	END_DISP	RUT_SHALL	RUT_DEEF	PATCHING	FAILURE	BLOCK	ALLIGATOR	LONGI	TRANS	2011DISTRESS	2011CONDITION	2010DISTRESS	2010CONDITION	DSD	CSD
2	2011	14	011	FM0812 K	548	1.5	0550	0	001	000	041	00	000	029	072	00	36	33	100	53	-64	-20
3	2011	14	011	FM0812 K	550	0	0550	0.5	000	000	030	00	000	039	118	00	32	31	37	29	-5	2
4	2011	14	011	FM0812 K	550	0.5	0550	1	000	000	000	00	000	034	140	00	45	35	43	37	2	-2
5	2011	14	011	FM0812 K	550	1	0550	1.5	001	000	008	00	000	040	150	00	37	26	39	10	-2	16
6	2011	14	011	FM0812 K	550	1.5	0552	0	001	001	015	00	000	059	100	00	36	19	38	10	-2	9
7	2011	14	011	FM0812 K	552	0	0552	0.5	000	000	005	00	000	028	139	00	44	34	50	17	-6	17
8	2011	14	011	FM0812 K	552	0.5	0552	1	001	000	012	00	000	027	118	00	40	36	46	7	-6	29
9	2011	14	011	FM0812 K	552	1	0552	1.5	000	000	015	00	000	030	099	00	40	17	58	13	-18	4
10	2011	14	011	FM0812 K	552	1.5	0554	0	000	000	011	00	000	019	065	00	51	46	64	61	-13	-15
11	2011	14	011	FM0812 K	554	0	0554	0.5	000	000	011	00	000	012	105	00	51	48	51	46	0	2
12	2011	14	011	FM0812 K	554	0.5	0554	1	000	000	000	00	000	025	120	00	50	48	49	49	1	-1
13	2011	14	011	FM0812 K	554	1	0554	1.5	000	000	000	00	000	007	038	00	83	83	42	42	41	41
14	2011	14	011	FM0812 K	554	1.5	0556	0	001	000	000	00	000	011	090	00	66	66	61	61	5	5
15	2011	14	011	FM0812 K	556	0	0556	0.5	003	001	000	00	000	035	130	00	46	46	39	28	7	18
16	2011	14	011	FM0812 K	556	0.5	0556	1	000	000	000	00	000	000	010	00	100	100	100	100	0	0
17	2011	14	011	FM0812 K	556	1	0556	1.5	000	000	000	00	000	029	080	00	55	55	90	58	-35	-3
18	2011	14	011	FM0812 K	556	1.5	0558	0	002	000	000	00	000	013	037	00	71	71	52	52	19	19
19	2011	14	011	FM0812 K	558	0	0558	0.5	000	000	018	00	000	021	070	00	44	44	56	56	-12	-12
20	2011	14	011	FM0812 K	558	0.5	0558	1	003	001	000	01	000	015	088	00	56	56	35	35	21	21
21	2011	14	011	FM0812 K	558	1	0558	1.5	002	000	000	00	000	006	080	00	79	79	33	32	46	47
22	2011	14	011	FM0812 K	558	1.5	0560	0	000	000	000	00	000	000	000	00	100	100	58	27	42	73
23	2011	14	011	FM0812 K	560	0	0560	0.3	000	000	000	00	000	045	070	00	52	52	33	33	19	19
24	2011	14	011	FM0969 K	466	0	0466	0.5	002	000	000	00	000	000	000	00	100	100	100	100	0	0
25	2011	14	011	FM0969 K	466	0.5	0466	1	003	000	000	00	000	000	000	00	100	100	100	100	0	0
26	2011	14	011	FM0969 K	466	1	0466	1.5	004	000	000	00	000	000	000	00	100	100	100	100	0	0
27	2011	14	011	FM0969 K	466	1.5	0468	0	003	000	000	00	000	000	000	00	100	100	100	100	0	0
28	2011	14	011	FM0969 K	468	0	0468	0.5	006	001	000	00	000	000	000	00	99	99	100	100	-1	-1
29	2011	14	011	FM0969 K	468	0.5	0468	1	004	001	000	00	000	000	000	00	100	100	100	100	0	0
30	2011	14	011	FM0969 K	468	1	0468	1.5	004	000	000	00	000	000	000	00	100	100	100	100	0	0
31	2011	14	011	FM0969 K	468	1.5	0470	0	006	001	000	00	000	000	000	00	99	99	100	100	-1	-1
32	2011	14	011	FM0969 K	470	0	0470	0.5	005	002	000	00	000	000	000	00	99	99	100	100	-1	-1
33	2011	14	011	FM0969 K	470	0.5	0470	1	005	000	000	00	000	000	000	00	99	99	100	100	-1	-1
34	2011	14	011	FM0969 K	470	1	0470	1.5	004	000	000	00	000	000	000	00	100	100	100	100	0	0
35	11	14	011	FM0969 K	470	1.5	0472	0	004	000	000	00	000	000	000	00	100	100	100	100	0	0

Main | Raw_data | Raw_CS | Proj_List | Potential_List | RM_List | Candidate

Figure A-2: A Screen Capture of Raw Data Worksheet.

The raw data worksheet is consisting of total 23 columns as follows:

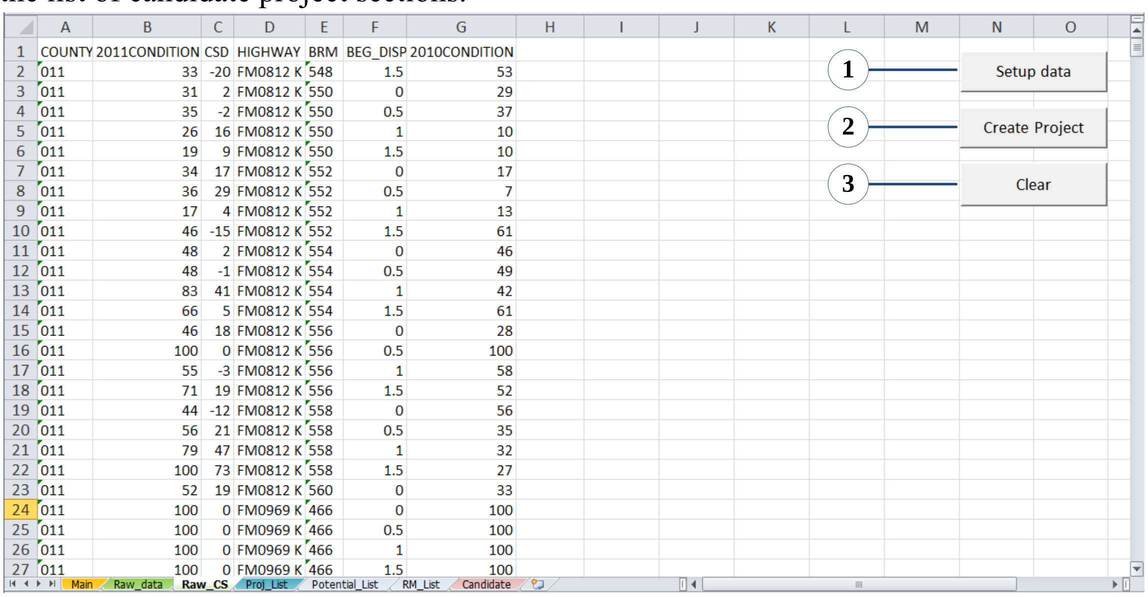
Column	Description	Example
Column A	Fiscal Year	
Column B	District Number	
Column C	County Number	
Column D	Maintenance Area Number	
Column E	Signed Highway and Roadbed ID	(e.g. IH0035 K, FM2222 R)
Column F	Beginning Reference Marker (BRM)	(e.g. 432, 243)
Column G	Displacement	(e.g. 0, 0.5, 1, 1.5)
Column H	Ending Reference Marker (ERM)	(e.g. 432, 243)
Column I	Displacement	(e.g. 0, 0.5, 1, 1.5)
Column M	Shallow Rutting Average Percent	
Column N	Deep Rutting Average Percent	
Column O	Patching Percent	
Column P	Failure Quantity	
Column Q	Block Cracking Percent	
Column R	Alligator Cracking Percent	
Column S	Longitudinal Cracking Percent	
Column T	Transverse Quantity	
Column X	FY 2011 Distress Score	
Column Y	FY 2011 Condition Score	
Column Z	FY 2010 Distress Score	
Column AA	FY 2010 Condition Score	
Column AB	Distress Score Drop (DSD)	
Column AC	Condition Score Drop (CSD)	

Table A-1: the Network-Level Project Screening Matrix.

Since PMIS does not automatically calculate the change in Scores from the previous year, Column AB (Distress Score Drop) and Column AC (Condition Score Drop) should be calculated manually using both the current and previous FY PMIS database. There are a few issues to consider when developing the raw data worksheet based on PMIS. The NLPS tool allows using only numerical value for TRM information. In some cases, PMIS includes a letter in TRM information (e.g. 420A, 435B). In that case, the letter should be removed before running the tool. Microsoft Office Excel has 'Text to Column' function to separate the contents of one Excel cell into separate columns. Users can use this function to separate a column of full TRM information into numbers and letters. In addition, the order of column (Column A through AC) should be the same as embedded in the tool

STEP 3: THE NECESSARY INFORMATION SETUP

Once the raw data preparation is completed , the user can proceed to step 3 by clicking on the tab 'Raw_CS' to check the project possibility of each section and create the list of candidate project sections.



COUNTY	2011CONDITION	CSD	HIGHWAY	BRM	BEG_DISP	2010CONDITION
011	33	-20	FM0812 K	548	1.5	53
011	31	2	FM0812 K	550	0	29
011	35	-2	FM0812 K	550	0.5	37
011	26	16	FM0812 K	550	1	10
011	19	9	FM0812 K	550	1.5	10
011	34	17	FM0812 K	552	0	17
011	36	29	FM0812 K	552	0.5	7
011	17	4	FM0812 K	552	1	13
011	46	-15	FM0812 K	552	1.5	61
011	48	2	FM0812 K	554	0	46
011	48	-1	FM0812 K	554	0.5	49
011	83	41	FM0812 K	554	1	42
011	66	5	FM0812 K	554	1.5	61
011	46	18	FM0812 K	556	0	28
011	100	0	FM0812 K	556	0.5	100
011	55	-3	FM0812 K	556	1	58
011	71	19	FM0812 K	556	1.5	52
011	44	-12	FM0812 K	558	0	56
011	56	21	FM0812 K	558	0.5	35
011	79	47	FM0812 K	558	1	32
011	100	73	FM0812 K	558	1.5	27
011	52	19	FM0812 K	560	0	33
011	100	0	FM0969 K	466	0	100
011	100	0	FM0969 K	466	0.5	100
011	100	0	FM0969 K	466	1	100
011	100	0	FM0969 K	466	1.5	100

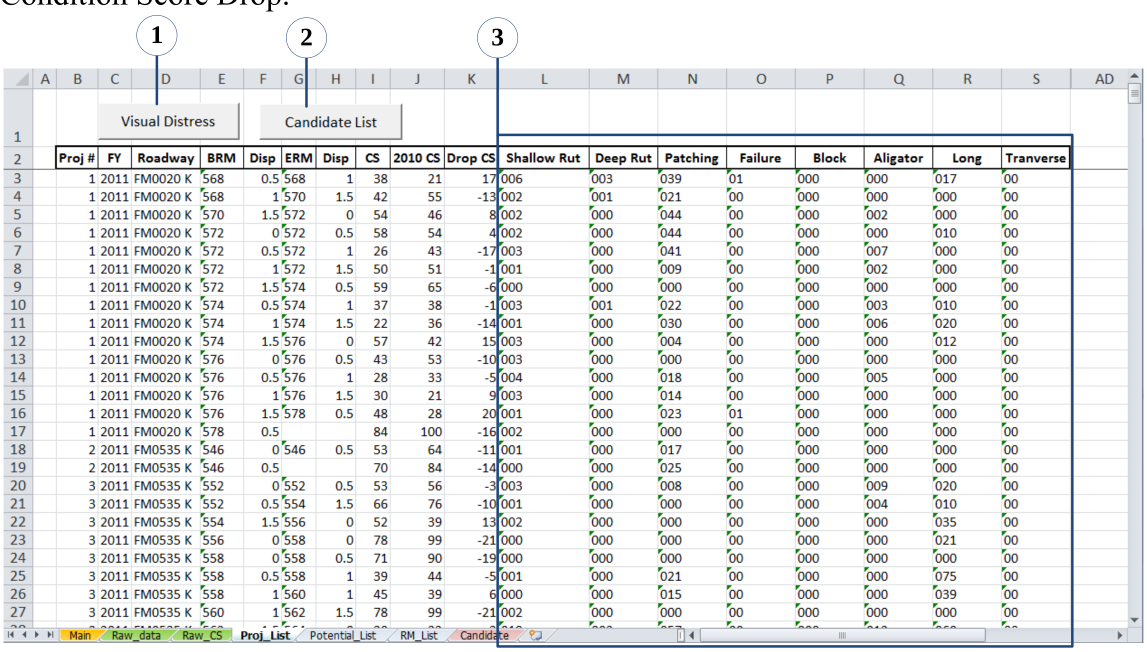
Figure A-3: A Screen Capture of Raw_CS Worksheet.

1. ‘Setup data’ button: User can setup the necessary information from the Raw_data worksheet to create the list of candidate project sections.
2. ‘Create Project’ button: User can create the list of candidate project sections. User can check the list in the tab labeled ‘Proj_List’ for the current year candidates, ‘Potential_List’ for the Year 2-3 projects, and ‘RM_List’ for Routine Maintenance Projects.
3. ‘Clear’ button: User can clear all the data on the screen

STEP 4: THE NECESSARY INFORMATION SETUP

Project_List Tab

In this tab, the list of candidate project sections for this current year is shown with Project ID number, Fiscal Year, TRM information, FY 2010-2011 Condition Score, and Condition Score Drop.



	Proj #	FY	Roadway	BRM	Disp	ERM	Disp	CS	2010 CS	Drop CS	Shallow Rut	Deep Rut	Patching	Failure	Block	Aligator	Long	Tranverse
3	1	2011	FM0020 K	568	0.5	568	1	38	21	17	006	003	039	01	000	000	017	00
4	1	2011	FM0020 K	568	1	570	1.5	42	55	-13	002	001	021	00	000	000	000	00
5	1	2011	FM0020 K	570	1.5	572	0	54	46	8	002	000	044	00	000	002	000	00
6	1	2011	FM0020 K	572	0	572	0.5	58	54	4	002	000	044	00	000	000	010	00
7	1	2011	FM0020 K	572	0.5	572	1	26	43	-17	003	000	041	00	000	007	000	00
8	1	2011	FM0020 K	572	1	572	1.5	50	51	-1	001	000	009	00	000	002	000	00
9	1	2011	FM0020 K	572	1.5	574	0.5	59	65	-6	000	000	000	00	000	000	000	00
10	1	2011	FM0020 K	574	0.5	574	1	37	38	-1	003	001	022	00	000	003	010	00
11	1	2011	FM0020 K	574	1	574	1.5	22	36	-14	001	000	030	00	000	006	020	00
12	1	2011	FM0020 K	574	1.5	576	0	57	42	15	003	000	004	00	000	000	012	00
13	1	2011	FM0020 K	576	0	576	0.5	43	53	-10	003	000	000	00	000	000	000	00
14	1	2011	FM0020 K	576	0.5	576	1	28	33	-5	004	000	018	00	000	005	000	00
15	1	2011	FM0020 K	576	1	576	1.5	30	21	9	003	000	014	00	000	000	000	00
16	1	2011	FM0020 K	576	1.5	578	0.5	48	28	20	001	000	023	01	000	000	000	00
17	1	2011	FM0020 K	578	0.5			84	100	-16	002	000	000	00	000	000	000	00
18	2	2011	FM0535 K	546	0	546	0.5	53	64	-11	001	000	017	00	000	000	000	00
19	2	2011	FM0535 K	546	0.5			70	84	-14	000	000	025	00	000	000	000	00
20	3	2011	FM0535 K	552	0	552	0.5	53	56	-3	003	000	008	00	000	009	020	00
21	3	2011	FM0535 K	552	0.5	554	1.5	66	76	-10	001	000	000	00	000	004	010	00
22	3	2011	FM0535 K	554	1.5	556	0	52	39	13	002	000	000	00	000	000	035	00
23	3	2011	FM0535 K	556	0	558	0	78	99	-21	000	000	000	00	000	000	021	00
24	3	2011	FM0535 K	558	0	558	0.5	71	90	-19	000	000	000	00	000	000	000	00
25	3	2011	FM0535 K	558	0.5	558	1	39	44	-5	001	000	021	00	000	000	075	00
26	3	2011	FM0535 K	558	1	560	1	45	39	6	000	000	015	00	000	000	039	00
27	3	2011	FM0535 K	560	1	562	1.5	78	99	-21	002	000	000	00	000	000	000	00

Figure A-4: A Screen Capture of Proj_List Worksheet.

1. ‘Visual Distress’ button: User can view the individual visual distress information of each section.
2. ‘Candidate List’ button: User can create the summarized candidate project list with the Network-Level Project Screening Matrix.
3. Individual visual distress information: If user click the button ⊖, ‘Visual Distress’, the visual distress information of each candidate section will be shown as follows: Shallow Rutting; Deep Rutting; Patching; Failure; Block Cracking; Alligator Cracking; Longitudinal Cracking; and Transverse Cracking.

Potential_List Tab

In this tab, the list of Potential 2-3 Year Plan project section is shown with Project ID number, Fiscal Year, TRM information, FY 2010-2011 Condition Score, and Condition Score Drop.

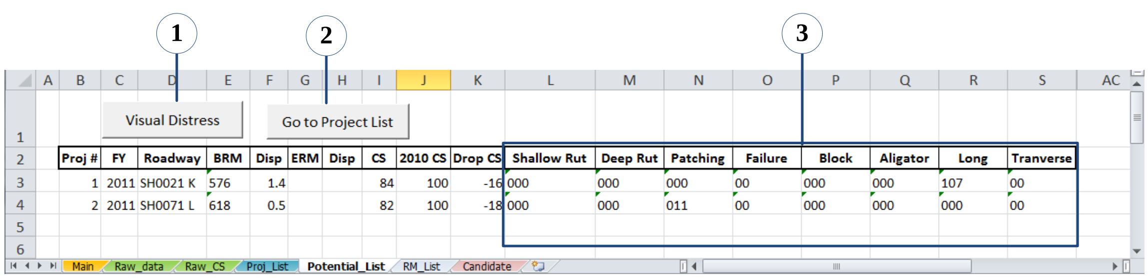


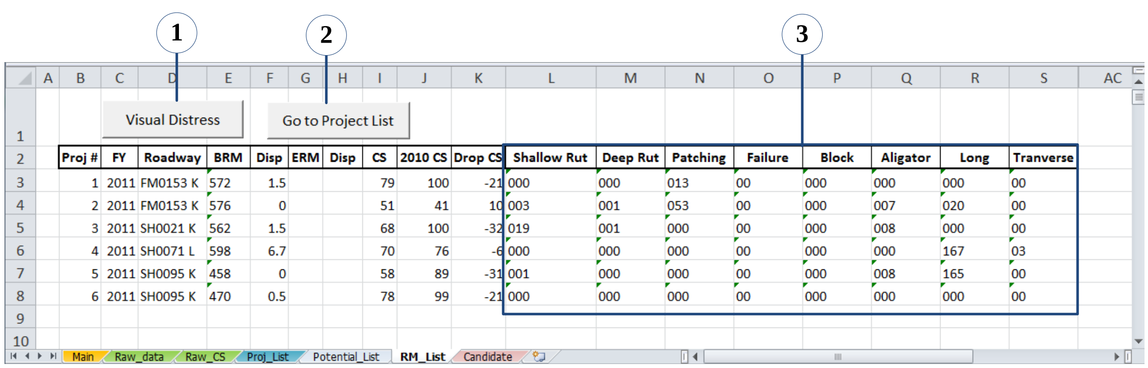
Figure A-5: A Screen Capture of Potential_List Worksheet.

1. ‘Visual Distress’ button: User can have the individual visual distress information of each Potential Project section
2. ‘Go to Project List’ button: User can go back to the ‘Project List’ Tab

3. Individual visual distress information: If user click the button ⊖, ‘Visual Distress’, the visual distress information of each candidate section will be shown as follows: Shallow Rutting; Deep Rutting; Patching; Failure; Block Cracking; Alligator Cracking; Longitudinal Cracking; and Transverse Cracking.

RM_List Tab

In this tab, the list of Routine Maintenance Project section is shown with Project ID number, Fiscal Year, TRM information, FY 2010-2011 Condition Score, and Condition Score Drop.



Proj #	FY	Roadway	BRM	Disp	ERM	Disp	CS	2010 CS	Drop CS	Shallow Rut	Deep Rut	Patching	Failure	Block	Aligator	Long	Tranverse
1	2011	FM0153 K	572	1.5			79	100	-21	000	000	013	00	000	000	000	00
2	2011	FM0153 K	576	0			51	41	10	003	001	053	00	000	007	020	00
3	2011	SH0021 K	562	1.5			68	100	-32	019	001	000	00	000	008	000	00
4	2011	SH0071 L	598	6.7			70	76	-6	000	000	000	00	000	000	167	03
5	2011	SH0095 K	458	0			58	89	-31	001	000	000	00	000	008	165	00
6	2011	SH0095 K	470	0.5			78	99	-21	000	000	000	00	000	000	000	00

Figure A-6: A Screen Capture of RMl_List Worksheet.

1. ‘Visual Distress’ button: User can view the individual visual distress information of each Potential Project section
2. ‘Go to Project List’ button: User can go back to the ‘Project List’ Tab
3. Individual visual distress information: If user click the button ⊖, ‘Visual Distress’, the visual distress information of each candidate section will be shown

as follows: Shallow Rutting; Deep Rutting; Patching; Failure; Block Cracking; Alligator Cracking; Longitudinal Cracking; and Transverse Cracking.

STEP 5: CANDIDATE PROJECT RANKING LIST

In this tab, the summarized list of candidate project is shown with Project ID number, TRM information, Condition Score and Condition Score Drop category matrix, the weighted total score and ranking, and the summation of individual visual distress.

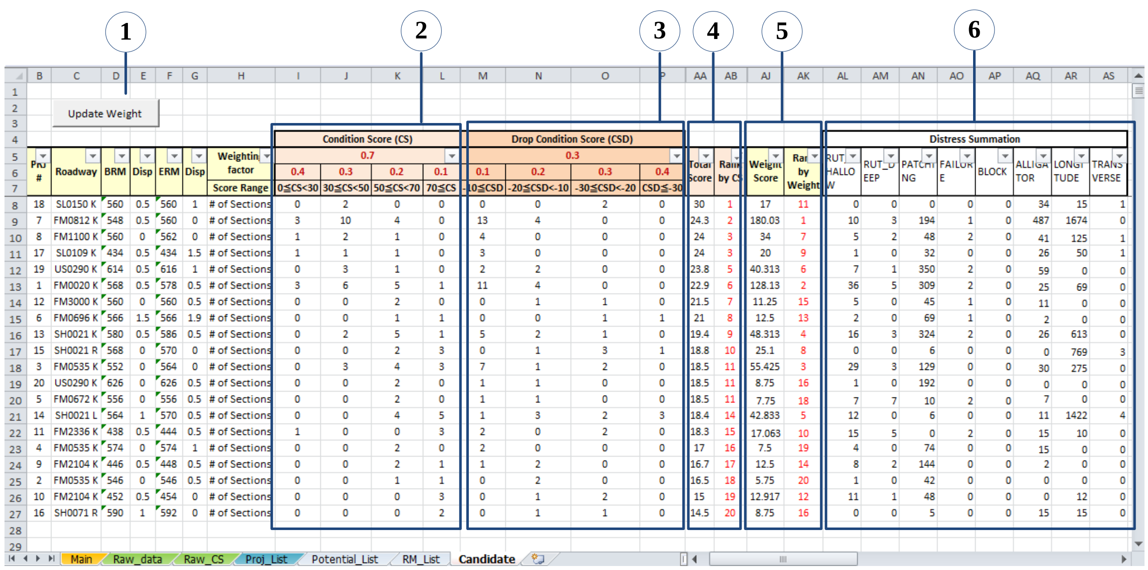


Figure A-7: A Screen Capture of Candidates Worksheet.

1. 'Update Weight' button: User can recalculate total score based on the updated weighting factors.
2. Condition Score matrix: It indicates section numbers fitting into each of the condition score categories.
3. Drop Condition Score matrix: It indicates section numbers fitting into each of the condition score drop categories.

4. Condition Score Ranking: This is the ranking list based on the Total Score.
5. Index Score Ranking: This is the ranking list based on the weighted Index Score obtained from the equation developed by Austin District Pavement Engineers.
6. Visual Distress summation: This is the summation of each visual distress of each project.

The macro will determine how many sections within a project fit into each of the Condition Score and Drop Condition Score categories. For example, in $0 \leqq CS < 30$ category, the number of sections with a Condition Score less than 30 are counted. In order to calculate total CS and CSD score, percentage of section in each category are calculated depending on the total number of sections within a project. Based on the percentage value and the weighting factor in each category, the weighted Condition Score and Drop Condition Score are calculated. Based on these two weighed scores and the weighting factors for each, the Total Score can be calculated, and then projects are ranked by the Total Score.

It should be noted that the sum of section count showing up in each category in candidate matrix can be the less than the total section counts that actually should be included in TRM range. The sections not considered as a project are excluded in Model and the candidate matrix will not count these sections. However, it these sections (with less than two sequential roadway ID and TRM) are existing between the sections considered as a project, these section will be all group together as a one project in Model 2. Since the candidate matrix will not count the sections having no project possibility but included in a project due to the adjacent sections' condition, the sum of section count in each category in candidate matrix can be different from the total section counts within TRM indicated.

Users can change the weighting factors for each CS category. Since the range of $0 \leqq CS < 30$ is the lowest CS category, the weighting factor has been set to 0.4, but users can change it to whatever they think is appropriate. Users can make similar changes to the weighting factors for the Condition Score Drop categories.

Also, note that user can make changes for the weighting factors for Condition Score (currently set to 0.7) and Drop Condition Score (currently set to 0.3). If users consider that the Drop Condition Score has more impact on project prioritization than the Condition Score, they can make this weight higher. User can tried with different weighting factors to come up with the best total score based on their experience. After changing the weights, just click 'Update Weights' and then the Scores will be recalculated.

Appendix B

User Manual of the Automated Project-Level Distress Survey Form

Based on the preliminary ranking list, the District Pavement Engineers (DPEs) will conduct a field survey for further Project-Level evaluation. Unlike visual distress rating at the Network-Level a thorough field survey is performed of distress type, density, severity and location (wheel path or non-wheel path) in terms of functional and structural distress type. The distress information will only play important role in ranking projects but also help engineers determine whether NDT is necessary for further evaluation.

Previously, the Austin DPE District Pavement Engineers used paper distress evaluation forms which were filled out manually. However, it is difficult to use in the field and may lead to safety concerns since the survey was conducted while driving along the route. In addition, after conducting a field survey, it was difficult to convert a number of rating sheets to automated data and it also takes a time to analyze and evaluate them.

To address these issues, an automated Project-Level distress evaluation form is developed in this study. While driving down the roadway user can type an 'x' in the cell that relates to the distress type, severity, and density. It is automatically stored in the database and evaluated based on weighting values of each category. This automated tool will help engineers to conduct a convenient survey and it will reduce safety concerns in the field. In addition, it will reduce the processing time to arrange and evaluate a number of rating results.

The user manual is prepared to assist TxDOT engineers in utilizing the automated Project-Level distress survey form. In order to use the tool, Microsoft Office version

2007 should be installed in the computer. The algorithm was written in macro enabled in Microsoft Office Excel using Visual Basic Applications (VBA).

STEP 1: MAIN TAB

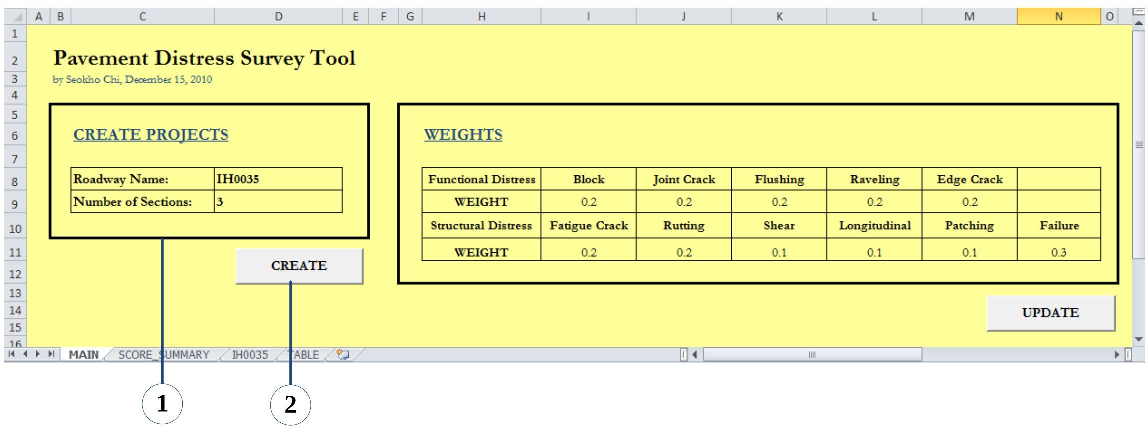
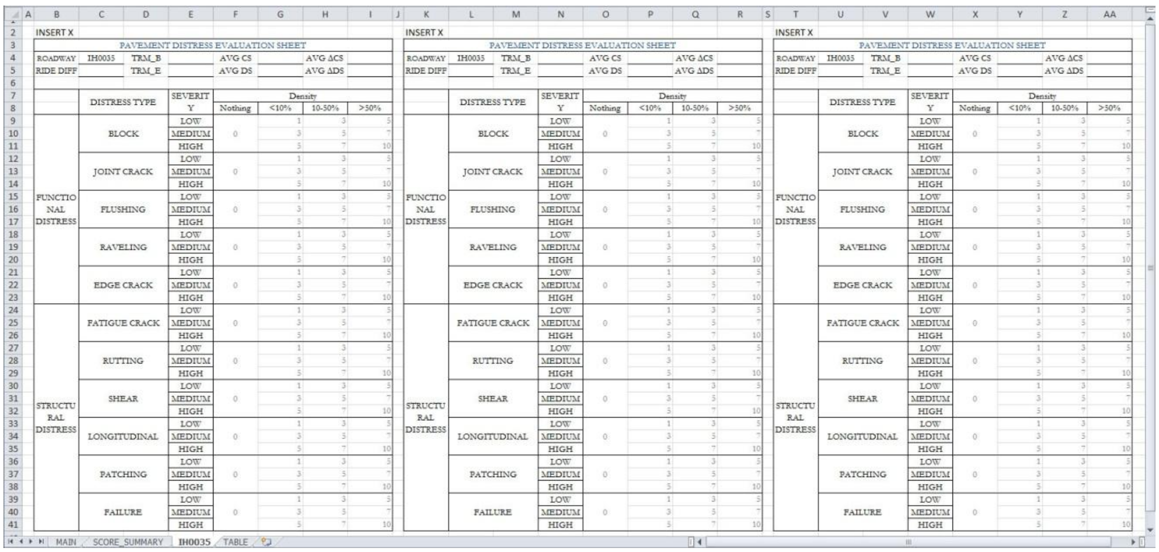


Figure B-1: A Screen Capture of Main Tab (Create Project Box).

1. Create Project box: User can type the roadway name (e.g. IH0035) and the number of section planning to rate.
2. ‘Create’ button: A new tab will be created with the number of rating forms.

The number of sections the user enters will result in a rating sheet being generated for each rating section (i.e. for each 1/2 mile PMIS section). After entering the number of Sections, hit Enter and then click 'CREATE'. A new tab will be created with the number of rating forms. For example, if user types IH0035 in the Roadway Name cell and 3 in the number of section cell, it can be seen that three rating forms are created in the tab labeled ‘IH0035’ as shown in the next figure.

If type IH 0035 in again for a second section, another tab will be created called IH35(x) (x) being the number of that tab in the spreadsheet. User can do this for each project he or she plans to rate and a new tab with the number of required rating forms will be created.


INSERT X

PAVEMENT DISTRESS EVALUATION SHEET

ROADWAY	IH0035	TRM_B		AVG CS		AVG ΔCS	
RIDE DIFF		TRM_E		AVG DS		AVG ΔDS	

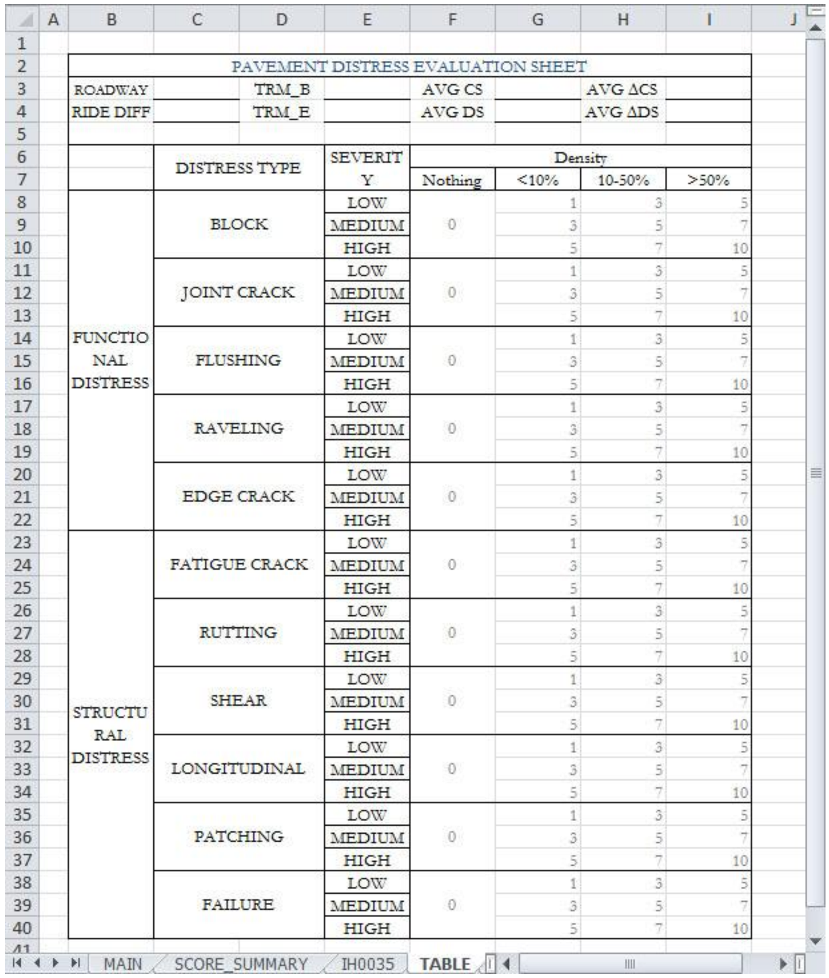
	DISTRESS TYPE	SEVERITY	Density: Nothing	<10%	10-50%	>50%
FUNCTIONAL DISTRESS	BLOCK	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	JOINT CRACK	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	FLUSHING	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	RAVELING	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	EDGE CRACK	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
STRUCTURAL DISTRESS	FATIGUE CRACK	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	RUTTING	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	SHEAR	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	LONGITUDINAL	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	PATCHING	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10
	FAILURE	LOW	0	1	3	5
		MEDIUM		3	5	7
		HIGH		5	7	10

MAIN / SCORE_SUMMARY / IH0035 / TABLE

Figure B-2: An Example of Creating a Tab for Survey Forms.

STEP 2: TABLE TAB

Referring to the tab labeled 'TABLE', the default form will be shown with values assigned to each functional or structural distress based on severity and density. Copy(ies) of this form are created when the user performs the actions discussed in Step 1. If the change of the score for a given distress severity/ density combination is necessary, user can make the change on the TABLE form.



PAVEMENT DISTRESS EVALUATION SHEET

ROADWAY	TRM_B	AVG CS	AVG ΔCS
RIDE DIFF	TRM_E	AVG DS	AVG ΔDS

	DISTRESS TYPE	SEVERITY	Density			
			Nothing	<10%	10-50%	>50%
FUNCTIONAL DISTRESS	BLOCK	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	JOINT CRACK	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	FLUSHING	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	RAVELING	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	EDGE CRACK	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
STRUCTURAL DISTRESS	FATIGUE CRACK	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	RUTTING	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	SHEAR	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	LONGITUDINAL	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	PATCHING	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10
	FAILURE	LOW		1	3	5
		MEDIUM	0	3	5	7
		HIGH		5	7	10

Figure B-3: The Default Survey Form.

STEP 3: RATING FORM TAB

Click on the 'IH0035' tab to see the rating sheets that were created in the earlier step. Before going to the field, user can create the number of rating sheets he or she will need for each project in the office and fill out any additional information necessary such as TRMs. While driving down the road all user will need to do is put an 'x' in the cell that relates to the distress type, severity, and density. For example, if there is no block cracking, type an 'x' in the cell labeled 'Nothing'. If there is medium severity edge cracking over 10 - 50% of the 1/2 mile section, type an 'x' in the Edge Crack field for MEDIUM - 10-50% which currently has a score five. Do this for each distress on each rating section. Once filling up is done, go back to the MAIN tab.

STEP 4: MAIN TAB FOR SCORE CALCULATION

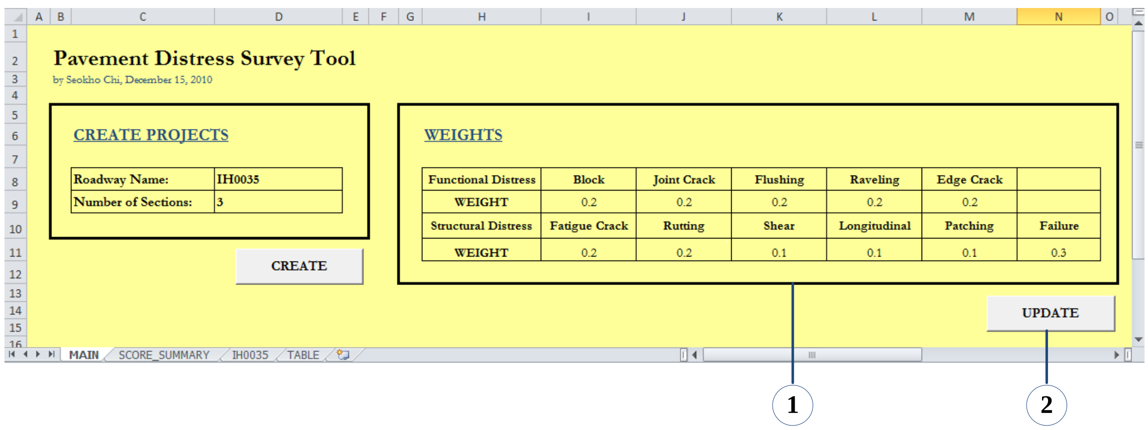


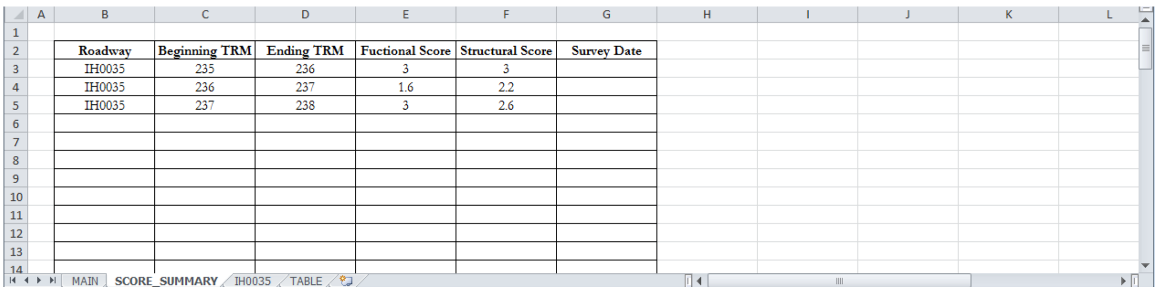
Figure B-4: A Screen Capture of Main Tab (Weights Table).

1. Weights table: User can type the weighting factors that are applied to each distress type listed on the rating form.
2. 'Update' button: user can find out what the score is by clicking the 'update' button on the weight table.
3.

User can tried with different weighting factors to come up with the best results based on their experience. If users change the weights, just click 'Update' and the score will be recalculated.

STEP 5: SCORE_SUMMARY TAB

Open the 'Score_Summary' tab and it can be seen that a functional Score and a structural score has been calculated for each TRM section for each roadway. The scores range from 0 meaning no distress at all on this section to 10 which is the maximum amount of distress.



Roadway	Beginning TRM	Ending TRM	Fuctional Score	Structural Score	Survey Date
IH0035	235	236	3	3	
IH0035	236	237	1.6	2.2	
IH0035	237	238	3	2.6	

Figure B-5: A Screen Capture of the Score_Summary Tab.

Glossary

PMIS is defined as an automated system developed by TxDOT for "storing, retrieving, analyzing, and reporting information to help with pavement-related decision-making processes" [TxDOT 1997]. Each District has developed a 4-Year pavement maintenance plan using the information from PMIS. The maintenance plan and the ranking process developed by this study are also based on the information derived from PMIS. The terminologies used in PMIS which may be helpful to readers unfamiliar with PMIS are summarized as below.

Condition Score describes the overall condition of the data collection section in terms of surface distress and ride quality. It represents the average score of what people see (distress) and what people feel (ride). Values range from 1 (very poor) to 100 (very good). [TxDOT 1997]

Drop Condition Score can be defined that the difference in condition score between the current year and the previous year. For example, FY2010 Drop Condition Score can be obtained by subtracting FY2009 Condition Score from FY 2010 Condition Score. The positive Drop Condition Score indicates that the pavement performance was improved; the negative Drop Condition Score indicates the pavement condition is deteriorating.

Texas Reference Marker (TRM) system is "an automated system documents the past, present and future state-maintained highway network of on-system roadways in the

State of Texas" [TxDOT 2005]. Besides pavement evaluation data, PMIS obtains other pavement data from other TxDOT automated system such as TRM system. PMIS obtain location data from TRM system such as District, County, Maintenance section, Highway, Beginning Reference Marker and displacement, Ending Reference Marker and displacement, and roadbed (for divided highways) [TxDOT 1997].

Beginning and Ending Reference Marker (BRM and ERM) is a reference marker on the highway that identifies the location on a highway. "Physical markers are numbered from state-line to state-line and from westernmost or northernmost point of the highway origin, i.e., south to north for interstate highway post numbering." [TxDOT 1997]

Beginning and Ending Reference Marker Distance specifies "the distance from a reference marker in tenths of a mile. This field may be negative indicating an opposite direction." [TxDOT 1997]

Signed Highway and Roadbed ID includes the highway system, the highway number, and the roadbed identification number. The highway system is a code to describe the signing of a highway section. It consists of two characters, the description of which is given in Table G.1. The highway number is a four character number adhered to the highway system. The roadbed ID is a code to identify separate roadbeds that constitute a highway section as shown in Table G.2. [André 2008]

Highway System Description	
IH	Interstate Highway
US	US Highway
UA	US Alternate
UP	US Highway Spur
SH	State Highway
SA	State Highway Alternate
SL	State Highway Loop
SS	State Highway Spur
BI	Off Interstate Business Route
BU	Off US Highway Business Route
BS	Off State Highway Business Route
BF	Off farm or Ranch to Market Road Business Route
FM	Farm to Market Road
RM	Ranch to Market Road
RR	Ranch Road
PR	Park Road
RE	Recreation Road
FS	Farm to Market Road Spur
RS	Ranch to Market Road Spur
RU	Ranch Road Spur
RP	Recreation Road Spur
PA	Principal Arterial Street System (PASS)
MH	Metropolitan Highway

Table G-1: PMIS Highway Systems [André 2008].

Roadbed ID Description	
K	Single mainlane road
A	Right frontage/service road
R	Right main lane road
X	Left frontage/service road
L	Left main lane road

Table G-2: PMIS Roadbed ID [André 2008].

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