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Nebraska Data Collection

Keyvan Zare Rami

University of Nebraska-Lincoln, keyvan.zare@huskers.unl.edu

Yong-Rak Kim

University of Nebraska - Lincoln, yong-rak.kim@unl.edu

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Nebraska Data Collection

Keyvan Zare Rami

Graduate Research Assistant
Department of Civil Engineering
University of Nebraska-Lincoln

Yong-Rak Kim, Ph.D.

Associate Professor
Department of Civil Engineering
University of Nebraska-Lincoln

2015

Nebraska Transportation Center
262 WHIT
2200 Vine Street
Lincoln, NE 68583-0851
(402) 472-1975

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Keyvan Zare Rami
Graduate Research Assistant
Department of Civil Engineering
362D Whittier Research Center
University of Nebraska, Lincoln, NE 68583
E-mail: keyvan.zare@huskers.unl.edu

and

Yong-Rak Kim, Ph.D.
Associate Professor
Department of Civil Engineering
362N Whittier Research Center
University of Nebraska, Lincoln, NE 68583
E-mail: ykim3@unl.edu

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ABSTRACT

Automated pavement performance data collection is a method that uses advanced technology to collect detailed road surface distress information at traffic speed. Agencies are driven to use automated survey techniques to enhance or replace their current manual visual distress survey because of the advantages of objective measurements and safety benefits. As agencies move toward the transition to fully automated data collection methods, there are common concerns regarding how the output of the new method will match the current manual survey ratings and how they will be adopted into the existing Pavement Management System (PMS). This study evaluates the newly implemented automated distress survey technique and its implementation into the Nebraska Pavement Management System (NPMS). To meet the objectives, a user-friendly program was developed to convert the automated distress ratings into the current manual visual distress ratings format. Then, a data set that includes more than 7000 miles of distress data collected by the automated method was converted to the manual data format and compared to the most recent manual rating data of those sections to assess the agreement between the two data formats after the conversion process. The results show that the automated pavement survey identifies slightly more bituminous pavement distresses with only a few distress types that could not be properly detected. Finally, a regression analysis of a core pavement performance indicator, Nebraska Serviceability Index (NSI), was conducted to examine how the new automated distress survey system will impact the NSI and ultimately affect pavement ratings if implemented into Nebraska's pavement management system.

CHAPTER 1

INTRODUCTION

The Moving Ahead for Progress in the 21st Century Act, or MAP-21, was signed into law by President Obama on July 6, 2012. Under MAP-21, U.S. Congress has required the development and implementation of uniform national performance measures on certain portions of the nation's highway system. Subsequently, the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) have been cooperating to develop performance measures that can be used by the state departments of transportation (DOTs) in order to improve the condition of the nation's highway networks. In particular, FHWA requests reports of condition and performance on the National Highway System (NHS) — an increase of 5% in mileage from past Highway Performance Monitoring System (HPMS) requirements.

To proactively manage the roadway system, state DOTs utilize Pavement Management System (PMS), which help them prioritize pavement maintenance and repair strategies in a cost-effective manner. Providing an optimum program of road development requires a large amount of road data collection and interpretation, which feeds decision-making analyses. The main part of data collection consists of road condition information in terms of pavement surface distresses. Traditionally, agencies inspect pavement performance manually, which means raters need to slowly drive along the shoulder to inspect of the road surface in a detailed Sample Site Survey. Then the detailed ratings are modified based on overall condition of pavement between Sample Sites. Taking into account the amount of roads to be surveyed each year, this method is highly time consuming and subjective. For these reasons, the Nebraska Department of Roads (NDOR), along with other state DOTs, is shifting from manual survey methods toward more automated

methods. In general, the automated data collection techniques that use multi-functional vehicles are capable of collecting a wealth of pavement information within a reasonable amount of time and cost.

In fully automated methods, the system is typically associated with an image processing software, which provides a tool to identify and categorize pavement distresses more objectively. This different approach between manual and automatic data collection methods brings some concerns as to how distress data obtained from the new method would be different from traditional manual survey results and how this difference might affect the existing decision-making process. Therefore, it is necessary to investigate how the new data collection output would be used in the current Nebraska Pavement Management System (NPMS). The approach is designed to keep the current decision-making process intact. Accordingly, a comprehensive research plan was designed to investigate the output data from the automated technique and convert it to the necessary performance measures. In addition, this study includes a detailed comparison of the data collected by the automated method and manual method. Converting the distress format between the manual and automated method is necessary and achieved in the form of a user-friendly program so that NDOR can routinely use any pavement condition data sets obtained from the automated data collection method.

This is clearly a pivotal moment in which new technology and new decision-making processes can advance quality of Nebraska's highway network. As illustrated in Figure 1.1, data collection and analysis of pavement distresses are core parts of the decision process. With more advanced data collection equipment being implemented, many new opportunities regarding data collection, use, and analysis will be possible. Thus, to ensure a smoother and more efficient implementation of the new data collection equipment and technology into the NPMS, it is

necessary to investigate features and functions of the new data collection equipment and study how the new performance measures would be used in the current NPMS.

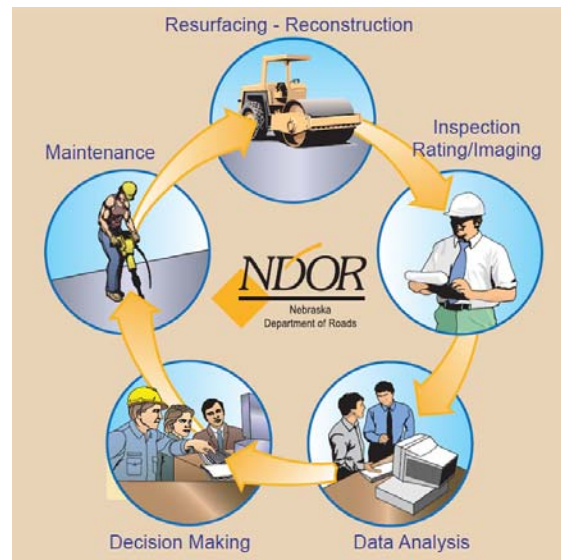


Figure 1.1 Overview of Nebraska PMS

1.1 RESEARCH OBJECTIVES AND SCOPES

The primary goal of this research is to find a rational way to implement the new automated data collection method so that no major revision is needed for the NPMS. To this end, the following specific objectives are targeted:

- To develop a process to convert the detailed output of the automated data collection method to the Nebraska distress survey format in terms of severity and extent rating of individual cracks. The result will be compatible with current NPMS and comparable to the manual visual survey report.
- To verify the validity of the automated data collection method through a comparison with manual visual survey data. This part includes the comparison of each distress individually

to determine which types of distresses should be collected more accurately. This task will then provide the vendor with reasonable insights for further improvement in distress detection procedure.

- To provide a relationship between the pavement performance indices calculated from the two sources of distress data: visual inspection and the automated method. This relation can then be used to amend the possible bias resulting from the use of the automated distress collection method.

1.2 ORGANIZATION OF THE REPORT

This report is organized in six chapters. Following this introduction, Chapter 2 provides a brief literature review of implementation of automated data collection method by other agencies. The focus is mostly on the adaptation of new method to current PMS and not quality assurance of automated method. Chapter 3 reviews the NPMS and pavement performance indices, which are necessary to be considered in data analysis. In addition, a quick review of manual surveying and automated surveying method is presented in this chapter. The goal is to provide a brief introduction to distress converting process which is explained in Chapter 4. Chapter 4 also includes a brief description of the Distress Format Converting (DFC) program, which is a primary deliverable of this research project. The comparison between automated survey results and manual survey results is discussed in Chapter 5. Because of several technical issues of the automated data collection system on rigid pavements and subsequent lack of data at this stage, this report mainly covers only the data analyses resulting from bituminous pavements. Finally, Chapter 6 provides a summary of the findings and conclusions of this study.

CHAPTER 2

LITERATURE REVIEW

In 2004, the Alabama Department of Transportation (ALDOT) investigated the differences between automatically and manually-collected distress measurements (Timm and McQueen 2004). First, they investigated the accuracy of the vendor's global positioning system (GPS) data. They showed that vendor could estimate the distance between two consecutive mileposts within the acceptable error range. The average calculated error was 0.65% of a mile. Then they examined the difference between distress measured by manual and automatic methods using regression plots. Excluding the International Roughness Index (IRI), they could not find any systematic errors in collecting other distress types (rut depth, alligator cracking, longitudinal cracking, and transverse cracking) by the automated method vs. manual method. All of those distresses demonstrated a random variability from the line of equality. In order to determine which distress has a higher impact on Pavement Condition Rating (PCR) and needs to be collected at higher level of accuracy, the sensitivity analysis of PCR equation was conducted. They used the Monte Carlo simulation method to analyze the sensitivity of each parameter.

ALDOT continued the work investigating PCR adaptation to the automated data collection method. In a report published in 2014, they developed a methodology to update PCR based on the automated survey while still reflecting the past experience of using the manual survey (Timm and Turochy 2014). Prior to this, they executed a statistical *t*-test to prove that automatically and manually-collected distress measurements are statistically different. The result showed that for all severities of transverse cracking, non-wheel path cracking, and wheel path cracking (which is defined similarly to alligator cracking in Nebraska's distress manual), the automatically and

manually-measured data were statistically different. In order to revise the PCR model, they performed an Artificial Neural Network (ANN) modeling and regression analysis. This analysis relied on samples of pavement distress data through automatically collected data paired with manually collected data as a “ground truth” data set, however, the ANN method did not result in an acceptable result. Finally, the multivariable non-linear least square regression was used to drive the recalibrated PCR model.

In another study (Vavrik et al. 2013), the Ohio Department of Transportation (ODOT) investigated the feasibility of transitioning from a manual data collection method to a semi-automated data collection method. In this study, they compared the automatically-collected data by three vendors with “ground truth” values from manual surveying. They selected 44 road sections and collected distress data in terms of distress type, severity, and extent (DSE) by all vendors and ODOT’s raters. Finally, they plotted the percent of sections in which each vendor’s automatic distress detection matched with the manual DSE rating. They also compared differences between vendor ratings and ODOT ratings. In addition, the vendors were asked to repeatedly survey a section in order to investigate the repeatability of each vendor’s system in measuring PCR. The PCR values from vendors and the manual survey were plotted in a scatter plot. They found poor R-square values (lower than 0.4) and concluded that these values indicate a weak agreement between data sets.

In 2010, New Mexico conducted a study on using automatic rutting measurement instead of manual measurement and the effect of this transition on the Pavement Serviceability Index (PSI) (Bandini and Pham 2010). First, they compared the rutting data and PSI collected by the manual and automated method using regression analysis. Then, they investigated two main approaches regarding this transition: (1) preserving the old PSI formulation and converting automatic rut depth

data to equivalent manual rutting data; (2) instead of converting rutting data, modifying the PSI formulation.

The Oregon Department of Transportation (ODOT) evaluated the automated pavement condition rating and rating crew survey by comparing those two results with a standard value from a manual survey (“walk and look”) by ODOT personnel (Mullis and Shippen 2005). They planned to conduct a set of field tests to investigate the accuracy and repeatability of both manual and automated pavement condition rating. They visually compared data sets and found that data collected by crew, only in the case of patching, raveling, and rutting, had a good agreement with ground truth. However, overall indices and fatigue-cracking indices presented a lower level of agreement. To complete the analysis, a correlation analysis was conducted to compare three data sets together. In addition to the distress indices, the total distress quantity for each distress and severity level was also compared with ground truth values.

CHAPTER 3

NEBRASKA PMS AND DISTRESS SURVEY METHODS

3.1 NEBRASKA PAVEMENT MANAGEMENT SYSTEM

Planning a strategy for cost-effective construction, maintenance, and rehabilitation of pavements in road systems needs to consider many factors that are related to current pavement condition data, annual budget, and agency policies. This planning cannot be accomplished only by implementing the Pavement Management System (PMS), which can be simply defined as a tool capable of collecting overall road condition data and using it to develop rehabilitation and maintenance strategies. The necessary detailed road information for PMS usually includes basic pavement information such as pavement inventory data, condition data, traffic data, and construction cost information. Among these, the collection and interpretation of pavement condition data are considered the core and most costly part of the operation of PMS.

Most agencies usually conduct the pavement evaluation process through a manual, semi-automated or automated survey to assess the pavement serviceability level. NPMS traditionally requires NDOR's personnel to annually visually survey roads to assess and record pavement surface deteriorations. Then, the detailed surface distress data are combined to summarize overall quality of pavement into two performance indicators, Nebraska Serviceability Index (NSI) and Present Serviceability Index (PSI). The NSI rating is calculated using visual surface distresses such as cracking, raveling, excess asphalt, and rutting, and formulated with sets of equations associated with two tables representing severity (see Table 3.1) and extent (see Table 3.2) of pavement distresses as follows (See Equations 3.1 to 3.6 (Nebraska Dept. of Roads, 2013))

Table 3.1 Severity numerical weight

Severity code	Edge, centerline, wheel path, between wheel path and alligator cracking, ravel/weathering, excessive asphalt	Grid/block cracking	Transverse cracking
Absent	0.0	0.0	0.0
L	0.2	0.2	0.2
M	0.8	0.4	0.4
H	1	0.8	0.8
X	-	1	1.2

Table 3.2 Extent numerical weight

Extent code	All distress types except ravel/weathering and excessive asphalt
Absent	0.0
T	0.1
O	0.3
F	0.5
E	0.7
C	0.9

$$crack = (0.556 \times c1) + (0.714 \times AG_{sev} \times AG_{ext} *) + F_{ext} \quad (3.1)$$

$$c1 = (0.125 \times EC_{sev} \times EC_{ext}) + (0.125 \times CL_{sev} \times CL_{ext}) + (0.25 \times BW_{sev} \times BW_{ext}) + (0.5 \times WP_{sev} \times WP_{ext}) \quad (3.2)$$

$$therm = (GB_{sev} \times GB_{ext}) + (TC_{sev} \times TC_{ext}) \quad (3.3)$$

$$cosmo = (0.6 \times W_{sev}) + (0.4 \times X_{sev}) \quad (3.4)$$

$$Factor1 = e^{-[0.6931473 \times (crack/0.5)^{0.887}]}$$

$$Factor2 = e^{-[0.6931473 \times (therm/1.4)^{1.200}]}$$

If Factor 2 < Factor 1

$$Factor3 = Factor2 \times Factor1^{0.1}$$

Else

$$Factor3 = Factor1 \times Factor2^{0.1}$$

End

(3.5)

$$Factor4 = Factor3 \times e^{-0.1109 \times cosmo}$$

$$Factor5 = e^{-0.5108260 \times (ru/15.875)^{2.0}}$$

If Factor 5 < Factor4

$$NSI = Factor5 \times Factor4^{0.1} \times 100$$

Else

$$NSI = Factor4 \times Factor5^{0.1} \times 100$$

end

(3.6)

where:

EC: Edge cracking

WP: Wheel path cracking

CL: Centerline cracking

BW: Between wheel path cracking

GB: Grid/block cracking

TC: Transverse cracking

AG: Alligator cracking

F: Failure

W: Raveling/weathering

X: Excess asphalt

ru: Average rutting (mm)

sev: Severity code

ext: Extent code

Similarly, the following equations provide the method to determine PSI value for bituminous pavements. PSI is a function of roughness (IRI), cracking, and rutting of bituminous pavements.

$$WPSI = 4.4 \times e^{-0.017474 \times SDPROF^{2.726} - 0.74118 \times (WGT_RUT/25.4)^2} \quad (3.7)$$

$$PSI = WPSI \times e^{-0.2 \times SEVTC \times EXTTC} \quad (3.8)$$

where:

- RUT: Weighted rut depth (mm)
- SDPROF: Weighted IRI
- IRI: International roughness index (mm/m)
- SEVTC: Severity of transverse cracking
- EXTTC: Extent of transverse cracking

Table 3.3 presents the NSI and PSI scale values and corresponding subjective interpretations. The PSI and NSI scale values vary between 0-5 and 0-100, respectively. For each index, a higher value means better pavement condition. These values are then used in the decision-making tree to determine prioritization of projects and maintenance strategies of Nebraska pavements.

Table 3.3 Performance indicators’ scales and subjective descriptions

NSI	PSI	Verbal Description
90-100	4.0-5.0	Excellent (Pavement like new)
70-90	3.0-4.0	Good (Several years of service life remaining)
50-70	2.0-3.0	Fair (Few years of service life remaining)
30-50	1.0-2.0	Poor (Candidate for rehabilitation)
0-30	0.0-1.0	Very Poor (Possible replacement)

As discussed, surveying the roads refers to the activities completed in order to measure the pavement deterioration by categorizing and evaluating pavement surface defects based on specific visual characteristics. NDOR has conducted this procedure with a combination of in-field visual rating of distresses and automated measuring of roughness and rutting, but is now transitioning to an automated crack detection system. The next two sections briefly discuss the two methods.

3.2 MANUAL DISTRESS SURVEY METHOD

Conventionally, a manual survey of pavement deterioration is carried out with a visual inspection and measuring of pavement surface distresses by one or more trained individuals. Surveyors assess the type of pavement defects according to visual appearance as they drive on the pavement. Pavement distresses are categorized into alligator cracking, edge cracking, longitudinal (wheel path, centerline, between wheel path) cracking, transverse cracking, grid block cracking, raveling/weathering, excess asphalt, and failures. All distress types are classified into different severity conditions, and extents which represents distress' deterioration intensity.

In order to take into account the density of each distress in a given segment of pavement, the extent levels are computed. For transverse cracks, extent level is defined according to the frequency of occurrence of cracks, and for other distresses, it is defined as the portion of total distress area (or length) to entire observed area (or length). Severity and extent level is typically calculated and reported at one-mile segments, between two consecutive reference posts. Therefore, all collected data are connected to each other by the reference post system. Since all levels of severity of a given distress type might appear in a single segment, NDOR reports the most severe, and the total extent is associated with all levels of severity over the segment.

To perform a manual survey in an efficient way, NDOR conducts a detailed distress evaluation only on the sample site. Typically, a sample site is approximately the first 200 feet of a one-mile segment, beginning at a reference post. Then the distress ratings from the sample site are adjusted based on the general conditions of the remaining portion of the segment using a windshield survey. A more detailed description of severity and extent levels can be found in the Nebraska Surface Distress Survey Manual (Nebraska Dept. of Roads January 2012).

3.3 AUTOMATED DISTRESS SURVEY METHOD

In the automated data collection method, agencies implement high-tech vehicles that are able to collect and store road condition data at highway driving speeds. NDOR has acquired two automated road survey vans (i.e., Pathrunner) from Pathway Service Inc. (Pathway Service Inc.), as presented in Figure 3.1. These vehicles are equipped with two laser line generators and high-resolution cameras that face the pavement surface to collect high quality three-dimensional surface images. This imaging system records continuous scanning images of the road surface. In addition, three cameras (rear view camera, perspective camera, and right shoulder camera) are assembled on vehicles to capture digital images of asset inventory and the overall condition of shoulders. In order to calculate rut depths and roughness values, the vans are able to measure longitudinal and transverse profiles of the road's surface using two laser sensors mounted on the vans. All road data collected by the vans are tied to the geographic location by the Global Positioning System (GPS) receiver. In addition to GPS, a Distance Measuring Instrument (DMI) computes the travel distance of the van and assigns it to the distress location.



Figure 3.1 Pathrunner from Pathway Service Inc.

After finishing surveying roads, the raw data collected are then transferred into the office for further analysis. The crack detection software, AutoCrack, analyzes 3D image data of pavement surfaces using image-processing techniques to evaluate and classify the surface distresses based on their specifications. The software has the ability to detect patterns and visual conditions of pavement defects and classify them into different type-severity categories. AutoCrack also determines and records other information about each type-severity, such as location information, dimensions, etc. In order to present distress information, Pathway delivers a supplementary software (PathViewII), which provides a convenient tool to access detailed distress information and pavement surface raw pictures. Distress information includes distress type, severity, location, dimensions and sealing condition. This form of reporting distress data is similar to the format suggested by the Long-Term Pavement Performance (LTPP) survey, however, identification of the type, severity and position of distresses is modified to meet Nebraska's distress category specifications (Miller and Bellinger 2014).

CHAPTER 4

PAVEMENT DISTRESS DATA CONVERSION

In this chapter, the conversion process to obtain Nebraska's distress codes from Pathway distress data is demonstrated. It should be mentioned that in chapters 4 and 5, only the surveying of bituminous pavement condition is discussed. Pathway distress data regarding Portland cement concrete pavements are not yet in full implementation due to several issues, such as the unclear identification of pavement cracks from joints.

4.1 CONVERSION PROCESS

NDOR is aiming to supplement the current visual manual (or semi-automated) data collection method with an automated data collection method while leaving the NPMS unchanged. Thus, there is a need to report the data collected by the automated system in a format that is compatible with the NPMS scheme that is based on the manual visual survey system. To make Pathway distress results applicable to the NPMS, a process of converting distress from the Pathway format to the manual format is established.

In the previous chapter, the methodology and structure of recording pavement performance distresses according to the manual and automated survey method were briefly discussed. NDOR summarizes the pavement condition of a one-mile segment in terms of distress type, corresponding predominant severity, and overall extent of each type of distress. Table 4.1 shows distress categories and corresponding severity and extent codes. These codes are necessary values to compute pavement performance indices (i.e., NSI and PSI) used in the NPMS. On the other hand, pavement distress data from the Pathway method is mainly based on the Long-Term Pavement

Performance (LTPP) Distress Identification Manual. This distress data report contains a continuous sequence of all distresses of pavement surfaces along with associated severity level. As severity code is evaluated by Pathway, for the most part, the conversion process contains the quantifying extent code of each distress within a specified segment.

Table 4.1 Nebraska bituminous pavement distress codes

Distress type	Severity*	Extent**
Edge cracking	A, L, M, H	A, T, O, F, E, C
Wheel path cracking		
Centerline cracking		
Between wheel path cracking		
Grid/block cracking	A, L, M, H, X	A, T, O, F, E, C
Transverse cracks	A, L, M, H, X	A, T, O, F, E, C
Alligator cracking	A, L, M, H	A, T, O, F, E, C
Failures	-	A, T, O, F, E, C
Raveling/weathering	A, L, M, H	-
Excess asphalt	A, L, M, H	-

* Severity codes:

A : Absent
L : Low
M : Moderate
H : High
X : Extreme

** Extent codes

A : Absent
T : Trace
O : Occasional
F : Frequent
E : Extensive
C : Complete

Table 4.2 Key information of distress data from PathViewII

Distress type	Severity*	Location along the road	Position across the lane	Dimensions	Sealing condition
Transverse C.	A, L, M, H	Distance from beginning of the segment	Left edge	Width & length	Yes or No
Longitudinal C.			Left wheel path		
Alligator C.			Centerline		
Block C.			Right wheel path		
Raveling			Right edge		

* Severity codes:
 A : Absent
 L : Low
 M : Moderate
 H : High

Since the 3D pavement surface images are limited to the width of the surveyed lane, pavement shoulder defects are not usually covered by the Pathway’s crack detection/analysis software, AutoCrack. Therefore, shoulder defects need to be rated manually by NDOR personnel based on front view or side view images.

In addition, as it is shown in Table 4.2, Pathway does not report distresses such as failures and excess asphalt. To address this shortcoming, NDOR personnel need to rate failures and excess asphalt using pavement surface images, similar to the manual survey procedure. Pathway AutoCrack software uses an image processing technique to label distresses with different levels of severity according to how much a distress has progressed. Nevertheless, unlike the Nebraska manual survey, it merely classifies all distresses into three levels of severity (low, moderate and high). These severity level mismatches raise issues with distresses such as grid/block cracking and transverse cracking, so this mismatch needs to be resolved in the conversion process of data formats.

To calculate distress extent codes resulting from Pathway, all distresses are first divided into different groups according to their location. Each group contains distresses within the interval between two consecutive reference posts. However, in manual survey, raters need to slowly drive along the shoulder for 200 feet beginning at a reference post (Sample Site) to inspect the road surface of the travel lane. Next, the rater drives at traffic speed between sample sites assessing the overall condition of pavement in a Windshield Survey. A detailed record of the pavement condition is created from the information gathered in the sample site and the windshield survey. In the conversion process, the overall severity of each distress category is reported by taking the most dominant level of severity in the entire 1-mile interval between two consecutive reference posts. The extent code of each distress is then quantified based on total amount of each distress within a segment surveyed regardless of distress severity.

As can be seen in Table 4.3, the extent level of transverse cracking is obtained by counting total number of transverse cracks per one mile of a road section, while other distresses such as alligator cracking or longitudinal cracking use the cumulative value of area (or length) of cracks, which is divided by full area (or length) of the surveyed road section (Table 4.4). The extent level of alligator cracking and block cracking are expressed in terms of cracked area, while the longitudinal cracking (at the edge or along centerline, wheel path, and between wheel path) is expressed in terms of crack length.

Table 4.3 Extent definition of transverse cracking

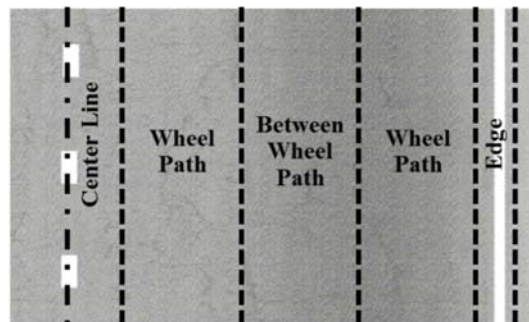
Number of cracks per mile	Extent code
0	Absent
01-10	Trace
11-26	Occasional
27-53	Frequent
54-105	Extensive
> 105	Complete

Table 4.4 Extent definition of longitudinal cracking, block cracking
and alligator cracking

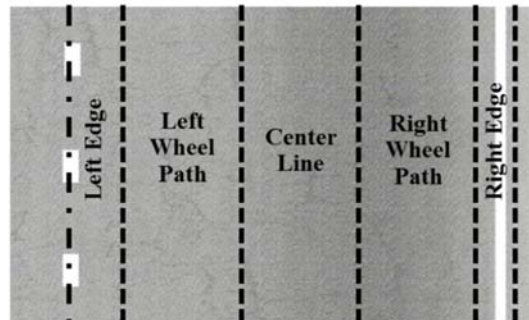
Ratio of distress's total area (or length) to segment's area (or length)	Extent code
0%	Absent
< 10%	Trace
10% - 30%	Occasional
30% - 50%	Frequent
50% - 80%	Extensive
> 80%	Complete

The Nebraska manual survey classifies longitudinal cracking with respect to location into four groups: centerline, wheel path, between wheel path, and edge cracking (Figure 4.1a). Figure 4.1b shows the different regions of a lane defined by the Pathway. The centerline, between the

wheel path, and edge cracking can be readily designated as they are respectively equivalent to left edge, centerline, and right edge. However, when the van is surveying the second or third lane, the right edge will not correspond to the road's edge anymore. To assess the wheel path cracking codes, NDOR only requires the severity and extent of worst condition wheel path, which is defined as the wheel path that shows the highest value of (severity \times extent). This particular categorization depends on how carefully the operator drives within the lane. When the vehicle wanders between lanes, substantial errors occur because camera is not able to capture the entire width of the survey lane.



(a) Manual survey



(b) Pathway survey

Figure 4.1 Different categorization of longitudinal cracking in manual survey and Pathway survey

4.2 DATA FORMAT CONVERTER (DFC) PROGRAM

The methodology discussed earlier in this chapter is proposed to be implemented in a user-friendly software to automatically convert distress reports from the PathViewII into the Nebraska manual distress format (levels of severity and extent). Figure 4.2 shows a user-friendly interface developed for the DFC software. As seen in the Figure 4.2, DFC is composed of two parts: Conversion and Comparison. Conversion part of DFC program needs the detailed distress report from PathViewII to find Nebraska distress rating codes. The Pathview distress report can be easily exported from PathViewII software (Figure 4.3). PathViewII's output must have, at minimum, the information presented in Table 4.5. DFC is capable of reading PathViewII's outputs in multiple data sets. Upon reading the data sets, DFC separates distresses into sections based on road name, intersection, road direction, and pavement type, and then discretize each section's distress data into sub-sections with respect to the distress report interval. The value of the distress report interval can be adjusted using a popup menu provided in the Conversion section. Once the input file and report interval are selected, clicking the convert button starts the conversion process. During the process, the amount of processed data is displayed in a progress bar. After finishing the conversion process, the user needs to choose a path to save the result as .csv file. The final output result is formatted based on the Nebraska distress database.

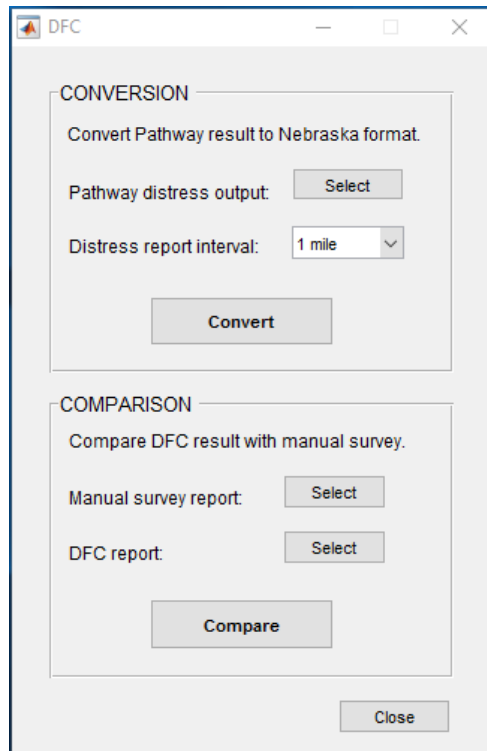


Figure 4.2 Distress format converter main window

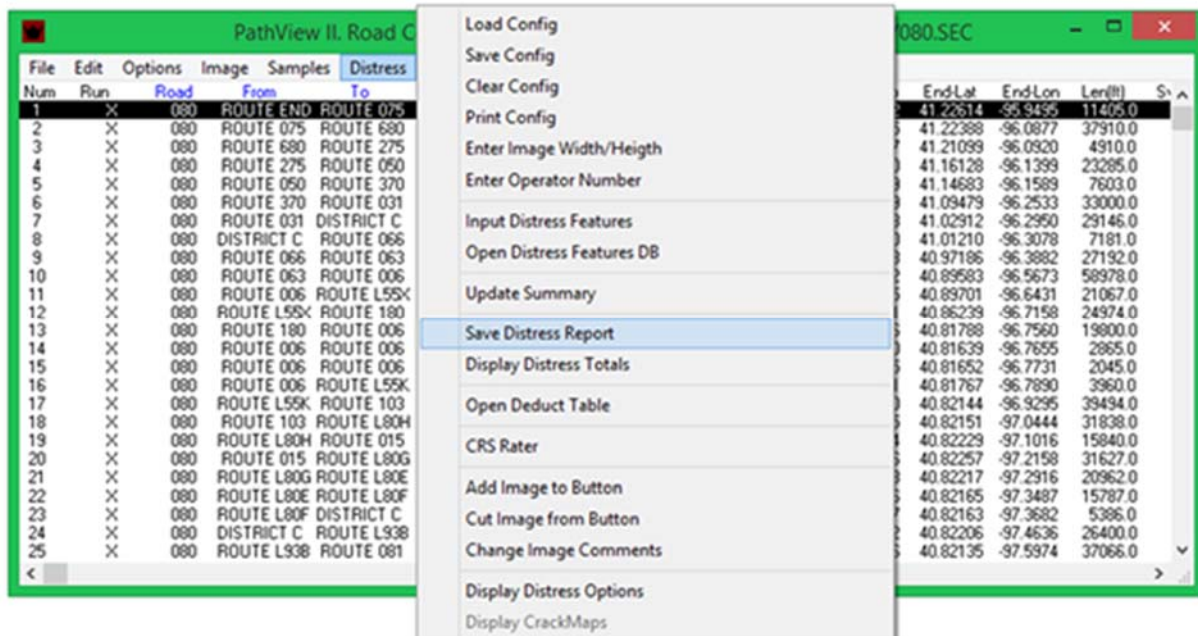


Figure 4.3 Exporting distress data from PathView II

Table 4.5 Necessary output information from PathViewII for DFC

Information	Tag
IRI	IRI R e
Road name	Road
Beginning intersection	From
End intersection	To
Beginning reference post	Frftpost
End reference post	Trftpost
Beginning log mile	Begin
End log mile	End
Section's survey length	SvyLeng
Line number	LN
Direction	D
Pavement type	P
Set number	Set
Distress' distance from beginning of the section	Dis(ft)
Distress' location in log mile	MilePnt
Distress' name	Name
Distress' location	Location
Crack's sealing condition	Seal
Distress' width	Width(ft)
Distress' length	Length(ft)

In addition to converting distress data formats, an Comparison module is also provided in the DFC program to compare two distress reports. This module can be used to compare current DFC's distress output with past manual distress reports available from the distress database or to investigate pavement condition deterioration over performance periods. The program finds the corresponding sections from two data sets and compares both distress codes (severity and extent) separately and demonstrates the results in graphs (as presented in chapter 5). It also writes all distress codes of each section from two data sets and corresponding NSI values, which is useful for users to detect questionable sections for further investigation.

CHAPTER 5

RESULTS AND DISCUSSION

To evaluate the automated data collection technique and its future implementation into the NPMS, a comparison between the two methods (i.e., automated and manual) was conducted for a total 7,254 lane-miles sections surveyed by the Pathway and their corresponding manual rating results from visual surveying of road surface images obtained in 2015. These ample road sections generally represent a broad range of distresses of different levels of severity. Therefore, the evaluation assures that the selected segments cover good, moderate, and poor conditions and provides a comprehensive comparison between the two distress surveying methods. Each distress data set contains the overall surface condition of road sections in terms of severity and extent codes of distresses. Since the format of data collected by the automated method does not match with the manual format, the DFC program was used to make the two data sets comparable.

In an attempt to assess the agreement between the two data sets after the conversion process through the DFC, the manual data were considered as a reference set and the converted data were compared with the reference distress data to quantify the level of differences between the two. With this in mind, the provided analogy is drawn in two steps. The first step includes the general comparison of two data sets, such as an overall comparison in detecting each distress and identification of the automated method's failures to meet the Nebraska manual's demands. The next phase focuses on identifying regression models to find the source of uncertainty of the converted automated data by visualizing the possible systematic bias between the two data sets.

Table 5.1 shows the bituminous pavement distress data that were collected by the two surveying methods. As can be seen and was mentioned before, the automated method does not

capture two distresses: failures and excess asphalt. Distinguishing edge cracking from others is technically similar to detecting other types of longitudinal cracking, but it depends on the lane where the van surveys. It is evident that the van is only able to cover the edge of the road when it is traveling within the outer lane.

Table 5.1 Distress codes collected from road segments

<i>Distress</i>	<i>Manual</i>	<i>Automated</i>
Edge cracking (Sev & Ext)	✓	-
Wheel path cracking (Sev & Ext)	✓	✓
Centerline cracking (Sev & Ext)	✓	✓
Between wheel path cracking (Sev & Ext)	✓	✓
Grid/block cracking (Sev & Ext)	✓	✓
Transverse cracking (Sev & Ext)	✓	✓
Alligator cracking (Sev & Ext)	✓	✓
Failure (Ext)	✓	-
Raveling/Weathering (Sev)	✓	✓
Excess asphalt (Sev)	✓	-

Figure 5.1 compares the ability of the Pathway method (after data conversion) to the manual survey in detection of distresses. For a given distress, the total number of sections is divided into four groups, the sections in which (1) only Pathway detects, (2) neither the manual nor Pathway detects, (3) both methods can detect, and (4) only the manual method detects. As expected, the automated survey method could detect better than the manual method with a higher

degree of sensitivity. However, it should be noted that this difference could be affected to some extent by pavement deterioration that occurred over the time span between the two surveys (approximately one year).

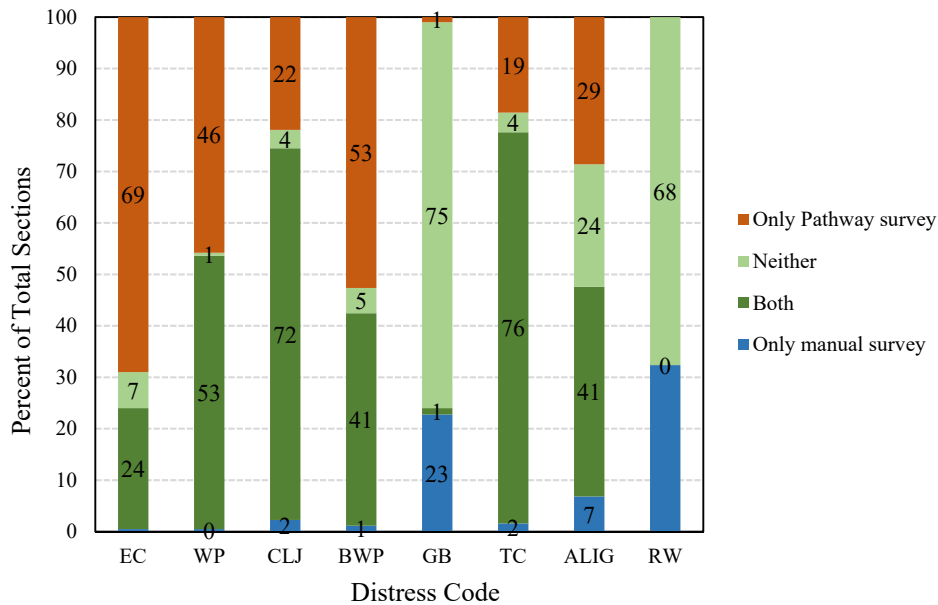


Figure 5.1 Comparing distress detection of manual survey and Pathway survey method

In Figure 5.2 and Figure 5.3, the distress code levels assigned to each distress are numerically compared. To examine differences on severity and extent codes between the two methods in a quantitative manner, each level of severity or extent was replaced by its numeric equivalents shown in Table 5.2. Each part of a column bar shown in each figure (Figure 5.2 and Figure 5.3) represents the percentage of total segment with different levels of *Diff* which, as written in equation 5.1, is simply a difference in numeric values between the manual rating and automated rating. Evidently, when the *Diff* is closer to zero, the automated rating is closer to the manual rating. Positive values of *Diff* implies more conservative ratings (overrating) of the manual survey results than the automated-and-converted survey results.

Table 5.2 Numeric values representing severity and extent codes

Severity code	Value	Extent code	Value
Absent	0	Absent	0
Low	1	Trace	1
Moderate	2	Occasional	2
High	3	Frequent	3
Extreme	4	Extensive	4
		Complete	5

$$Diff = manual\ rating - automated\ rating \quad (5.1)$$

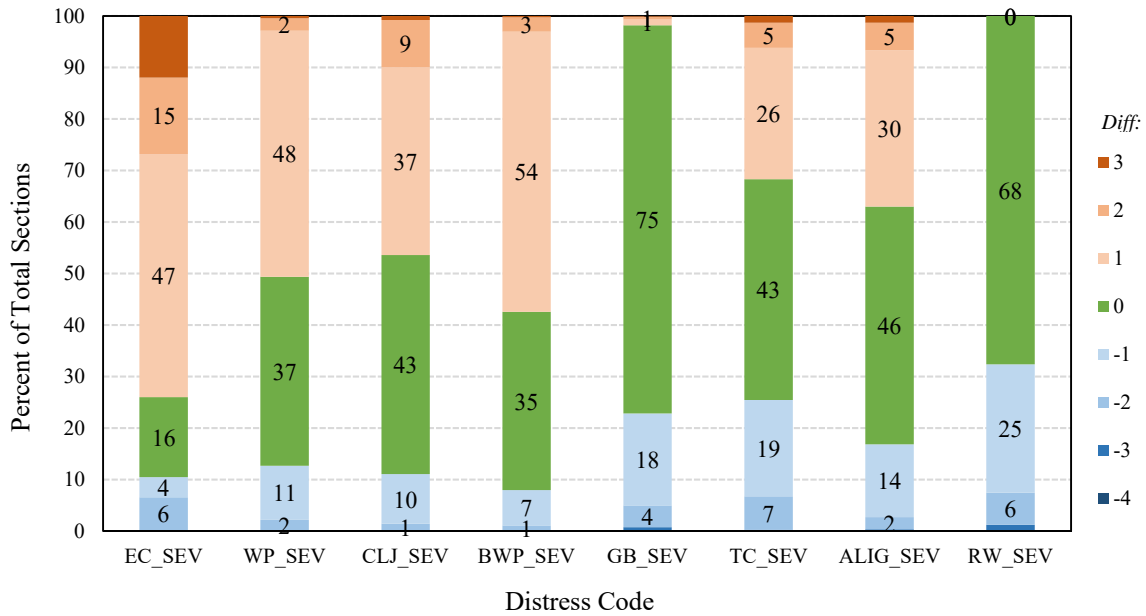


Figure 5.2 Difference between severity codes assessed by manual and Pathway survey method

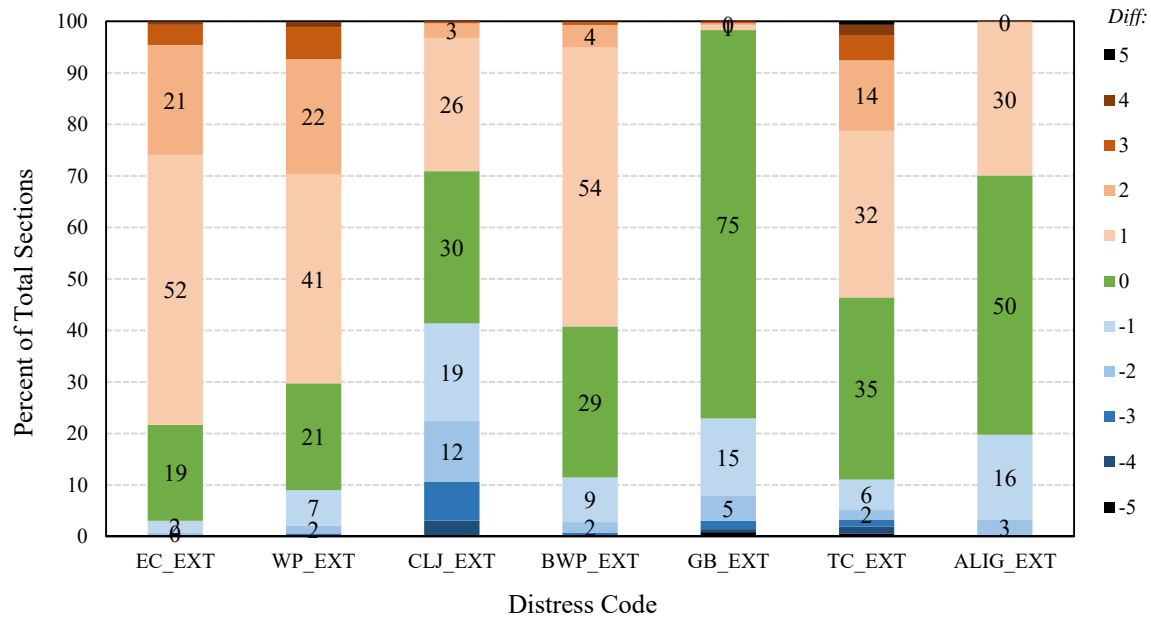


Figure 5.3 Difference between extent codes assessed by manual and Pathway survey method

In both figures, similar to Figure 5.1, the general trend is that automated methods usually overrate distress codes, except for centerline cracking and transverse cracking extents. Nebraska’s manual survey indicates that transverse cracking must be counted only when it has a length equal to or longer than 12 ft. However, automated crack detection software often cannot capture the whole length of the transverse cracking accurately when the crack is meandering (see Figure 5.4). Therefore, the transverse crack length threshold should be set to a smaller value than 12 ft. to achieve better matching with manual surveying. Figure 5.5 shows the comparison between the manual and automated-and-converted method with a different threshold (i.e., 8 ft.).

The second amendment to be taken was associated with the centerline crack extent code. Similar to transverse cracking, crack detection software was often unable to capture the actual length of centerline cracks (see Figure 5.6). The reason is not quite clear at this stage, but it seems

related to interference between cracks and centerline lane marks, as illustrated in the pavement surface image (see Figure 5.6).

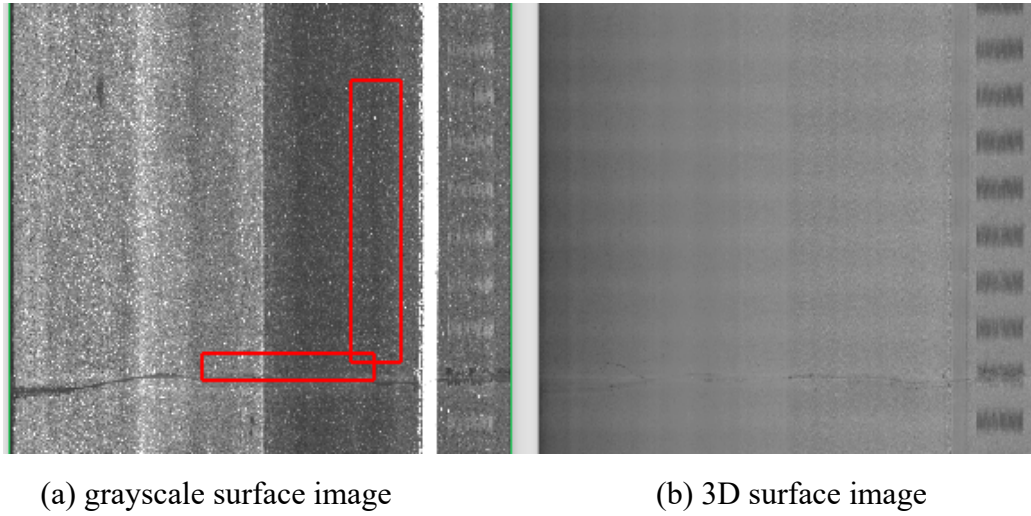


Figure 5.4 Example of failing of automated method in detecting transverse crack

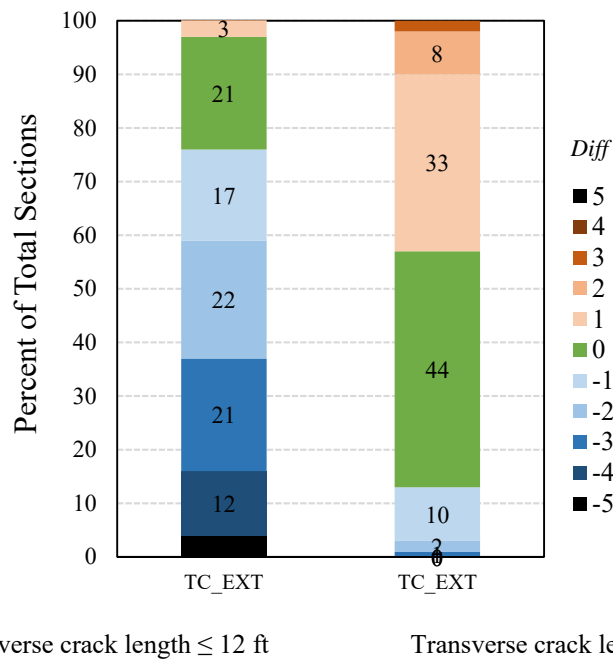


Figure 5.5 Change in transverse cracking extent ratings by shifting its definition threshold

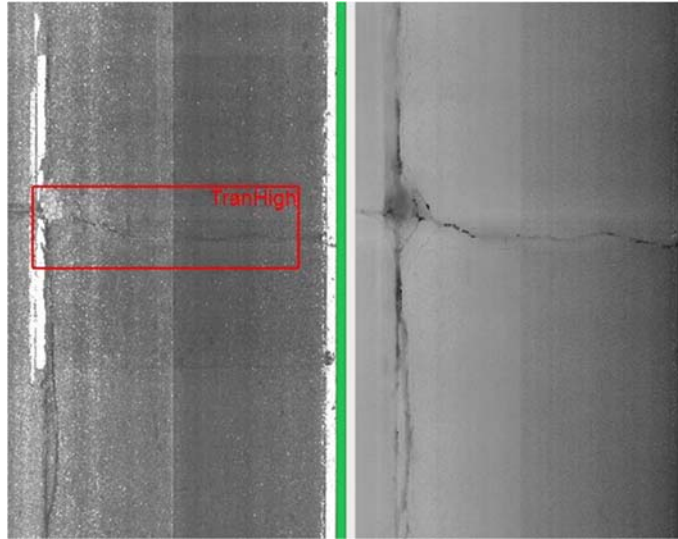


Figure 5.6 Example failing of automated method in detecting centerline cracks

Comparisons of the NSI values resulting from the manual distress ratings and the automated-and-converted distress ratings are plotted in Figure 5.7. Each point represents the NSI value for a specific section. Equations 3.1 to 3.5 were used to derive NSI values. To exclude the effect of changing rutting values on NSI, same rutting values were used for both datasets. Thus, the only difference evident in the graph is result of the difference in distress codes from two different data collection methods. The dotted line shows the equality line and two red lines indicate $\pm 10\%$ from the equality. The graph shows that more than 80% of points (i.e., sections) are placed between the two red lines, although it would be ideal if all points were close to the line of equality. When a point is located above the line of equality, NSI resulting from the automated distress surveying method would predict greater level of pavement distresses than the manual method, which will correspondingly result in a more conservative (or proactive) maintenance strategy toward bituminous pavements in Nebraska. The trend line is also shown in the graph as a bold dashed line. As shown in Figure 5.7, the R-square value is relatively low, which is due to a high level of scattered data. At this stage, no solid conclusion regarding the presence of a systematic

error can be drawn; however, the bias of data from the line of equality can still be explained. For example, the aggregation of points at top-right corner of the graph might be because the Pathway appears to pick up more hairline cracks on very good pavements, however those good sections are more likely to be rated as a flawless surface in manual visual rating process.

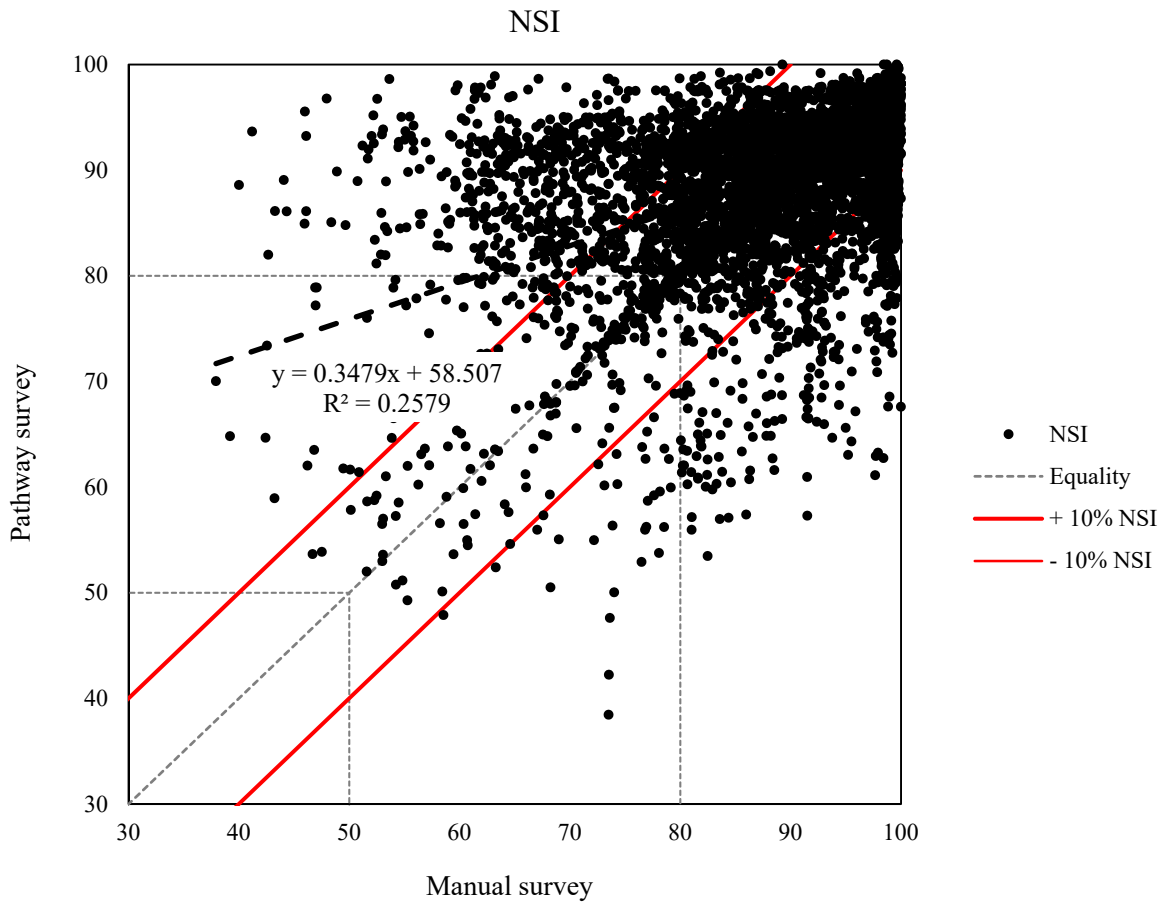


Figure 5.7 Regression plot for NSI index

CHAPTER 6

SUMMARY AND CONCLUSIONS

The new automated data collection method that is being implemented in Nebraska to replace the traditional manual (or semi-automated) pavement distress surveying system was investigated in this research. Toward that end, a user-friendly program was developed to convert automated survey results to make them compatible with the current NPMS system. Converted distress data were then compared to their corresponding manual survey data for a total of 7,254 one-mile sections in Nebraska. The distresses from both methods were compared to examine if the new automated-and-converted pavement distress surveying method can identify and rate distresses similarly to the conventional manual surveying methods so that the current NPMS can be used without any major changes. Finally, NSI value, which is a key parameter in the NPMS decision making process, was derived from the distress data collected by both methods. Based on this study, the following conclusions can be drawn.

6.1 CONCLUSIONS

- Due to the limitations of the automated survey method, the Pathway survey was unable to capture failures and excess asphalt distresses. Also, in some cases, centerline cracks and edge cracks were out of view of the camera. Thus, the NDOR data collection division needs to continue to collect those distresses manually.
- Since the automated method only surveys travel lane, shoulder rating must be conducted manually by NDOR personnel for all sections.
- The Distress Format Converter (DFC) program can be used as a core bridging tool from

the automated data collected to the ultimate use of NPMS decision making. It also calculates severity and extent of each distress directly from Pathway outputs.

- NDOR can review the DFC analysis results to identify any discrepancies between the two measuring methods and use it for evaluating distress detection software.
- By comparing the manual data and automatically-collected data from Pathway, it was found that the new automatic distress detection system detects distresses with a higher level of sensitivity than the manual method; however, in some cases like centerline cracking, it cannot capture the cracks due to image interference with lane marks. This needs to be resolved by the vendor.
- Comparisons of the NSI values resulting from the manual distress rating and the new automatic distress rating imply that in most cases the difference between NSI from two methods is within the range of $\pm 10\%$.

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