Statistical Analysis of Highway Needs Condition Data: Manual vs. Automated

Iowa DOT Project TR-494
CTRE Project 03-134

Sponsored by
the Iowa Department of Transportation
and the Iowa Highway Research Board

Iowa Department of Transportation

CTRE
Center for Transportation Research and Education

Iowa State University

Final Report • September 2003

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation.

CTRE's mission is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, and reliability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Technical Report Documentation Page

1. Report No. Iowa DOT Project TR-494	**2. Government Accession No.**	**3. Recipient's Catalog No.**	
4. Title and Subtitle Statistical Analysis of Highway Needs Condition Data: Manual vs. Automated		**5. Report Date** September 2003	
		6. Performing Organization Code CTRE Project 03-134	
7. Author(s) Omar Smadi		**8. Performing Organization Report No.**	
9. Performing Organization Name and Address Center for Transportation Research and Education Iowa State University 2901 South Loop Drive, Suite 3100 Ames, IA 50010-8634		**10. Work Unit No. (TRAIS)**	
		11. Contract or Grant No.	
12. Sponsoring Organization Name and Address Iowa Highway Research Board 800 Lincoln Way Ames, IA 50010		**13. Type of Report and Period Covered** Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes			

16. Abstract

This project examines similarities and differences between the automated condition data collected on and off county paved roads and the manual condition data collected by Iowa DOT staff in 2000 and 2001. Also, the researchers will provide staff support to the advisory committee in exploring other options to the highway need process.

The results show that the automated condition data can be used in a converted highway needs process with no major differences between the two methods. Even though the foundation rating difference was significant, the foundation rating weighting factor in HWYNEEDS is minimal and should not have a major impact.

In terms of RUTF formula based distribution, the results clearly show the superiority of the condition-based analysis compared to the non-condition based. That correlation can be further enhanced by adding more distress variables to the analysis.

17. Key Words highway condition data collection—highway needs process—road use tax fund allocation		**18. Distribution Statement** No restrictions.	
19. Security Classification (of this report) Unclassified.	**20. Security Classification (of this page)** Unclassified.	**21. No. of Pages** 13	**22. Price** NA

STATISTICAL ANALYSIS OF HIGHWAY NEEDS CONDITION DATA: MANUAL VS. AUTOMATED

Principal Investigator
Omar Smadi
Center for Transportation Research and Education
Iowa State University

Sponsored by the Highway Division
of the Iowa Department of Transportation
and the Iowa Highway Research Board
Iowa DOT Project TR-494

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its research management agreement with the
Center for Transportation Research and Education,
CTRE Management Project 03-134

Center for Transportation Research and Education
Iowa State University
2901 South Loop Drive, Suite 3100
Ames, Iowa 50010-8634
Phone: 515-294-8103
Fax: 515-294-0467
www.ctre.iastate.edu

Final Report • September 2003

TABLE OF CONTENTS

ACKNOWLEDGMENTS

This research project was made possible through funding from the Iowa Highway Research Board (IHRB) project TR-494. We are grateful to the IHRB members for their support and cooperation in completing this project.

The researchers also wish to thank the Iowa Department of Transportation Office of Systems Planning staff for providing their time and resources throughout this project. Especially, the researchers would like to thank Stuart Anderson for serving as project monitor and for all of his help in providing the needed data.

INTRODUCTION

Iowa's quadrennial need study was first conducted in 1960, and the process used to conduct the needs study was updated in 1982 to include the use of a computer program to project financial needs and to allocate financial resources to counties. Iowa's quadrennial need study serves two main purposes. The first is to determine the 20-year funding needs in terms of construction, rehabilitation, maintenance, administration, and engineering costs. The second purpose is to allocate road use tax funds (RUTFs) to the counties in proportion to their relative needs.

The Iowa Department of Transportation (Iowa DOT) in cooperation with the counties decided to stop conducting the highway need process with the last study being conducted in 2002. A committee of county engineers, board of supervisors members, and Iowa DOT staff was formed to study different alternatives to the highway need process and recommend a method to be presented to the legislature for final approval (Secondary Road Fund Distribution Advisory Committee). This project examines similarities and differences between the automated condition data collected on and off county paved roads and the manual condition data collected by Iowa DOT staff in 2000 and 2001. Also, the researchers will provide staff support to the advisory committee in exploring other options to the highway need process.

In Iowa, automated pavement condition data are being collected for the entire county paved network through the Iowa Pavement Management Program (IPMP) for federal-aid portions and the Iowa DOT non-federal-aid-eligible county project for the remaining paved miles. The IPMP is a statewide program to develop pavement condition databases to support the application of pavement management by the Iowa DOT and cities and counties for the federal-aid-eligible (FAE) highways within their jurisdictions. Condition data are collected using automated equipment. This equipment uses lasers and digital video to collect roughness, rutting, and cracking information. Automated distress data are objective and consistent and provide for a complete coverage of the pavement surface.

Study Objectives

The main objective of this project is to conduct a statistical analysis to examine the differences and/or similarities of the condition data collected manually and in an automated fashion. This information will help the advisory committee responsible for finding alternatives to the current highway needs process to make an informed decision whether HWYNEEDS should be converted to a PC platform and modified to be used by counties to distribute the counties share of the RUTF. Another objective is to provide support to the advisory committee to investigate other options to distribute RUTF among the counties.

Proposed Work

The work described in this report addresses the comprehensive analysis and evaluation of the condition data (automated and manual). The study looked at the system as a whole,

counties individually, and also considered different pavement types and whether the road is part of the farm-to-market or the secondary system.

Another component to this study was to look at other options for RUTF distribution among the counties to help the advisory committee with the different options available. The researchers investigated developing a formula for distribution of RUTF that is condition or non-condition based. The report will discuss all these aspects as they relate to the highway need process

Project Tasks

The research was divided into two major parts. Part I covered statistical analysis. Part II covered the formula development. The following is a brief description of the tasks conducted for the successful completion of the research objectives.

1. Work with the project advisory committee consisting of county and Iowa DOT staff. The researchers will report progress and issues to the advisory committee at their regular meetings. The advisory committee was consulted and provided direction during the entirety of the project.

2. Obtain the manually collected data from the Iowa DOT base record system. The research team worked closely with Stuart Anderson and the Iowa DOT Office of Systems Planning to acquire all the needed information to run the statistical analysis.

3. Summarize the automated condition data to base record segments used in the statistical analysis.

4. Conduct the statistical analysis. This will determine if there is any correlation between the two sets of data. Also, an analysis of the 2002 quadrennial needs study will be conducted to look at the winners and losers in terms of funding and the relationship to condition differences.

5. Report the results to the advisory committee.

6. Provide staff support to the advisory committee.

7. Provide a short report documenting the research project for the Iowa Highway Research Board and the advisory committee members.

Report Organization

Following the introduction, with proposed work and objectives, the report then covers the research methodology. The methodology and results section covers both Part I and Part II of the research project. The final part of the report summarizes the results and provides conclusions and recommendations of the research project.

METHODOLOGY AND RESULTS

This section describes the methodology followed to achieve the goals and objectives of the research project. This section is divided into two parts. The first part covers an in-depth investigation of the automated and manual condition data statistical analysis. The second part discusses formula development of both condition and non-condition based parameters.

Throughout the entire project, the advisory committee consisting of county engineers and board of supervisors members supervised the research and provided valuable input to the research team.

Statistical Analysis

The statistical analysis of the similarities and/or differenced between the automated and manually collected condition data was conducted to give the advisory committee a better handle on considering one of the options to replace the current highway needs process. The advisory committee considered converting the current highway needs process from the main frame environment (the Iowa DOT used the HWYNEEDS program to calculate needs) to a PC environment. The new software will use the automated condition data collected for the IPMP on the federal-aid network and through the agreement between the Iowa DOT and the counties to cover the remaining paved county roads (off the federal-aid system).

The statistical analysis examined the manually collected data versus the automated condition data by base record segments. Then segments were combined together, and county averages were calculated. Finally, the data were analyzed by county and surface type. Two parameters were considered in the analysis. On the manual condition data side, both the surface and foundation ratings were used (scale of 1 to 10). For the automated condition data, two ratings were calculated from the individual distress measurements (cracking, patching, rutting, and roughness). A pavement condition index (PCI) on a scale of 0 to 100 and a structural rating (STR) also on a scale of 0 to 100 were both determined for each base record segment. Both the PCI and STR were converted to a scale of 0 to 10 to correspond to the surface and foundation ratings, respectively. Since the automated condition data covered only one half of the county roads in 2002, only those counties were compared with the manual data. Figures 1 through 4 show a comparison between the manual and automated condition data for the counties considered in this study.

Figure 1 is a summary of all sections in each county. The counties were split in half for display purposes. As it can be seen from Figures 1a and 1b, a noticeable difference can be seen between the foundation ratings from the manual and automated condition data. A hypothesis test on the mean shows that the difference between the manually collected foundation rating and the automated calculated foundation rating is statistically significant at the 95% confidence level. The same holds true when the sections are

divided by pavement type (Figures 2a and 2b for asphalt cement concrete [ACC], Figure 3 for COM, and Figures 4a and 4b for portland cement concrete [PCC]).

The same hypothesis testing was conducted on the surface rating (manual and automated). The results showed that the difference in the mean was not statistically significant at the 95% confidence level for all except the ACC. The ACC was not significant at the 94.5% confidence level (see Figures 1 through 4).

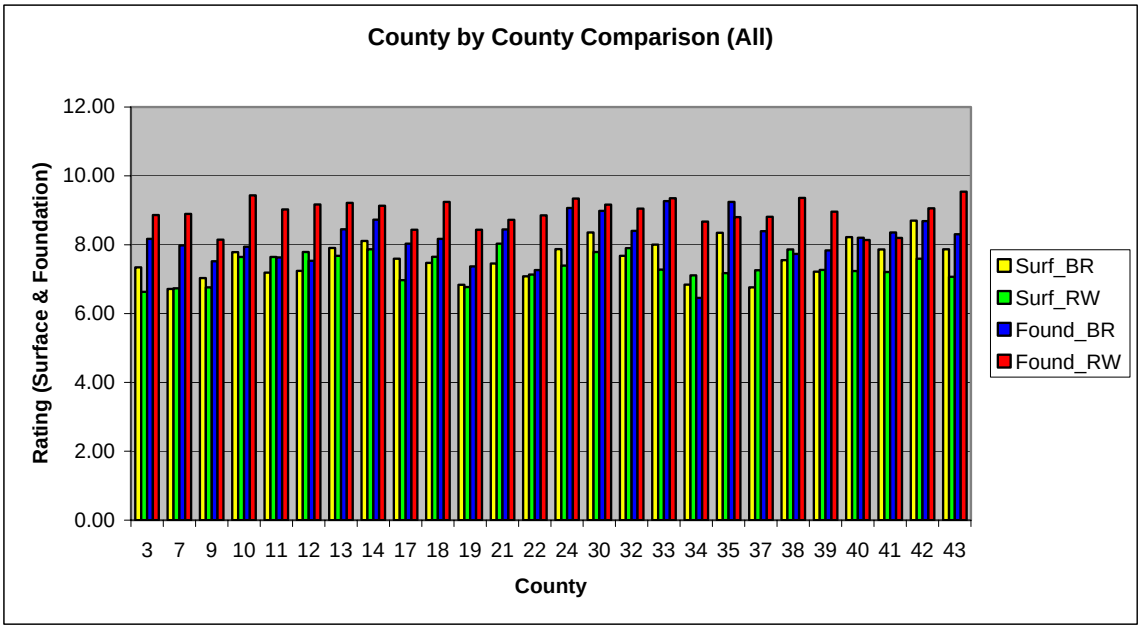

Figure 1a. Comparison of manual and automated data by county

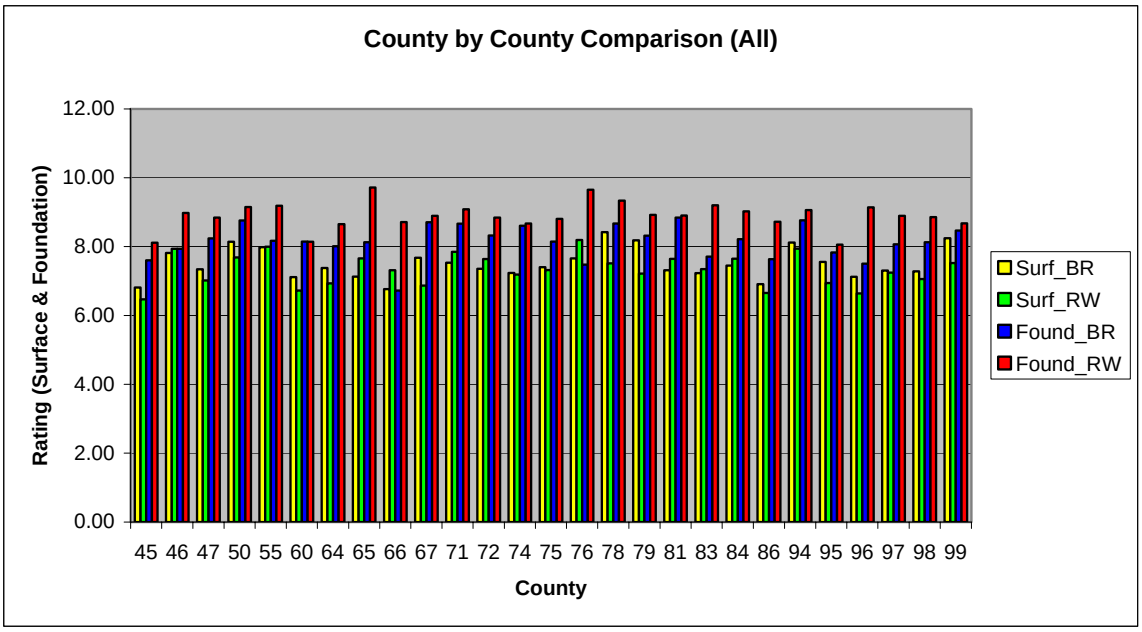

Figure 1b. Comparison of manual and automated data by county

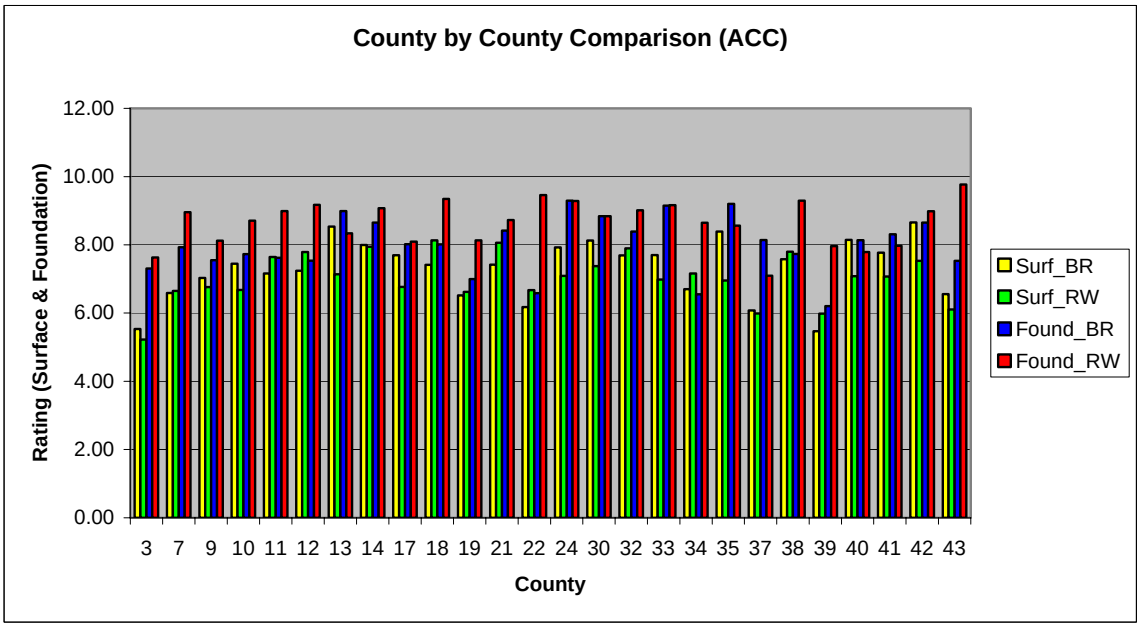

Figure 2a. Comparison of manual and automated data by county (ACC)

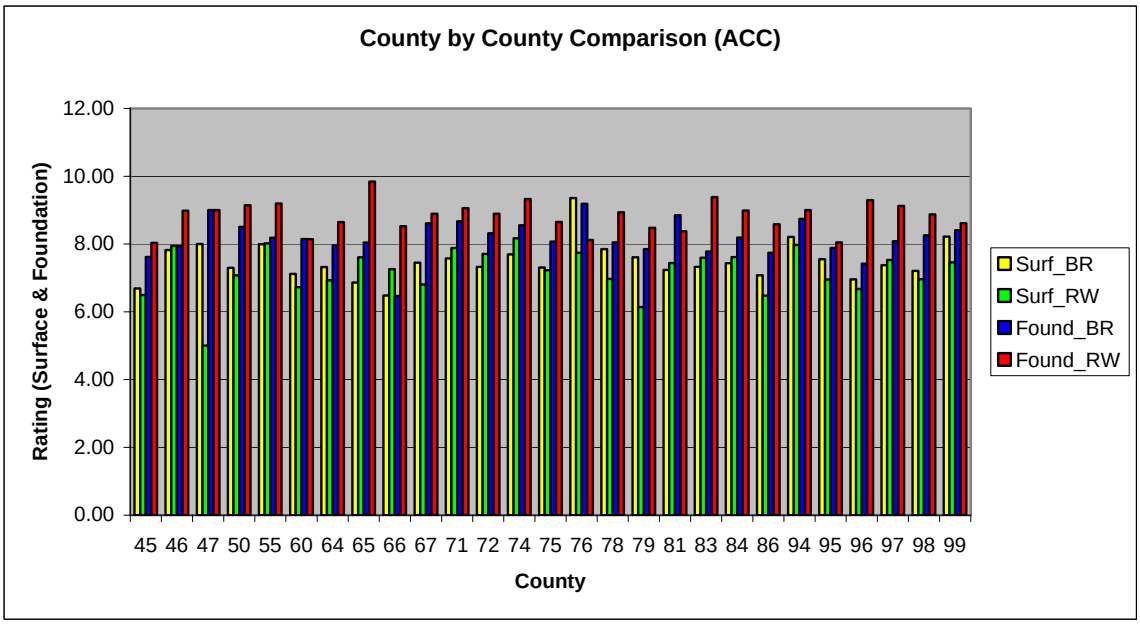

Figure 2b. Comparison of manual and automated data by county (ACC)

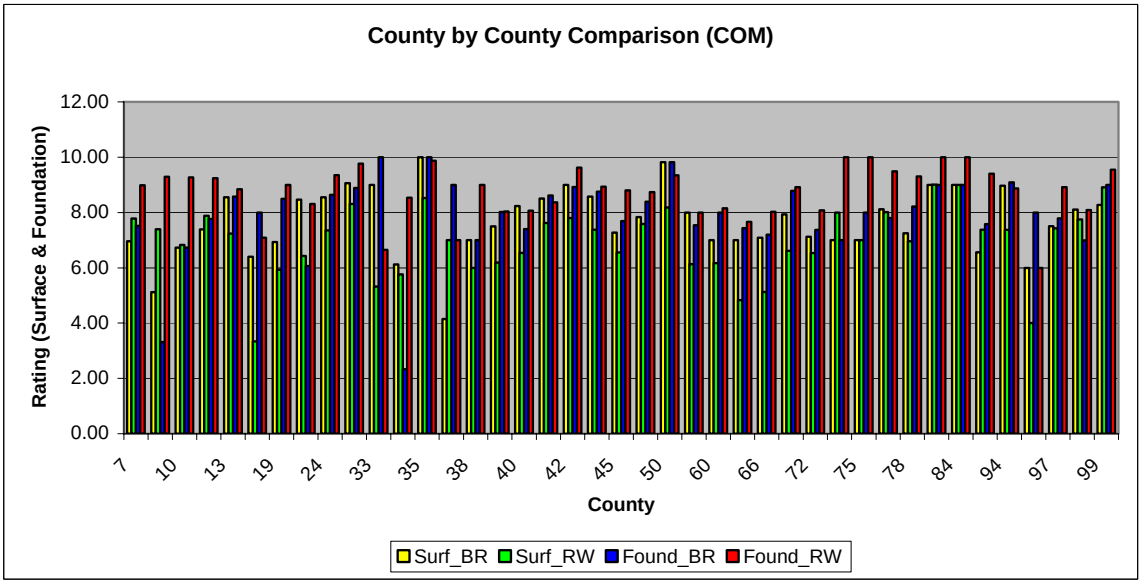

Figure 3. Comparison of manual and automated data by county (COM)

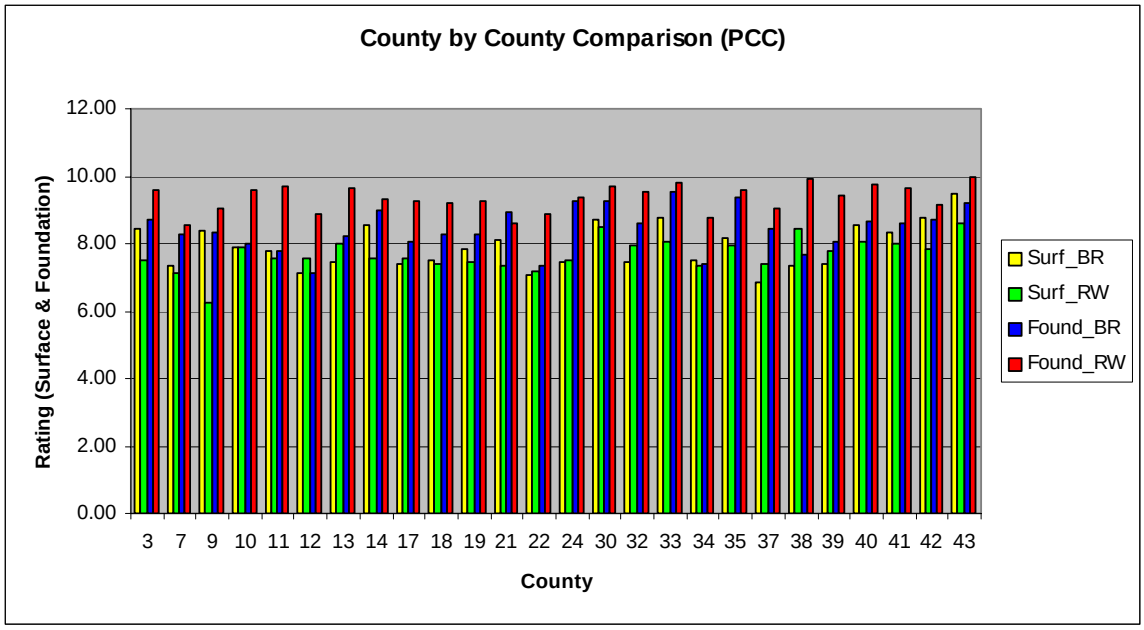

Figure 4a. Comparison of manual and automated data by county (PCC)

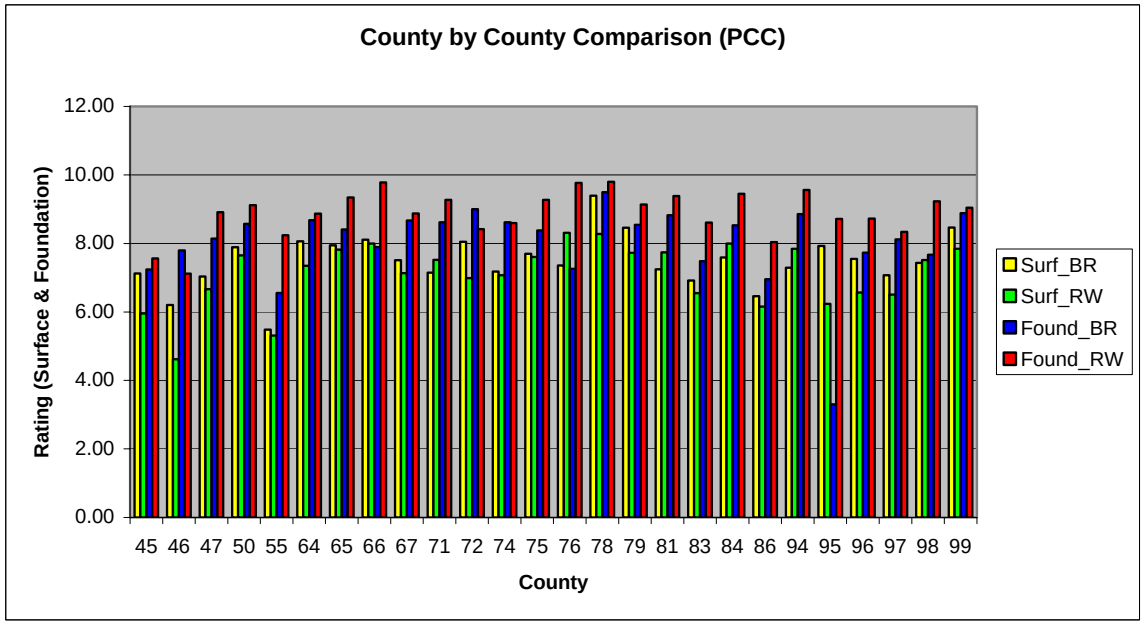

Figure 4b. Comparison of manual and automated data by county (PCC)

RUTF Distribution Formulas

Even though the main objective of the research project was the statistical analysis of the condition data, part of the research effort was used to support the advisory committee in investigating other options for replacing the current highway needs process. The research team was asked to investigate the use of a formula distribution both based on condition data and non-condition data for only the paved road network. County Service Bureau staff members are still investigating the development of a formula for RUTF distribution for the entire system (paved, gravel, structures, etc.).

For non-condition based formula, parameters such as miles and vehicle-miles-traveled were used to regress against the 2002 HWYNEEDS study results. Figures 5 through 7 show an example of the results. As it can be seen from the figures (comparison between actual needs and predicted-formula needs by county), the scatter of the data is big and the factor of regression (R-square) is in the 0.6 ranges, which means that the non-condition data can explain only 60% of the variability in the data. Other parameters can be added if further interest in this type of analysis is required. The addition of more parameters might improve the R-square value and result in a tighter distribution of the points.

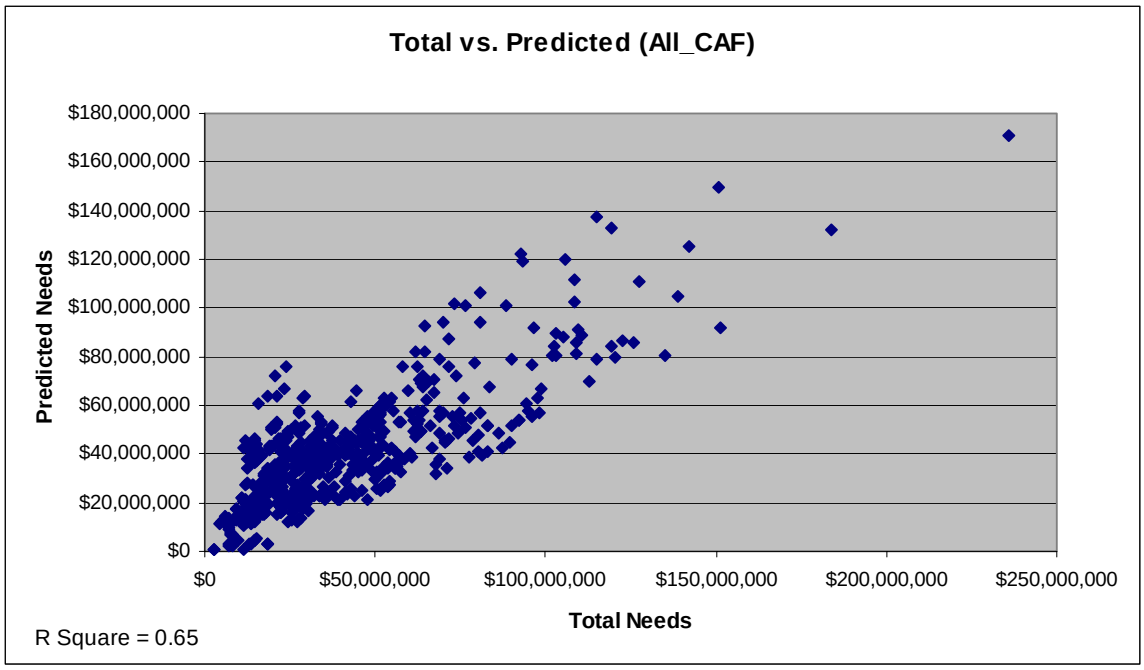

Figure 5. Non-condition based formula results (paved and cost area adjustment factors)

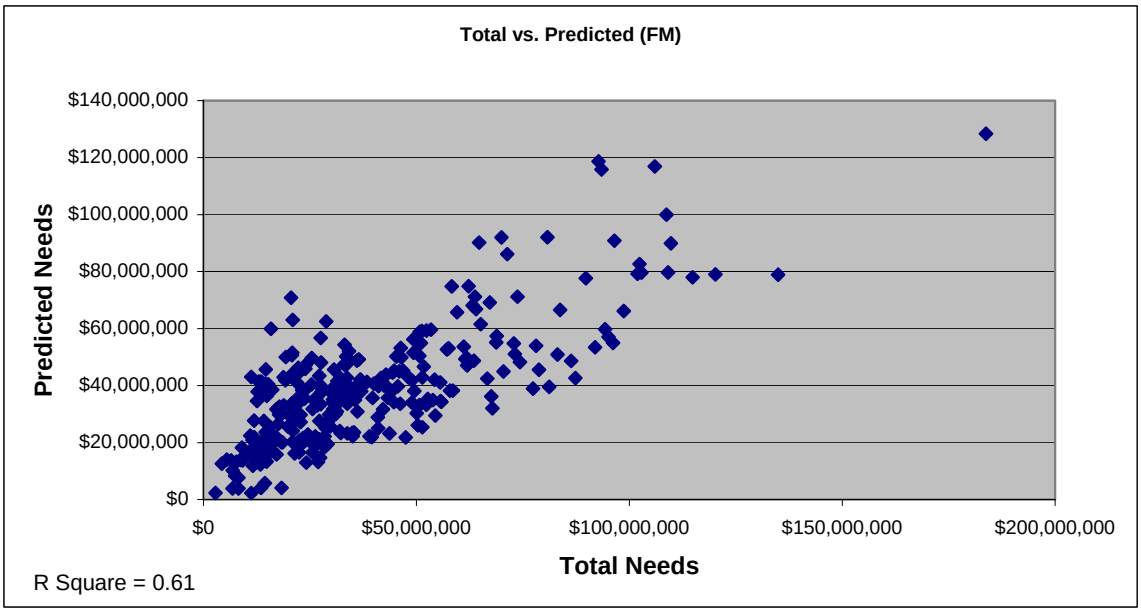

Figure 6. Non-condition based formula results (FM and cost area adjustment factors)

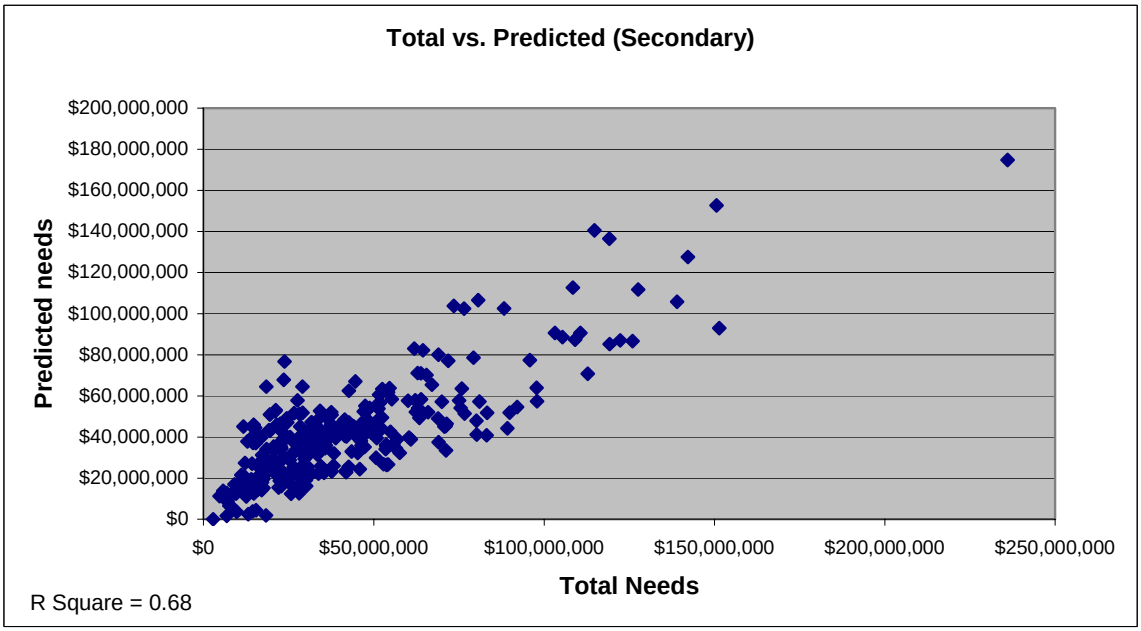

Figure 7. Non-condition based formula results (secondary and cost area adjustment factors)

For condition-based formula, the results were more promising. Several parameters from the automated distress data were considered, and a combination of distress, traffic, and vehicle miles traveled were used. The regression analysis was conducted using the 2002 Highway Need Study. The 20-year total needs (maintenance, construction, and administration) for paved roads were regressed against the condition data collected in an automated fashion through the IPMP. The regression analysis considered a multitude of variables, but the initial assessment found the following variables to be more significant. Regression equations were developed for the farm-to-market and secondary systems separately. Under each system, different regression equations were developed for the different pavement types (concrete, asphalt, composite, and treated surfaces). Here are the variables selected:

1. Pavement Condition Index: The PCI is a composite measure of the pavement condition. It combines all of the distresses collected (cracking, patching, ride, and roughness) into a single measure of pavement condition (0 to 100 scale). Different distresses can have different weights in the PCI calculation process.

2. Structure Index: The structure index is a quasi measure of structure. The IPMP data collection does not collect and material or structure values. Distresses that relate more to the materials (d-cracking in concrete pavement) and structure (alligator cracking in asphalt pavements) were used to calculate an index (0 to 100 scale) to represent the structure integrity of the pavement.

3. International Roughness Index: The IRI is a direct measure of the roughness of the pavement along the direction of travel. The IRI is measured in both wheel paths and the average left and right IRI values are used in the regression analysis. The average IRI values are then converted to an index (0 to 100 scale) for the final analysis.

4. Rutting: This represents a direct measurement of the rutting across the lane width. Rutting is measured in both wheel paths. The average rutting is used to calculate a rutting index (0 to 100 scale) to be used in the regression analysis.

5. Vehicle Miles Traveled (VMT)

6. Average Annual Daily Traffic (AADT)

Figure 8 shows the comparison between actual and predicted needs. With an R-square of 0.976, the use of the condition data proves to be very useful in predicting needs. Compared to the non-condition based, this represents a much better correlation and minimizes the differences between the actual needs from the 2002 HWYNEEDS study and the predicted formula needs. Table 1 shows a county-by-county analysis of the formula and a comparison between actual and predicted needs. As can be see from Table 1, the max increase is 8.2% and the maximum decrease is 6.9%. Figure 9 shows a histogram based on the results from Table 1. The histogram shows that the majority of the counties (39 out of 52) fall within the –5% to +5% range.

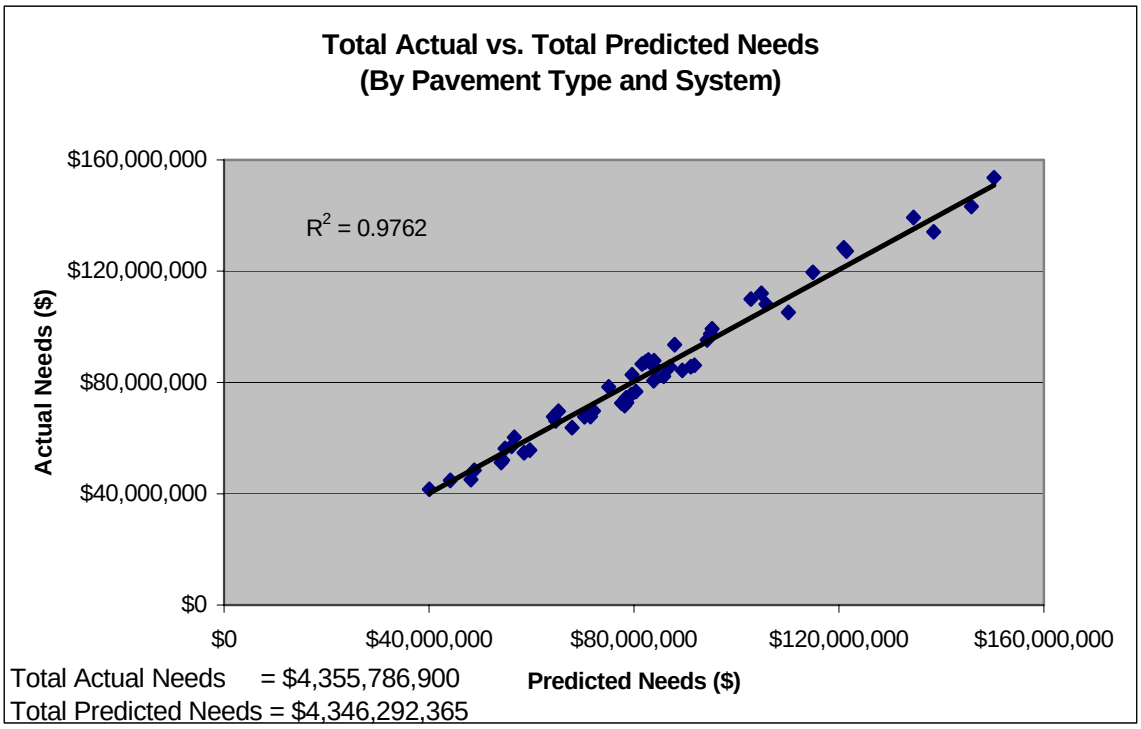

Figure 8. Condition-based comparison (combined FM and secondary)

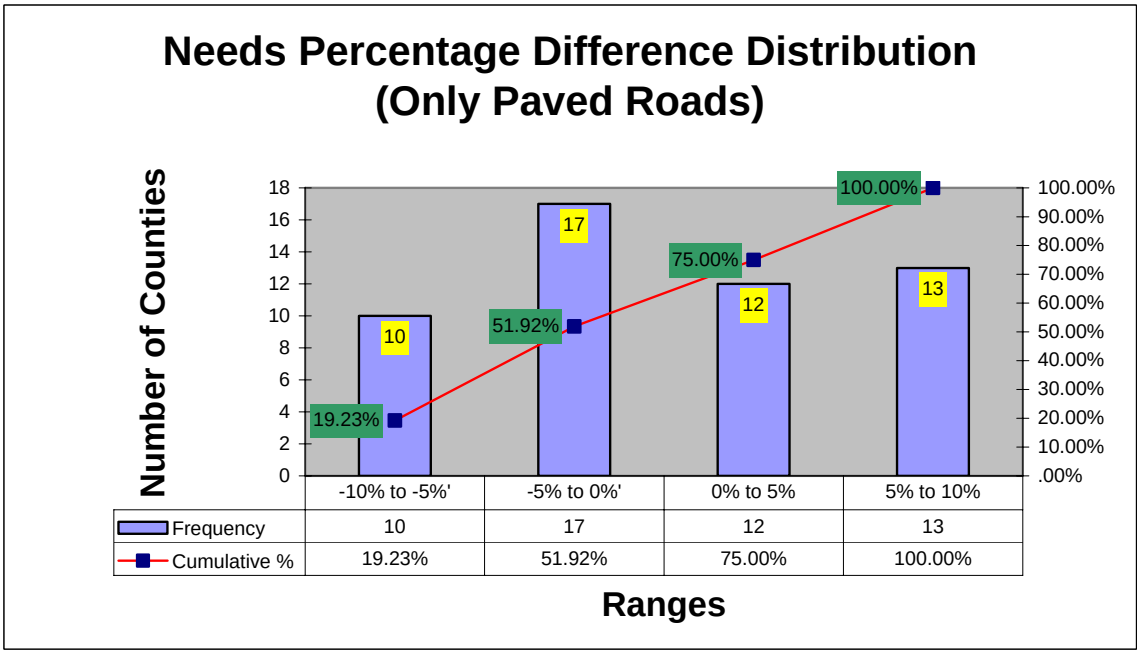

Figure 9. Percentage difference distribution

Table 1. County-by-county analysis of the condition-based formula

County	Paved roads needs FM+Sec (predicted)	Paved roads needs FM+Sec (actual)	% difference
03	$54,808,815	$56,248,653	-2.63%
07	$145,862,933	$143,210,000	1.82%
09	$72,108,472	$69,748,835	3.27%
10	$84,191,387	$85,208,251	-1.21%
11	$102,824,557	$109,970,000	-6.95%
12	$83,886,488	$87,842,457	-4.72%
13	$54,072,272	$51,216,023	5.28%
14	$89,448,884	$84,334,206	5.72%
17	$120,953,050	$128,363,661	-6.13%
18	$64,720,671	$66,210,000	-2.30%
19	$70,367,276	$67,706,100	3.78%
21	$94,932,222	$97,482,115	-2.69%
22	$82,250,916	$87,375,684	-6.23%
24	$48,180,751	$45,080,241	6.44%
30	$79,433,580	$75,600,000	4.83%
32	$67,917,313	$63,736,089	6.16%
33	$110,157,414	$105,173,916	4.52%
34	$86,976,416	$85,530,000	1.66%
35	$91,075,594	$85,660,000	5.95%
37	$78,609,677	$72,707,112	7.51%
38	$87,943,546	$93,580,155	-6.41%
39	$44,128,791	$44,823,405	-1.57%
40	$82,783,783	$88,066,139	-6.38%
41	$94,295,564	$95,259,085	-1.02%
42	$91,819,231	$86,179,131	6.14%
43	$59,666,548	$55,670,340	6.70%
45	$54,367,169	$52,096,347	4.18%
46	$81,592,002	$86,628,516	-6.17%
47	$40,070,884	$41,619,102	-3.86%
55	$150,271,137	$153,580,000	-2.20%
60	$95,228,971	$99,296,756	-4.27%
64	$104,838,719	$112,025,556	-6.86%
65	$58,533,826	$54,760,000	6.45%
66	$78,185,786	$71,720,837	8.27%
67	$65,282,634	$69,665,852	-6.71%
71	$77,558,570	$72,570,600	6.43%
72	$78,495,138	$74,459,980	5.14%
74	$56,638,248	$60,275,325	-6.42%
75	$134,563,613	$139,290,000	-3.51%
76	$75,056,338	$78,388,769	-4.44%
78	$85,789,476	$82,260,000	4.11%
79	$48,832,934	$48,426,386	0.83%
81	$71,505,715	$67,725,859	5.29%
83	$56,106,316	$57,059,596	-1.70%
84	$114,908,274	$119,579,707	-4.07%
86	$79,608,476	$82,732,564	-3.92%
94	$138,471,321	$134,140,410	3.13%
95	$64,249,898	$67,701,300	-5.37%
96	$105,769,711	$108,180,000	-2.28%
97	$121,469,082	$127,190,000	-4.71%
98	$83,834,228	$80,643,522	3.81%
99	$80,389,750	$76,754,051	4.52%
Total =	**$4,345,034,366**	**$4,355,786,900**	**Max + Change = 8.2%**
			Max - Change = 6.9%

CONCLUSIONS

The results presented in the previous section show that the automated condition data can be used in a converted highway needs process with no major differences between the two methods. Even though the foundation rating difference was significant, the foundation rating weighting factor in HWYNEEDS is minimal and should not have a major impact.

In terms of RUTF formula based distribution, the results clearly show the superiority of the condition-based analysis compared to the non-condition based. That correlation can be further enhanced by adding more distress variables to the analysis.

In terms of recommendations, the goal of this research was to provide information to the advisory committee so that they can make an informed decision to what direction the counties need to take for a future RUTF distribution mechanism. The researchers will leave the recommendations for the advisory committee to make.