HWYNEEDS:
METHODOLOGY, ANALYSIS, AND EVALUATION

FINAL REPORT

Sponsored by the Iowa Department of Transportation
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FINAL REPORT

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Sponsored by the Highway Division
of the Iowa Department of Transportation
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ABSTRACT

The quadrennial need study was developed to assist in identifying county highway financial needs (construction, rehabilitation, maintenance, and administration) and in the distribution of the road use tax fund (RUTF) among the counties in the state. During the period since the need study was first conducted using HWYNEEDS software, between 1982 and 1998, there have been large fluctuations in the level of funds distributed to individual counties. A recent study performed by Jim Cable (HR-363, 1993), found that one of the major factors affecting the volatility in the level of fluctuations is the quality of the pavement condition data collected and the accuracy of these data. In 1998, the Center for Transportation Research and Education researchers (Maze and Smadi) completed a project to study the feasibility of using automated pavement condition data collected for the Iowa Pavement Management Program (IPMP) for the paved county roads to be used in the HWYNEEDS software (TR-418). The automated condition data are objective and also more current since they are collected in a two-year cycle compared to the 10-year cycle used by HWYNEEDS right now. The study proved the use of the automated condition data in HWYNEEDS would be feasible and beneficial in reducing fluctuations when applied to a pilot study area. In another recommendation from TR-418, the researchers recommended a full analysis and investigation of HWYNEEDS methodology and parameters (for more information on the project, please review the TR-418 project report).

The study reported in this document builds on the previous study on using the automated condition data in HWYNEEDS and covers the analysis and investigation of the HWYNEEDS computer program methodology and parameters. The underlying hypothesis for this study is that along with the IPMP automated condition data, some changes need to be made to HWYNEEDS parameters to accommodate the use of the new data, which will stabilize the process of allocating resources and reduce fluctuations from one quadrennial need study to another. Another objective of this research is to investigate the gravel roads needs and study the feasibility of developing a more objective approach to determining needs on the counties gravel road network.

This study identifies new procedures by which the HWYNEEDS computer program is used to conduct the quadrennial needs study on paved roads. Also, a new procedure will be developed to determine gravel roads needs outside of the HWYNEED program.

Recommendations are identified for the new procedures and also in terms of making changes to the current quadrennial need study. Future research areas are also identified.

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 among 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 computer program, HWYNEEDS, developed by the Federal Highway Administration (FHWA), was adopted as the main programming tool for the need study. HWYNEEDS forecasts the condition of highways, automates the determination of financial needs, and provides a tool to help in the allocation of a percentage of the RUTF money to the counties. Since the implementation of HWYNEEDS, highway condition data have been collected manually, through visual surveys. Visual surveys are performed on one-tenth of the state's highway network each year; thus data for the entire network are covered once every 10 years. This project examines the methodology used in HWYNEEDS and recommends changes to be made to HWYNEEDS parameters to accommodate the use of automated condition data and improve the needs determination process. Also, gravel roads need determination will be investigated and a more objective and consistent method will be recommended.

In Iowa, automated pavement condition data are being collected for parts of the county network through the Iowa Pavement Management Program (IPMP). The IPMP is a statewide program to develop pavement condition databases to support the application of pavement management by the Iowa Department of Transportation (Iowa DOT) and cities and counties for the federal-aid-eligible highways within their jurisdictions. Condition data for the IPMP 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.

Background

Quadrennial need studies conducted in the past have exhibited large changes (positive and negative) in the funds allocated to individual counties. The shifts in funding following each four-year study make it difficult for counties that experienced these shifts to plan for future highway improvement programs. Several studies have been conducted in the past to investigate the sensitivity of HWYNEEDS to specific factors including pavement condition (HR-363 and TR-418). The work described in this report builds on the recommendations from the two projects and expands the investigation into HWYNEEDS methodology and parameters.

Study Objectives

The main objective of this study is to investigate HWYNEEDS methodology and assess the feasibility of continued use in the quadrennial needs study. From the in-depth investigation of HWYNEEDS parameters and their impact on the determination of needs, a better set of parameters will be determined. Another objective is to develop procedures

to facilitate the use of automated condition data in HWYNEEDS and gravel roads needs determination.

Proposed Work

The work described in this report addresses the comprehensive analysis and evaluation of HWYNEEDS methodology to improve the quadrennial need study process and, in return, try to minimize the volatile fluctuations in the fund allocation for individual counties.

As part of the analysis and evaluation of HWYNEEDS, the researchers investigated all of HWYNEEDS parameters, including condition forecasting, treatment alternatives, treatment improvements, decision trees, trigger limits, cost area factors, and gravel roads.

Another component to this study is to develop a process to use automated condition data collected for the IPMP as input to HWYEENDS and the quadrennial need study. Forecasting parameters and trigger limits will be developed based on the automated condition data, and changes to some of HWYNEEDS parameters will be recommended to facilitate the use of the newly collected condition data.

Project Tasks

The research was divided into two major parts. Part I covered HWYNNEDS parameters analysis and evaluation. Part II covered HWYNEEDS improvements. The following is a brief description for each part.

Part I—HWYNEEDS Parameters

This process covers the different components (modules) of the HYWNEEDS computer program and its resource allocation and project selection parameters. This includes an in-depth study of the HWYNEEDS computer program modules, process, and parameters. This will cover the following:

1. Performance parameters: used to predict (forecast) the future condition of the different infrastructure assets used in the quadrennial needs study (highways and structures). HWYNEEDS forecasts the condition for 20 years in each analysis run.

2. Decision trees: used to determine the appropriate treatment strategy for the different infrastructure assets considered in the analysis based on condition and other parameters (traffic, geometry, etc.)

3. Trigger limits: also used for treatment selection.

4. Available improvements: this is the list of the different treatments available to improve the infrastructure asset (highways and structures). Those treatments are selected using decision trees and trigger limits.

5. Improvement values: determine the resulting condition of the infrastructure asset after implementing a treatment strategy. It provides information about the final condition and also changes in functional classification, type, and geometry.

6. Cost areas: the counties are divided into different cost areas to reflect different labor, material, and other costs between counties. The impact of changing cost areas and their factors on HWYENEEDS will be investigated with the help of the supervisory committee and recommendations will be made.

7. Gravel roads: procedures will be developed to deal with gravel roads in the quadrennial needs study as part of the overall evaluation and improvement of the system. This is necessary due to the fact that automated distress data will be used for the paved system. Data collection procedure, condition evaluation, and resource allocation will be investigated.

Part II—HWYNEEDS Improvements

This process covers the possible options to improve the quadrennial need study. The first would be to continue using HWYNEEDS but with improved parameters. The second option considers a new methodology for determining needs. This part also includes a discussion on the use of automated distress data in the quadrennial need study.

1. HWYNEEDS: this option assumes that the HWYNEEDS computer program will continue to be used with modifications to the different parameters based on the results from Part I. This will include improvements in the performance prediction and treatment selection parameters to fit the needs of Iowa counties.

2. New system: this option covers the investigation of an alternative resource allocation and project selection methodology. HWYNEEDS utilizes a single-year prioritization technique to determine needs for the quadrennial needs study. Different possible methodologies (multiyear prioritization, optimization, etc.) will be investigated and comparisons of the advantages, disadvantages, and differences of each methodology will be evaluated. To accomplish this task, a search of the literature on the available infrastructure asset management systems will be conducted. An operational test of some available software tools might be required to determine the applicability and feasibility to the conditions present in the different counties.

3. Automated distress data: the use of the automated distress data proved feasible and different runs of the HWYNEEDS computer program were conducted to investigate the differences between the original condition surveys and automated data in TR-418. This task will use the automated distress data with the new parameters developed under option 1 and/or the new system for determining needs. The impact of using automated distress data on final needs will be determined and recommendations will be made.

Report Organization

Following the introduction, with proposed work and objectives, the report then covers the research methodology. The methodology section covers both Part I and Part II of the research project tasks. The section is dedicated to the discussion of the sensitivity of HWYNEEDS to variations in parameter weights. The final part of the report discusses the conclusions and recommendations of the research project.

METHODOLOGY

This section describes the methodology followed to achieve the goals and objectives of the research project. This section is divided into three parts. The first part covers an in-depth investigation of HWYNEEDS parameters. The second part discusses the use of automated condition data in HWYNEEDS. The third part investigates gravel roads needs determination through a new process outside of HWYNEEDS.

Throughout the entire project, an advisory committee consisting of 12 county engineers supervised the research and provided valuable input to the research team. Also, a technical monitor from the Iowa DOT Office of Systems Planning provided advice and technical guidance to the advisory committee and the research team.

HWYNEEDS Parameters

This task covered the investigation of the different modules and parameters of HWYNEEDS computer program. The investigation covered HWYNEEDS methodology and analysis of its modules and parameters. Also included in that was a look at the use of automated condition data and new forecasting parameters based on the data. A total of 15 HWYNEEDS runs were conducted by the Iowa DOT Office of Systems Planning. Table 1 identifies each run and the different parameters examined. The following is a description for each parameter examined in different HWYNEEDS computer runs.

1. Surface condition. This covers pavement condition. "Original" refers to the manually collected data on a 10-year cycle, and "new" refers to the newly collected automated condition data on a 2-year cycle.

2. Surface life. This covers the performance parameters in terms of surface life. "Original" is what exists right now in HWYNEEDS computer program, and "new" refers to the performance parameters developed based on the automated condition data. A more detailed description is available in the next section as part of the research methodology.

3. Foundation. This covers the foundation condition. "Original" refers to the manually collected data based on a 10-year cycle, and "new" refers to the approach used to calculate foundation rating based on specific automated distress measurements collected on a 2-year cycle.

4. New weights. This refers to the foundation weight used to calculate the overall rating for each needs section. The "original" weights vary by highway class, and the "new" weights refer to the different weights assigned to measure the impact of

foundation rating on overall needs (see Tables 2 and 3 for a complete listing of weights).

TABLE 1 HWYNEEDS Runs

Run	Surface Condition	Surface Life	Foundation	New Weights
1	Original	Original	Original	Original
2	Original	Original	Original	New
3	Original	Original	New	Original
4	Original	Original	New	New
5	New	New	New	Original
6	New	New	New	New
7	New	New	Original	New
8	New	New	None	New*
9	Original	Original	None	New*
10 New base data with 30% foundation	Original	Original	Original	Original
11 0% foundation	Original	Original	Original	Original
12 5% foundation	Original	Original	Original	Original
13 10% foundation	Original	Original	Original	Original
14 20% Foundation	Original	Original	Original	Original
15 All objective (surf type/shoulder type/pavement condition)	Original	Original	Original	Original

*New weights with weight of zero for foundation.

The different runs were analyzed to determine the impact of the different parameters on total needs. Runs 1 through 9 were conducted to determine the impact of the following parameters:

1. The use of automated pavement condition data.

2. The newly developed performance parameters (surface life).

3. The use of automated condition data to calculate a new foundation condition based on alligator and block cracking for asphalt pavements and joint distresses (d-cracking and joint spalling) for concrete pavements.

4. The impact of assigning new weights to calculate the overall rating for each needs section.

As a result of the analysis of the first nine runs, the research team recommended a more detailed look at the weights assigned for the foundation condition. Runs 10 through 15 addressed the foundation condition weights in relation to the other parameters included in the determination of the overall rating. The result section will discuss the impact of each parameter on the overall needs assessment.

TABLE 2 Condition Aggregate Weighting

Factor	Original	New	New*	10	11	12	13	14	15
Foundation	Varies by highway group. See Table 3.	10%	0%	30%	0%	5%	10%	20%	0%
Drainage		20%	20%	20%	29%	27%	26%	23%	0%
Surface type		10%	10%	15%	21%	20%	19%	17%	30%
Shoulder type		10%	10%	0%	0%	0%	0%	0%	10%
Pavement condition		40%	45%	30%	43%	41%	39%	34%	60%
Shoulder condition		10%	15%	5%	7%	7%	6%	6%	0%
Total		100%	100%	100%	100%	100%	100%	100%	100%

*New weights with weight of zero for foundation.

TABLE 3 Original Condition Aggregate Weighting by Highway Group

Factor	Highway Group							
	1	2	3	4	5	6	7	8
Foundation	35%	30%	30%	30%	35%	35%	35%	40%
Drainage	15%	20%	25%	30%	20%	20%	20%	20%
Surface type	15%	15%	10%	10%	10%	10%	10%	10%
Shoulder type	0%	0%	0%	0%	0%	0%	0%	0%
Pavement condition	30%	30%	30%	30%	30%	30%	30%	30%
Shoulder condition	5%	5%	5%	0%	5%	5%	5%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%

The final aspect of the parameter's analysis was the cost area factors. Cost area factors (CAF) are used to adjust the cost of construction and maintenance activities based on right-of-way costs and the annual county engineer's construction surveys. Currently, HWYNEEDS uses 23 different cost area factors. One of the recommendations from HR-363 (the Cable study) was to keep the cost areas the same from one need study to another to minimize the fluctuations. By comparing the results from 1994 and 1998 quadrennial need studies, when cost areas stayed the same, this did not result in less fluctuations.

The advisory committee and the research team investigated two different scenarios for coat areas. One was based on the regional planning agencies (18 RPAs throughout the state), and the other was based on the Iowa DOT districts (six throughout the state). The Iowa DOT Office of Systems Planning ran the different scenarios for 1994 and 1998 data. A total of eight different runs covering no CAF, original CAF, RPAs CAF, and DOT districts CAF for 1994 and 1998 were simulated. No significant difference in reducing fluctuations from one study to another was detected. The result section will cover this in more details.

Automated Condition Data

This task builds on the recommendations from both HR-363 and TR-418 on the use of automated distress data in the quadrennial need study. TR-418 proved feasible the use of automated pavement condition data as input to the HWYNEEDS program. TR-418 was conducted on a pilot study area of 21 different sections. This study included all of the federal-aid-eligible paved county roads in the state. Federal-aid eligible-paved roads constitute about 65 percent of all paved county roads. The same weighting factors used in TR-418 to convert the individual distress measurements (ride, rutting, cracking, and patching) to a five-point scale used in HWYNEEDDS computer program were utilized. In addition, new performance parameters to predict surface life were developed using regression analysis for the three different pavement types (flexible, composite, and rigid pavements) based on the automated condition data. Table 4 summarizes the new performance parameters. There were only slight differences between the original and new surface life ratings. Runs 5 through 8 (Table 1) included the newly calculated surface life.

TABLE 4 Surface Life

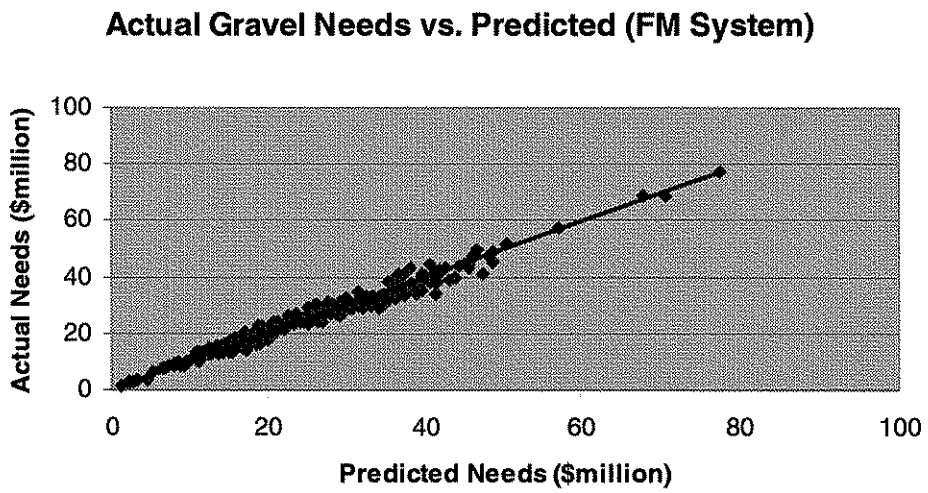
Pavement Type	Original Surface Life	New Surface Life
Asphalt	20 years	15 years
Composite	20 years	15 years
Rigid	20 Years	18 years

Gravel Roads

Gravel roads comprise the majority of the county road system with about 67,000 miles out of the 85,000 total county road miles. Gravel roads needs are currently determined using the same process in HWYNEEDS for paved roads. Surface condition rating, foundation rating, and other factors are collected manually on a 10-year cycle for all of the gravel roads on the county highway network. The data are subjective and outdated because of the lengthy data collection cycle. On another hand, the gravel road system is very dynamic and conditions change rapidly due to different environmental conditions (dry or rainy weather, summer, or winter). The rapid change in gravel road condition speaks against a condition-based needs calculation approach. One of the tasks included in this research project is to investigate a formula-based approach based on needs to determine gravel roads needs outside of HWYNEEDS computer program.

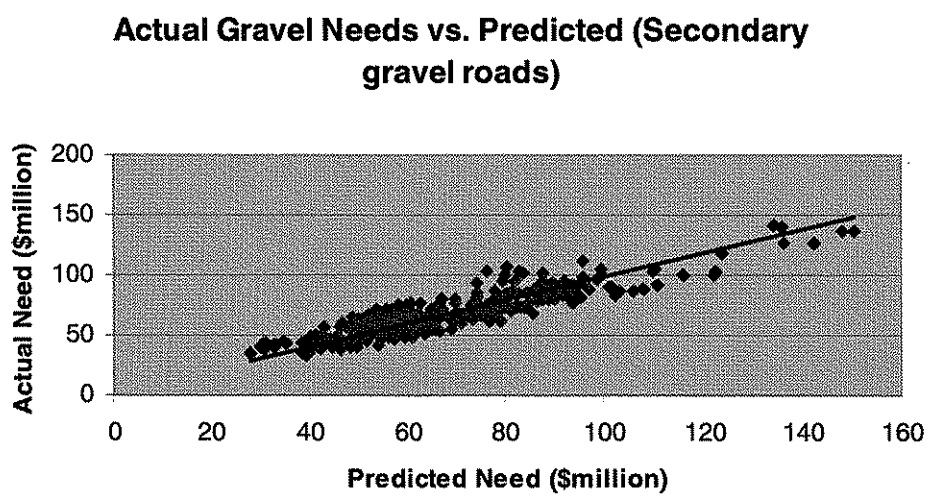
To accomplish this task, the research team investigated the different parameters that influence the determination of needs on gravel roads. Traffic, miles of gravel roads, vehicle mile traveled, and gravel roads expenditures were considered. An effort to include cost to account for differences among counties was not successful because of the fact that the necessary cost information was not available.

Data from three quadrennial need studies (1990, 1994, and 1998) were considered in the analysis of gravel roads needs. A regression analysis between needs calculated through HWYNEEDS computer program (condition-based) and the different parameters was conducted for both the farm to market system and secondary roads. Only two variables (vehicle miles traveled [VMT] and total gravel miles) had a good correlation in the regression analysis. Figures 1 and 2 show the results of the regression analysis for the two systems. The result section provides a more detailed look at the newly developed approach for gravel roads and its impact on overall needs determination.



Total Needs = (63613.63***Miles**) + (1507.665***VMT**)
R Square = 0.972

FIGURE 1 Farm to market gravel roads analysis.



Total Needs = (21418.51***Miles**) + (1700.556***VMT**)
R Square = 0.811

FIGURE 2 Secondary gravel roads analysis.

RESULTS

This section presents the results from the research project. This section is divided into two parts. The first past presents the results from HWYNEEDS computer program runs and analyzes the sensitivity to the different parameters considered in the evaluation process. The second part presents the gravel road analysis.

Each run simulates the road portion (structures were not included) of the quadrennial need study conducted on the paved federal-aid-eligible county roads. The HWYNEEDS computer program utilizes all of the information originally found in the base record in addition to the automated condition data, new surface life, and new weighting factors where appropriate. Runs in Table 1 (1 through 15) were conducted to achieve the following objectives:

1. To investigate HWYNEEDS parameters and their impact on overall needs.

2. To investigate the use of automated condition data on a larger sample (compared to the pilot study considered in TR-418) and the newly developed surface life numbers.

3. To determine the impact of the foundation condition rating on overall needs.

4. To determine the best possible combination of weighting factors that result in minimum changes in needs for individual counties from one quadrennial need study to another.

The gravel roads analysis objective was to develop a new approach to calculate gravel roads needs outside of the HWYNEEDS computer program. Regression analysis on the different parameters was conducted to determine the best possible alternative for determining needs.

Analysis of HWYNEEDS Parameters

To compare the differences in needs between the different HWYNEEDS computer program runs, each run was compared with run number 1, which included data used originally in HWYNEEDS. Subsequent runs included changes in the parameters that the research team wanted to investigate (foundation rating, weighting factors, automated condition data, and surface life). The following provides a description for each one of those parameters.

1. Foundation condition rating. The automated condition data were used to calculate an objective foundation rating as input to HWYNEEDS. The difference between the needs between the original HWYNEEDS foundation condition and the objective condition ranged between –60 percent and 90 percent. Figure 3 shows the needs difference between the two runs (run 1 and run 15).

2. Foundation condition rating weight. As it was shown in Tables 1 and 2, different weighting scenarios have been used to investigate the sensitivity of the weighting factors and also the foundation condition rating. Runs 10 through 14 of

HWYNEEDS were analyzed to determine the impact of the weighting factors. Figures 4 through 7 show the needs difference for the different weighting scenarios starting with 0, 5, 10, and 20 weighting for the foundation condition rating. The needs differences ranged from –60 percent to 70 percent, –30 percent to 45 percent, –18 percent to 35 percent, and –16 percent to 25 percent for the different weighting factors, respectively.

3. New surface life. The automated condition data were used to calculate new surface life numbers to determine the impact on total needs (Table 4). Figure 8 shows needs comparison between original condition data, automated condition data with original surface life, and automated condition data with new surface life. There was not a significant difference between automated condition with original surface life or new surface life. Once automated condition data are used in HWYNEEDS though, new surface life numbers will be utilized.

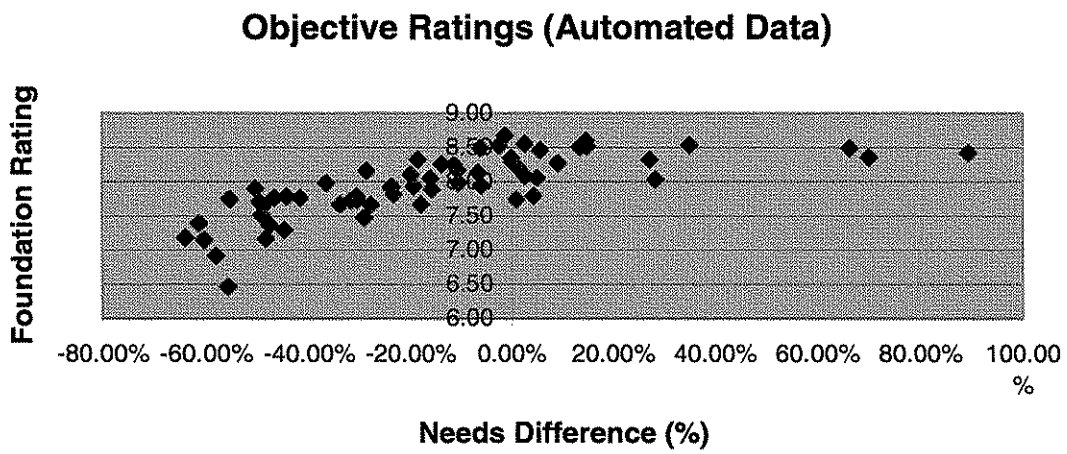


FIGURE 3 Objective foundation ratings.

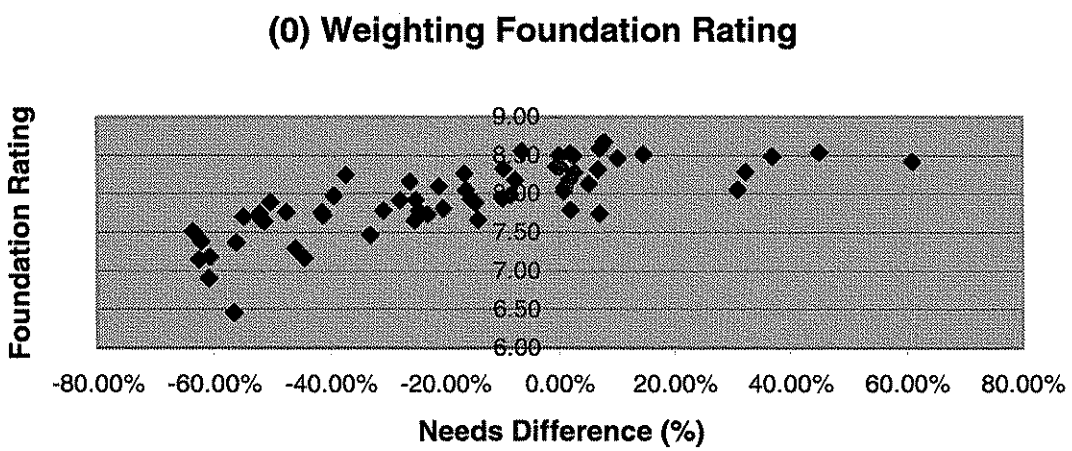


FIGURE 4 Zero (0) weighting foundation condition rating.

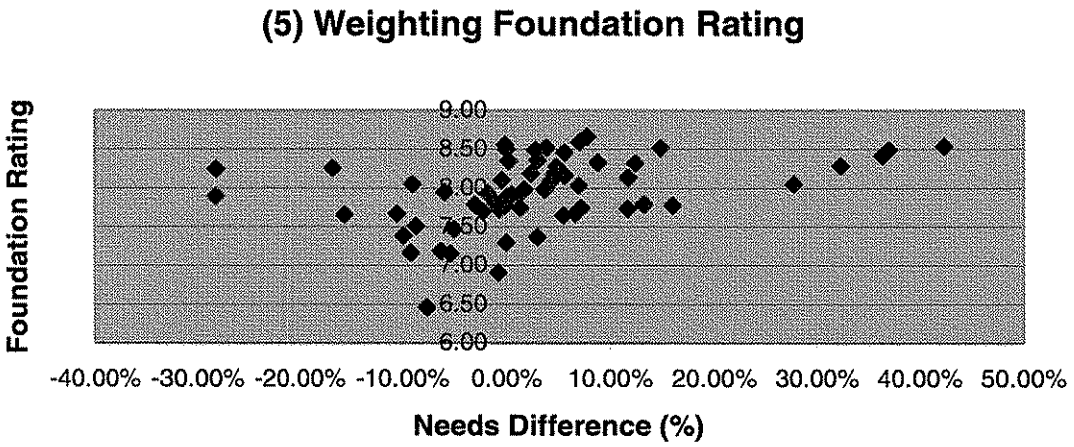


FIGURE 5 Five (5) weighting foundation condition rating.

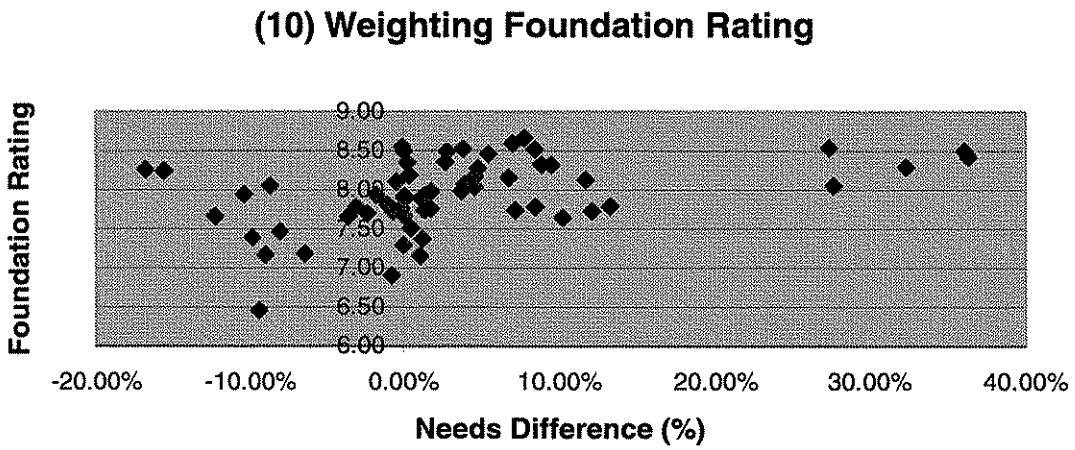


FIGURE 6 Ten (10) weighting foundation condition rating.

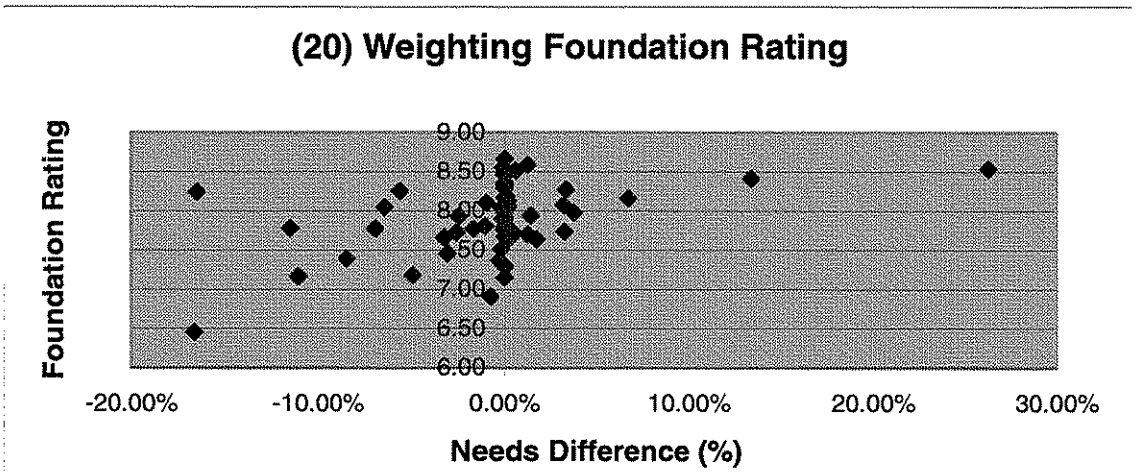


FIGURE 7 Twenty (20) weighting foundation condition rating.

Gravel Roads

To complete the analysis of gravel roads needs, a need comparison between the predicted needs using the new process and HWUNEEDS was conducted. Three quadrennial studies (1990, 1994, and 1998) were used in the comparison. Figures 9 and 10 show the predicted needs from one study to another using the regression equations developed for gravel roads. Figures 11 and 12 show the needs calculated by HWYNEEDS.

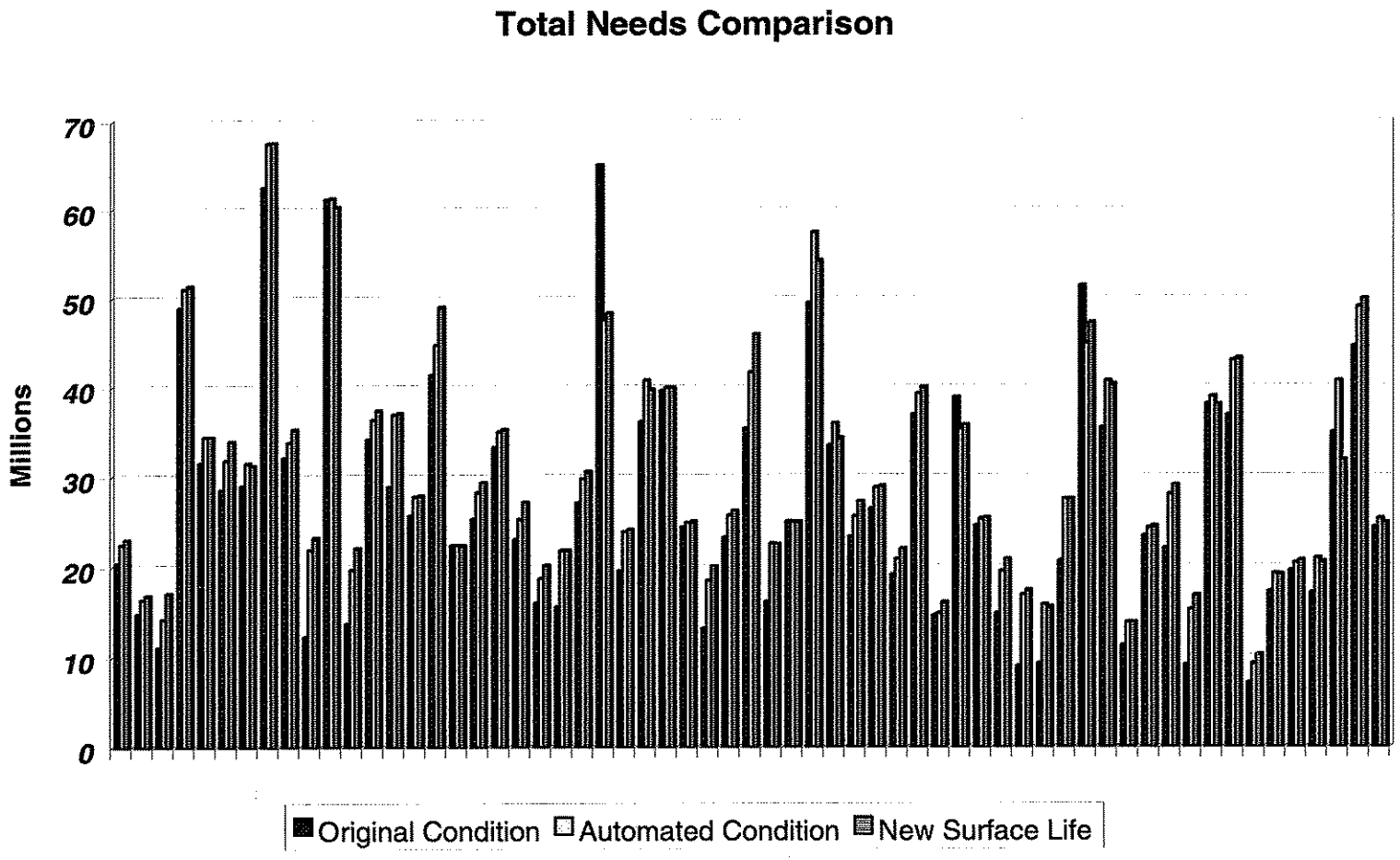


FIGURE 8 Automated condition data and new surface life comparison.

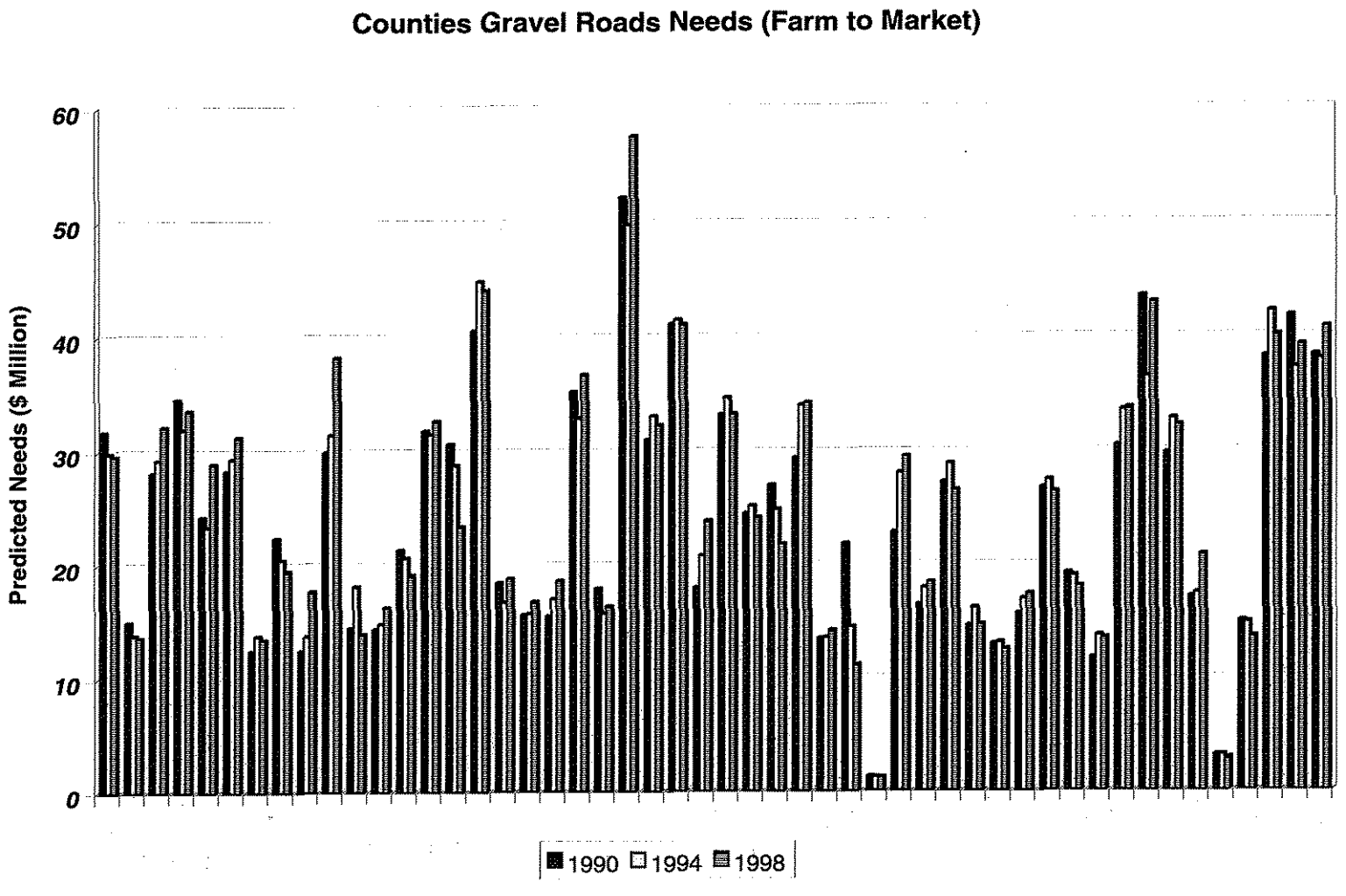


FIGURE 9 Predicted gravel roads needs.

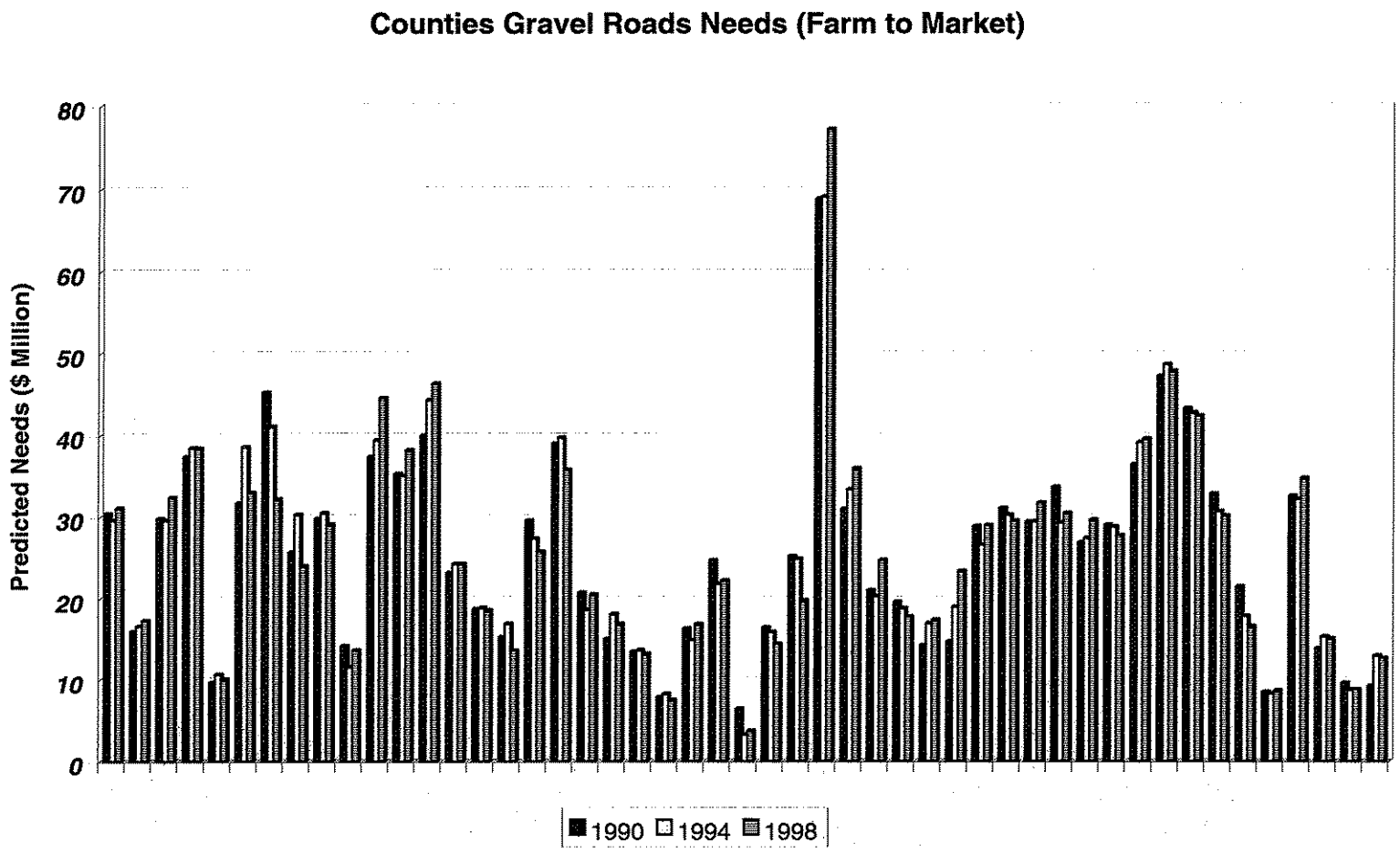


FIGURE 10 Predicted gravel roads needs.

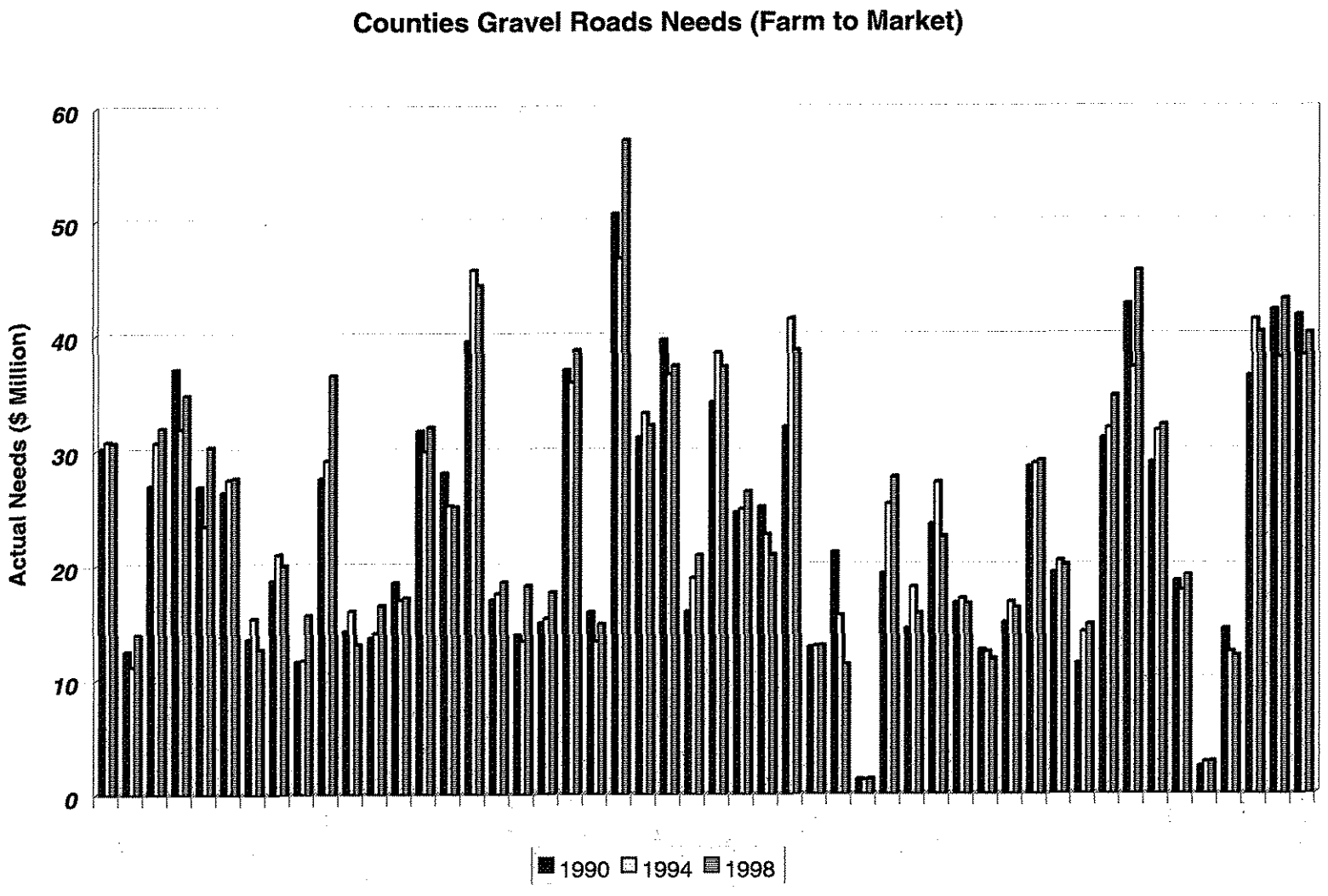


FIGURE 11 HWYNEEDS gravel roads needs.

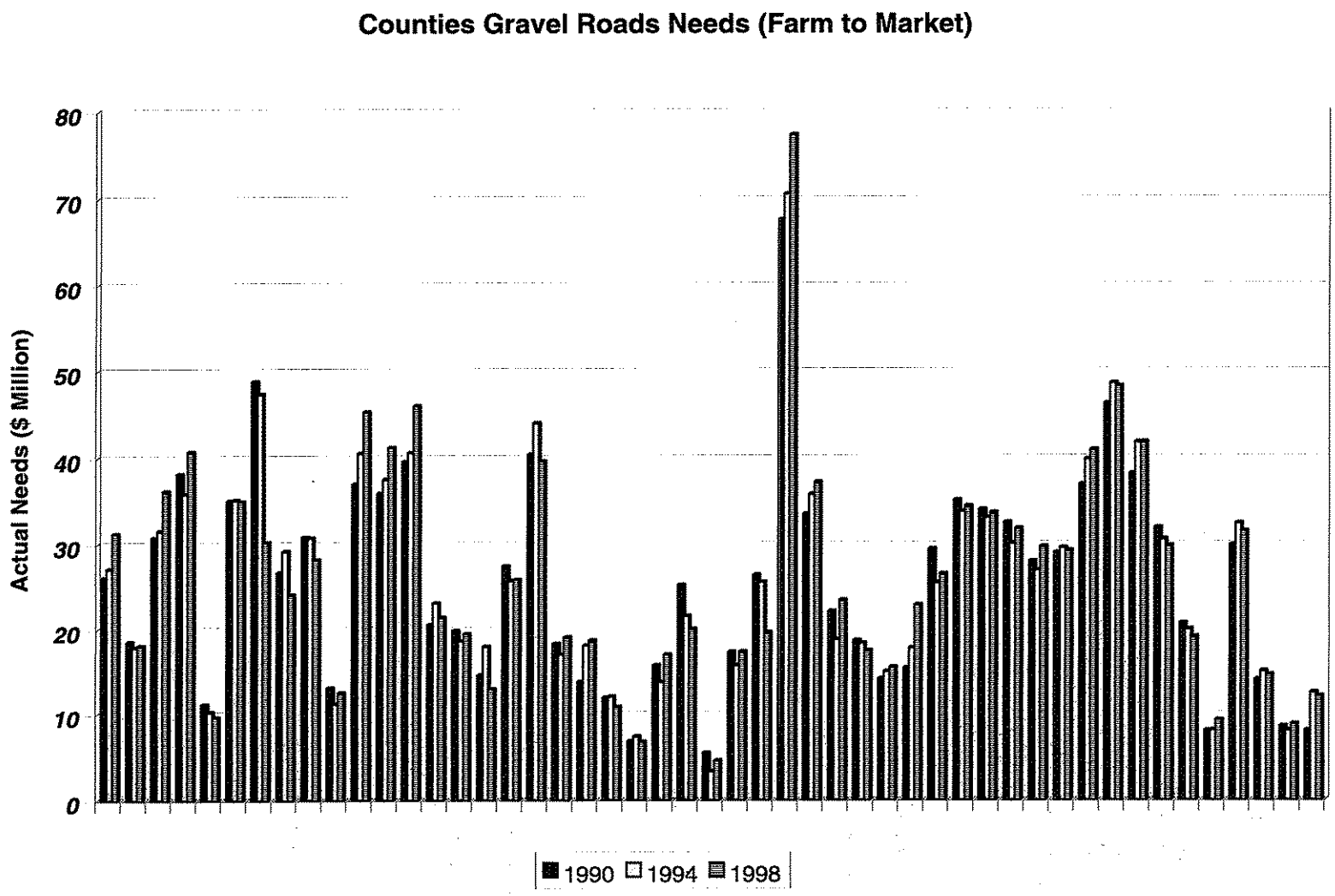


FIGURE 12 HWYNEEDS gravel roads needs.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results presented in the previous section clearly shows the sensitivity of HWYNEEDS to the parameters investigated specifically the foundation condition rating and the foundation condition rating weights. It was also shown that the process developed to use the automated condition data as part of TR-418 as input to HWYNEEDS is flexible and the accuracy of needs determination can be increased by using the new surface life developed based on the automated condition data.

The process developed to determine gravel roads needs using a formula-needs-based approach showed a clear relationship between past needs calculated by HWYNEEDS and the regression analysis needs.

Recommendations

This study was designed to investigate HWYNEEDS methodology and analyze HWYNEEDS parameters and make recommendations to change HWYNEEDS to minimize the volatile fluctuations in funds allocated to individual counties. The following is a description of the resulting recommendations:

1. Change the weighting factors in HWYNEEDS to reflect the changes made in the foundation condition rating. Table 2 shows the different weighting factors. The one designated as run 13 is going to be used in HWYNEEDS to replace the current weighting factors. This changes the foundation condition rating weighting factor from 30 to 10 and increases the pavement condition rating weighting factor from 30 to 40. Iowa DOT Office of Systems Planning is currently making those changes.

2. The use of automated distress data collected for the IPMP as input to the quadrennial need study is both feasible and beneficial. A recommendation to collect the entire county roads paved system has been approved by the county engineer's executive board. Currently, funding mechanisms and data collection procedures are being investigated. Through the IPMP, about 65 percent of all county paved roads are covered. Through individual contracts with counties, the Center for Transportation Research and Education has been collecting data on another 10 percent, which leaves about 25 percent of the system (3,000 miles) to be covered. Once a full cycle of automated condition data has been completed, the data can be used in HWYNEEDS. In addition to the automated data, the new surface life numbers should be used instead of what is currently used by HWYNEEDS.

3. Use a formula-needs-based approach to determine gravel roads needs. This recommendation has been approved by the county engineer's executive board, and the Iowa DOT Office of Systems planning is making the changes to reflect that in the next quadrennial need study (2002).

4. Based on the changes to the gravel roads network, the Iowa DOT was able to reduce the current data collection cycle from 10 to 4 years. This will produce a more accurate and up to date assessment of needs for the 2002 quadrennial need study. Automated condition data will be used in future quadrennial need studies once funding mechanisms and data collection procedures are established.

5. A task of this research project was to investigate different methodologies for the allocation of resources other than HWYNEEDS (option 2). This was not selected in this research project, but there is still a need to investigate different methodologies that does not have the inherent problems that exist in HWYNEEDS right now. This recommendation basically follows on what recommended from TR-418.

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