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A Study of Selected Strategies for Allocating Funds to Improve County Roads

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A STUDY OF SELECTED STRATEGIES FOR ALLOCATING FUNDS TO IMPROVE COUNTY ROADS

by

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Strategies for the ranking of county road improvement projects can be based on a rating that reflects the physical condition of the pavement, a rating that reflects the pavement roughness, a rating that incorporates the combination of physical condition of the pavement and the pavement roughness (its pavement serviceability rating), or a rating that takes into account the age of the pavement and amount of traffic.

This study compared the relationship between the strategy of the ranking of each road segment based on that segment's: (a) surface distress rating and roughness rating, (b) surface distress rating and pavement serviceability rating, (c) surface distress rating and traffic/age rating, (d) roughness rating and pavement serviceability rating, (e) roughness rating and traffic/age rating, and (f) pavement serviceability rating and traffic/age rating.

Only the worst one-third of the road segments as determined by each ranking strategy were included for evaluation. The segments were in ordinal data format. The Spearman rho (ρ), a nonparametric test statistic for ordinal data, was used to determine if there is a correlation among the rankings. To test the null hypotheses, the alpha level was set at .05.

Based on the data and analysis no conclusions could be drawn between the strategy of ranking of each road segment based on that segment's: (a) surface distress rating and roughness rating, (b) distress rating and traffic/age rating, or (c) pavement serviceability rating and traffic/age rating.

However, there was a relationship between the strategy of the ranking of each road segment based on that segment's: (a) surface distress rating and pavement serviceability rating, (b) roughness rating and pavement serviceability rating, and (c) roughness rating and traffic/age rating.

The pavement serviceability rating was derived from an average of the pavement condition and pavement roughness ratings. It was therefore expected that a high level of correlation would be found between the order of projects ranked for improvements by the surface distress rating and pavement serviceability rating systems, and between the order projects ranked for improvements by the roughness rating and pavement serviceability rating systems.

The collection of both surface distress rating and roughness rating appears not to be a duplication of ratings. The results of this study suggest that the elimination of certain data does change the rank of road improvement priorities. The additional expense to collect data is warranted depending on the organization's goals, objectives, and policies.

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CHAPTER I

BACKGROUND AND STATEMENT OF PROBLEM

Introduction

Expenditures for road repairs and improvements have a direct impact on social, economic, political, environmental, cultural, and physical systems (e.g., Jackson, 1985; Lemmerman, 1984; Mak & Jones, 1976; McPherson & Poole, 1988; Pedigo & Hudson, 1982; Poole & Cribbins, 1983; Ruth, 1980; Sinha, 1980). Roads are deteriorating faster than funds to repair and improve them are becoming available. Revenues are not meeting the demands that are being placed on the road systems. The appointed or elected stewards of these roads must allocate funds to improve roads in such a way to obtain the most benefit to the public for each dollar spent. Managers must meet this challenge by using a strategy which provides for the optimal expenditure of public funds for the maximum benefit of the users of the road system.

For Michigan county roads, the responsibility for road maintenance and improvement issues is delegated to county road commissions. Cena (1977) stated that it is the duty of each county road commission "to keep [roads] in reasonable repair, so that they shall be reasonably safe and convenient for public travel" (p. 286). The requirement to provide a reasonably safe and convenient road system is mandated by the state of Michigan's general highway law, which was adopted in the early 1900s, and is further affirmed by the courts. The state's courts have offered considerable guidance via case law in defining what is convenient and what is reasonably safe (Cena, 1977). Using standard engineering principles, management tools, and the court's guidance, it is the county road commission's responsibility to make the initial analysis to attempt to provide the best road possible within the imposed funding constraints.

Employment of a pavement management system aids in the ranking of needed road improvement projects. A pavement management system (PMS) incorporates various technical factors associated with ranking road improvements. Those factors can include the physical condition of pavement (e.g., cracking, rutting, patching), the roughness of pavement (ride comfort), pavement age and traffic volume, structural capacity (ability to withstand traffic loadings), and roadway geometry (e.g., lane and shoulder width) and safety (e.g., horizontal and vertical curves, intersections, and skid resistance) (American Association of State Highway and Transportation Officials, 1990a; Baladi & Snyder, 1990; Carmichael & O'Grady, 1983; Colucci-Rios & Sinha, 1985; Curry & Shearin, 1980; Feighan, Shahin, Sinha & White, 1989; Karan, Christison, Cheetham & Berdahl, 1983; Karan, Longenecker, Stanley, & Haas, 1983; Kulkarni, 1984a; Manubay, Kerr & Obenchain, 1985; Maser, Brademeyer & Littlefield, 1988; McNeil & Hendrickson, 1982; Mercier & Stoner, 1988; National Association of County Engineers, 1992; Pedigo & Hudson, 1982; Shahin & Kohn, 1982; Shufon & Hartgen, 1982; Simon, Mackie, May & Pearman, 1988; Tamburri & Smith, 1970; Theberge, 1987; Transportation Research Board, 1987).

The U. S. Department of Transportation's Federal Highway Administration (FHWA, 1989) has recognized the importance of PMS and has mandated that each state highway agency develop a PMS satisfactory to the Federal Highway Administration by January 13, 1993. Each state must include all the routes under its jurisdiction. In late 1991, the United States Congress passed Public Law 102-240. Public Law 102-240 is better known as the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Section 1034 of ISTEA mandates the United States Secretary of Transportation to issue "regulations for State development, establishment, and implementation a system for managing . . . highway pavements of Federal-aid highways" (p. 105 STAT. 1977). In addition ISTEA mandates urban areas of over 50,000 to also develop a system for managing highway pavements.

A pavement management system (PMS) is valuable and offers a rational, systematic approach to maintaining and, when adequate funding is available, improving roads. PMS has been defined as: (a) "an orderly process for providing, operating, maintaining, repairing, and restoring a network of pavements" (American Public Works Association, 1985, p. 157); (b) a concept "that involves the coordination, scheduling, and accomplishment of all of the activities performed by a highway agency in the process of providing adequate pavements for the public" (Pedigo & Hudson, 1982, p. 30); (c) "the systematic development of information and procedures necessary in optimizing the design and maintenance of pavements" (Way, Eisenberg, & Kulkarni, 1982, p. 49); (d) a "strategy to protect the capital investment in the highway system to ensure maximum serviceability of the highway system to the motoring public at a reasonable cost" (Hartgen, 1984, p. 85); and (e) "an established, documented procedure treating. . . pavement management activities . . . in a systematic and coordinated manner" (Baladi & Snyder, 1990, p. 1-32).

A pavement management system allows managers of the road system to analyze the quality and character of the entire road network. In addition, when found necessary by the analysis, a PMS will recommend the needed methods to improve a specific road in the network.

A pavement management system requires numerous actions which must be coordinated and completed annually. These actions include collecting and analyzing the data, determining the recommended response, developing the cost factors for the response, establishing the budget constraints, and finally implementing the appropriate activity.

Problem Statement

The county road manager is faced with different strategies in determining the allocation of limited road improvement funds. The county road manager is bombarded with information and approaches by literature and vendors offering assistance in the allocation process. Further, the public demands an effective approach which is rational and understandable. To assist in determining priorities for the rational expenditure of public funds for the various road improvement projects, it is necessary to use a strategy which employs technical factors to assist in the project selections. A pavement management system meets that need. However, it appears that not every technical factor is necessary for the implementation of a selected strategy. If certain factors are not needed, that is, do not change the ranking of the projects selected, there is no need to bear the cost of acquiring the data. Technical factors include the physical condition of pavement, the roughness of pavement, pavement age and traffic volume, structural capacity, and roadway geometry and safety.

The physical condition of the pavement and the pavement roughness in combination are the two most frequently mentioned technical factors required for any allocation strategy for road improvement projects (American Association of State Highway and Transportation Officials, 1990a; Elton & Juang, 1988; Hartgen, 1984; Karan, Christison, Cheetham, & Berdahl, 1983; Kulkarni, 1984b; Majidzadeh, Luther, & Long, 1982; Manubay et al., 1985; Martin, 1988; Maser et al., 1988; McHattie, & Connor, 1983; Mercier & Stoner, 1988; Pedigo & Hudson, 1982; Shufon & Hartgen, 1982; Theberge, 1987; Turner, Walters, Glover, & Mansfield, 1986; van Gurp, Molenaar, Valk, & van Velzen, 1984; D. M. Walker & Thiede, 1987; Way et al., 1982).

The question is, does it make a difference in the allocation of funds to improve county roads if the strategy for fund allocation is based on only one of the two most commonly cited technical factors, and if so, what is the difference? Or is there another strategy which will yield the same results that could be developed in the manager's office without data collected in the field, such as ranking improvement projects using pavement age and traffic volume? Given the financial limitations of the public works environment, the county road manager must look for other less expensive strategies that will yield the same results, that is, the selection of road improvement projects.

Anticipated Results

County road managers must determine on a rational basis the ranking of road improvement projects. The strategy for allocating funds for road improvement projects is based on technical rating factors; however, not all the factors may be appropriate or necessary to rank the projects.

This dissertation studies the two most often used technical rating factors (i.e., pavement distress and pavement roughness), the combination of the pavement distress and pavement roughness factors, and a rating based on pavement age and traffic volumes (information which is readily available), and their relationship on the various ranking strategies for the county road improvement projects.

This dissertation is an incorporation of a leadership issue which Katz (1955) noted is required for effective administration. Katz stated that effective administration requires a proficiency in technical skills which "involves specialized knowledge, analytical within that specialty, and facility on use of the tools and techniques on the specific discipline" (p. 34). Managing resources is an important discipline of a leader. As the chief administrative officer of a local public agency, technical skills must be in place in order to provide a basis for human and conceptual skills of the leader. In order to discuss, or convey information, the leader must understand fundamental engineering principles and be able to explain issues in terms that are understandable. But before issues can be discussed, the leader must understand and appreciate the technical issues at hand. Burns (1978) considers these technical skills as part of the engagement when a leader is a transactional leader. Burns noted that transactional leadership is one of the two types of leadership styles available to leaders. The other leadership style is transformational leadership.

The results of this study provide county road mangers an opportunity to gain a better understanding of the relationship of selected strategies for the allocation of limited public funds. The allocation of funds for road improvements is an important part of the county road manager's responsibility. If the results of this study were to suggest that the collection and incorporation of certain data do not change the rank of the road improvement priorities, then there is no need to spend the money to collect the data.

Overview

A review of literature is reported in Chapter II. The literature review includes an itemization of the technical factors found in the ranking strategies for allocating funds for road improvements. The literature review includes information on how the data are collected and their importance to the project selection process.

Chapter III provides the methodology for the comparison of ranking strategies for allocating funds for road improvements. The comparison is based on data collected in the summer of 1991 for the Kalamazoo County Road Commission's primary road system.

Chapter IV contains the compared results of the relationship of selected strategies for allocating funds to improve county roads.

Chapter V provides a summary of research problem, method, and findings; the conclusions drawn from the project; and the project's implications.

CHAPTER II

REVIEW OF LITERATURE

Introduction

A review of literature found numerous reports, research studies, and related documents regarding strategies for allocating funds for road improvements. The review revealed considerable information on how to acquire and rate the various technical factors associated with determining project priorities. Technical factors include the physical condition of pavement, the pavement roughness, pavement age and traffic volume, structural capacity, and roadway geometry and safety.

The two technical factors which are considered the most important for the implementation of a pavement management system are the road's pavement condition and its roughness.

Physical Condition of Pavement

The physical condition of the pavement is determined by rating the amounts and types of distresses on the road's surface. Surface distress factors are of the following types: alligator cracking, map cracking, transverse cracking, longitudinal cracking, edge cracking, distortion, excessive crown, rutting, ravelling/streaking, potholes, bleeding/flushing, and rippling/shoving (American Public Works Association, 1985).

Benson, Elkins, Uddin, and Hudson (1988) noted that pavement distress surveys, or condition surveys, play a critical role in any pavement performance study. There are several alternatives available for data collection of the physical condition of the pavement. A visual inspection is the dominant approach to determining the assessment of the pavement's condition (American Public Works Association, 1985).

The data collected on the survey should be more than just pavement distress information. The data typically include a complete inventory of all paved streets with block number, length, width, type of pavement, date of last improvement, average daily traffic, percentage of truck traffic, functional classification, shoulder, curb and gutter, sidewalks, drainage, and right-of-way information. This additional information allows for an opportunity to build all road related information into a comprehensive data file for future purposes and analysis.

Between 1984 and 1988, the Institute for Transportation Research and Education (ITRE cited in Martin, 1988) developed and successfully implemented pavement management programs for more than 80 municipalities in North Carolina. The ITRE Pavement Condition Survey is a visual inspection of the bituminous paved roads. "Surveys should be conducted at least every other year to update condition data. Streets with serious structural pavement distress should always be checked annually" (Martin, 1988, p. 70). Hartgen and Herschenhorn (1986) noted that the New York State Department of Transportation annually collects surface distress condition data for its 16,400 mile road system. The raters receive intensive training each spring. The data are collected during the summer by regional crews.

Distress surveys for pavement management purposes are conducted on two distinct levels. Distress surveys are critical for the network-level evaluations as well as project-level evaluations.

Shufon and Hartgen (1982) noted that the goal of the visual or windshield (so called because the work is done looking out a vehicle window) survey is to provide information which is indicative of overall condition. To be of value "the data must be: consistent between regions or highway types; rapidly collectable; repeatable over time;

reasonably accurate, but not overly precise; easily understandable by lay persons; inexpensive to collect; [and] consistent with existing procedures" (pp. 4 and 6).

The American Public Works Association (1985) has developed a system of rating roads. The system, known as PAVER, is based on a visual rating scale. The scale rates pavement distress types and their severity and amount of distress on a 0 to 100 scale. The higher the score the better the road. PAVER includes the following distress types: alligator cracking, bleeding, block cracking, bumps and sags, corrugation, depression, edge cracking, joint reflection cracking, laying/shoulder drop off, longitudinal and transverse cracking, patching and utility cut patching, polish aggregate, pot holes, railroad crossing, rutting, shoving, slippage cracking, swell and weathering, and raveling. In addition, each distress type is characterized by its severity and its density. (American Public Works Association). PAVER sample inspection rating Form A for concrete pavement and PAVER sample inspection rating Form B for asphalt pavement can be found on page 20 and page 22 in the United States Department of Transportation's 1988 publication Safety Resource Allocation Programs and Input Processor: Users Manual (Publication No. FHWA-IP-88-20).

Van Gurp et al. (1984) collected data for the secondary roads in the province of Zuid-Holland in the Netherlands. Van Gurp et al. rated five general survey distress-type combinations. These ratings incorporate both the extent and severity of the distress on a scale from 1 to 5. The distress types are texture (raveling, flushing, skid resistance), roughness (transverse roughness, irregularities, longitude roughness), soundness (transverse cracks and joints, longitude cracks and joints, alligator cracking potholes, joint width, element quality), roadside (edge distress, curb), and miscellaneous (drainage, verge, parking strip, bus stop). Van Gurp et al. stated that the key to data collection, which includes uniform and consistent data, requires the training of the data collectors as an integral part of the process. Accuracy is not the most critical issue in data collection. Uniformity and consistency of the data is required. Shufon and Hartgen (1982) stated that "intricate measurements are not required. Data can be collected, processed, and summarized in a very short time at relatively low cost to the agency" (p. 22). In 1982, Shufon and Hartgen noted that the entire process for the state of New York highway system from data collection through summarization took about 5 months and cost approximately $75,000.

Visual inspection is not the only way to collect surface distress data. Benson et al. (1988) conducted field tests to review and evaluate various forms of data collection required for research studies. Ten test sections of 1,000 feet each were used and all sections were roads which were under use. The tests were conducted on flexible, rigid, and composite pavements exhibiting a range of pavement distresses. The distress survey methods and equipment were evaluated based on their performance and capabilities in the field. The distress survey methods and devices selected for the field testing were as follows:

1. Manual mapping.
2. Detailed visual survey, manual recording.
3. Detailed visual survey, automated data logging.
4. PASCO Road Reconnaissance (ROADRECON) survey vehicle, featuring photographic equipment and laser height sensors. PASCO Corporation of Japan developed the continuous pavement surface photographing device.
5. Groupe Examen Routier Photographic (GERPHO) survey vehicle, featuring photographic equipment. The GERPHO system was developed in France by the Ministere des Transports. It employs a survey vehicle to take continuous 35 millimeter photographs of the pavement surface.

6. Automatic Road Analyzer (ARAN) survey vehicle, featuring video equipment, ultrasonic height sensors, and on-board computer. The ARAN vehicle is produced by Highway Products International, Inc. of Paris, Ontario, Canada.

7. Laser Road Surface Tester (RST) survey vehicle, featuring laser height sensors and on-board computer. The RST was developed by the Swedish Road and Traffic Research Institute and has been used in Sweden for about 3 years.

The study concluded that the GERPHO and PASCO ROADRECON can be used for both network-level and project-level distress surveys and are well suited for pavement research studies. The ARAN and Laser RST are recommended for use in network-level surveys. It is also recommended that automatic data loggers be used when manual distress surveys are conducted. The manual recording of visual survey method and manual mapping were ranked last as cost-effective approaches to collecting data.

Manubay et al. (1985) noted that the automated data capture has several advantages. It relieves the data collection crew of much fine detail work in the field; increases the uniformity, speed, and accuracy of data collection; decreases the size of the data collection crews; and decreases the amount of human data handling both in the field and in the office. The Idaho Department of Transportation collection of the field data has been modernized with the use of automated data logging equipment. Data from the field are transferred directly from microcomputer tape cartridges to mainframe disk files.

Maser et al. (1988) noted improvements in the collection of data. High-speed sensors have been developed which can be operated from highway speed vehicles. There have been developments in acoustic, laser, optical strobe, and image processing techniques for the continuous measurement of transverse profile, automated detection, and quantification of cracking to determine levels of surface distress. Ground penetrating radar has been used to determine the pavement layer thickness, subsurface moisture, and voids. Highway speed vehicles can be used to implement all of these technologies.

Turner et al. (1986) performed multiple regression techniques on distress data for the state of Alabama Highway Department. Turner et al. determined that "no single variable appeared to dominate the regression analysis, although alligator cracking, transverse cracking, and severe raveling were strong contributors" (p. 14). In conclusion, the study noted that there were various factors which contributed significantly to inclusion of a road into the priority ranking system for the Alabama Highway Department. The factors which were most critical were roughness, patterns of lightly spalled alligator cracking, 1/8 inch to 1/4 inch block cracking, and hairline to 1/4 inch transverse cracking.

In conclusion, collection of data for the determination of the pavement's physical condition is time consuming and expensive. It is a very labor-intensive effort. The typical cost of accumulating the physical condition data is approximately $90 per lane mile. Capital investments are being made to make this work less labor intensive and more machine-intensive. While currently in use, improvements, such as video, laser, sonar, do not have the support of any research which documents their benefits over the current approach. It is expected that the machine-intensive approach may not be necessarily less expensive, but will offer other advantages, such as high replicability and physical documentation of each road segment.

Pavement Roughness

The pavement's roughness, riding comfort, smoothness are terms often used interchangeably in the literature. The roughness of a pavement is sometimes expressed in terms of its riding comfort or present serviceability index (PSI). The pavement's roughness can be measured by subjective or objective means. Researchers de Velasco and McCullough (1983) noted that "in general, riding quality has been the most important factor considered" (p. 54) for ranking road improvement projects. "Roughness represents the traveling public's perception of pavements" (Kulkami, 1984b, p. 15). The rougher the pavement, the worse the road.

From the road user standpoint, roughness depends on the vehicle being driven (e.g., truck vs. full-size car vs. small car), condition of springs and shocks, and vehicle speed. From the road manager's perspective, smoother pavements yield a reduction in future maintenance costs, an improvement in pavement structural integrity, reduced user operating costs, and an improved pavement performance. As a pavement deteriorates, it consumes performance. The remaining performance for a pavement is until it reaches its terminal state (Theberge, 1988).

For the motorist, rough pavement will increase travel time, fuel consumption, vehicle maintenance costs, and decrease ride quality (Ross, 1982). Roughness is a technical factor for ranking road improvements. Garg, Horowitz and Ross (1988) stated that "from the public's viewpoint pavement roughness, more than structural adequacy, drives the desire for pavement improvement" (p. 276). Colucci-Rios and Sinha stated that "roughness measurements and ADT (as a surrogate of traffic) can be used . . . for establishing resurfacing priorities at the network level during a given 5-year horizon" (p. 22).

Kilareski and Krammes (1984) noted that the Pennsylvania Department of Transportation (PennDOT) collected roughness information for over 25 years. One of the early devices used, from 1965 to 1967, was the Bureau of Public Roads road roughness indicator. In 1967 PennDOT began using a Portland Cement Association road meter, and in 1972 PennDOT switched to the Mays Ridemeter as the device to measure pavement roughness.

Another approach which offers a very subjective evaluation criteria is known as the serviceability evaluation. This evaluation develops a present serviceability index (PSI) which is determined by the score given to the road segment based upon the riding smoothness of the road. The present serviceability index (PSI) is a measure from 0 to 5 of the public's perception of the pavement's condition. A value of 0 to 1 is very poor, 1 to 2 is poor, 2 to 3 is fair, 3 to 4 is good, and 4 to 5 is very good (Baladi & Snyder, 1990).

D. M. Walker and Thiede (1987) reported that the Wisconsin DOT has traditionally used the present serviceability index (PSI) in programming state roadway improvements. "The PSI is a mechanical measure of surface roughness determined by an electromechanical meter mounted in an automobile" (p. 84).

Pedigo and Hudson (1982) recognized the importance of PSI and noted "PSI offers an inexpensive, reasonable, overall assessment of the adequacy of a pavement to serve traffic and, in conjunction with structural and/or condition survey variables, can be used to prioritize and derive generalized rehabilitation strategies for programming purposes" (p. 35).

PSI is a relative number. A PSI is usually compared to the traffic volume of the roadway. For example, a road with a volume of over 10,000 vehicles per day should not have a PSI value that falls below 3.0 to 3.5 for its pavement. A roadway with medium volume of 3,000 to 10,000 vehicles per days will tolerate a minimum PSI of 2.5 to 3.0. A road with traffic volumes under 3,000 will find its critical PSI in the 2.0 to 2.5 range (Baladi & Snyder, 1990).

To take some of the subjectivity out of this approach, instruments such as a Mays Ridemeter are available which measure the road's roughness (American Public Works Association, 1985).

Anderson (1986) stated that the Michigan Department of Transportation conducts a roughness survey using the Rapid Travel Profilometer. The Rapid Travel Profilometer uses a lightsensor to measure pavement roughness every 0.1 of a mile.

In Alaska, according to McHattie and Connor (1983), the Mays Ridemeter was the instrument of choice. Queiroz, Hudson, Visser, and Butler (1984) reviewed the worldwide standards for a stable, consistent, and transferable roughness scale. They noted that "roughness measuring systems such as the Mays Ridemeter, bump integrator, and roughometer have in common the fact that their roughness output for the same road section can vary with time as changes in machine conditions (e.g., tires, springs, shock absorbers, mass) occur" (p. 50). R. S. Walker and Lin (1988) stated that the Mays Ridemeter and the Walker Self-Calibrating Roughness Measuring Device are currently used in Texas for large scale roughness measurements. There are more expensive units available, but due to their initial cost and high maintenance costs, the units are not used.

R. S. Walker and Lin tested the difference between several various machines to measure road roughness in order to determine the present serviceability index (PSI) for each road segment. Tested were the Rainhart profilograph, the California profilograph, the Surface Dynamics Profilometer, and the Walker Self-Calibrating Roughness Measuring Device. R. S. Walker and Lin concluded that there is a good to high correlation between each of the units.

Garg et al. (1988) studied the relationship between pavement roughness and public perception of roughness. Garg et al. randomly selected 50 paid subjects from the general population in Wisconsin. The researchers noted that from "the public's viewpoint, pavement roughness, more than structural adequacy, drives the desire for pavement improvement" (p. 276). Garg et al. discovered that "road surface appearance was found to be highly correlated with all measures of road roughness (subjective, physical, and acceptability)" (pp. 278-279) and concluded that the "relationship between roughness measured with a profilometer and subjective ratings of ride quality are nearly identical" (p. 283). The study also noted that the "appearance of the road surface is extremely important to subjects rating ride quality" (p. 282).

Karan, Christison, Cheetham, and Berdahl (1983) tested the relationship between a road's current riding comfort index (RCI) and its future RCI. It was expected that there would be a recursive relationship. The future RCI is a function of the present RCI, with terms that relate to age, traffic, soil type, and structural thickness used as independent or explanatory variables. Tests performed on their models indicated that "regression analyses showed that the traffic, structural thickness, and soil type do not affect RCI performance significantly" (p. 13).

In conclusion, pavement roughness data can be collected in one of two ways, subjectively or objectively. Although subjectively collected data have been found to be highly correlated with objectively collected data, they are not recommended, due to their lack of technical support, for ranking road improvement projects. The typical cost for collecting roughness data is approximately one-third the cost of collecting distress data.

Physical Condition and Pavement Roughness

The blending of the two major technical factors, physical condition and pavement roughness, is typical. As noted in Baladi and Snyder (1990), all state highway authorities in the United States use the pavement condition or distress index and pavement roughness or ride index in their ranking and prioritization routine. The combination of the two factors is commonly known as the overall pavement rating (Fernando & Hudson, 1983).

Pavement Age and Traffic Volume

McNeil and Hendrickson (1982) noted that "as the age of the pavement increases, and the road is subjected to the cumulative effects of weather and time, the cost of maintenance increases" (p. 74). Even pavements without traffic will bear the impact of the environment. Environmental influences such as temperature, rainfall, and frost penetration will cause pavement deterioration.

Nunez and Shahin (1986) worked with an index known as the pavement condition index, or PCI. "PCI is a composite index of the pavement's structural integrity and operating condition. PCI of a pavement section is determined based on distress type, quantity, and severity" (p. 125). Their research revealed that the "PCI is strongly related to pavement's age for a given pavement family" (p. 130).

The volume of traffic impacts the quality of the pavement. Pavements constructed to withstand the beating of traffic will not require overlays as frequently as other roads. Likewise, pavements that have very little traffic will not require overlays as frequently. As a general rule, roads that have the most traffic require paving or overlays more often.

The National Association of County Engineers (1992) noted that traffic, both the number of vehicles as well as the types of vehicles, will impact road surface performance. Vehicles that carry a heavy load per axle have a substantially greater impact on the road.

Carmichael and O'Grady (1983) noted that a "substantial amount of pavement damage can be related to traffic" (p. 41). Kulkarni (1984b) reported that traffic causes pavement surface distresses such as fatigue cracking and pavement roughness. Traffic volume is a critical component in design requirements and serves as surrogate for deterioration of the pavement over time.

Pavement deterioration is a function of pavement age and traffic. The older the road and the higher the volume of traffic, the sooner the pavement will need to be overlayed or the road will need to be reconstructed. A rating based on these two factors could be instrumental in the development of a network-level pavement management system at a very nominal cost.

Structural Capacity

Structural capacity is the "ability of a pavement to accommodate traffic loadings with little or no cracking or deformation" (American Association of State Highway and Transportation Officials [AASHTO], 1990a, p. 19). The structural integrity of the road base and subgrade can be measured by either nondestructive (deflection survey measurements) or destructive testing devices (coring or excavation). The nondestructive testing (NDT) device, commonly known as a deflectometer, applies a load to the pavement and sensors record the resulting deflections. The test results indicate the structural strength of the pavement and, thus, predict the pavement's continued life expectancy. Karan, Christison, Cheetham and Berdahl (1983) defined structural adequacy as the pavement's "structural ability to withstand the expected traffic loadings" (p. 15).

Shahin, Davis, and Kohn (1984) noted that "non-destructive testing (NDT) deflection data are an important addition to the pavement management system for the purpose of pavement design and evaluation and condition prediction" (p. 70). Idaho uses the deflectometer or the Dynaflect brand units to determine the structural adequacy of its roads (Karan, Longenecker, Stanley, & Haas, 1983). Over time, deflection testing can assist in the development of deterioration curves for a given type of pavement.

Badu-Tweneboah, Ruth, and Miley, (1988) stated:

> Nondestructive testing (NDT) and deflection measurements are now universally recognized methods for the structural evaluation of road and airfield pavements. NDT of pavements has evolved from the very basic Benkelman Beam to the more refined equipment such as Dynaflect, Road Rater, and Falling Weight Deflectometer. (p. 96)

NDT or load capacity information is important for the engineering design of individual projects; but due to its relatively expensive cost to acquire the data, it is not necessarily required information for a network-level analysis.

Roadway Geometry and Safety

Roadway geometry refers to the width of the pavement's travel lane and width of usable shoulder. The American Association of State Highway and Transportation Officials published their 1990 guidelines in their book A Policy on Geometric Design of Highways and Streets (1990b). If a roadway is inadequate it must be updated at the time of the road improvements. For example, the minimum lane width for a rural road is 10 feet. There are currently in existence roads with lane widths of 8 to 9 feet. Usable shoulder widths, like lane widths, depend on many factors, including the amount of traffic volume, traffic speed, traffic characteristics, and amount of truck traffic. Because of geometric concerns, additional budget monies must be allocated for these roads to be improved since it is more expensive to widen lanes and shoulders than to simply overlay the existing adequate road and add gravel to match the shoulder to the pavement's edge. Improvement to roadway geometry is one of several actions that can improve the roadway safety.

Evaluating for safety is an important aspect for evaluating current roadway conditions and for proposed improvements. This evaluation includes accident experience (frequency and rate), roadway geometrics, and traffic volumes (D. M. Walker & Theide, 1987).

The American Association of State Highway and Transportation Officials (1984) noted that "the safety of the traveling public must be reflected throughout the highway program; in spot safety projects, in rehabilitation projects, in the construction of new highways, and elsewhere" (p. 131). Relatively inexpensive projects, such as increasing the pavement's skid resistance, should be undertaken as a result of on-going testing and inspection, particularly when traffic accidents reflect the need.

The Transportation Research Board (1987) stated that highway features affect safety by:

> 1. Influencing the ability of the driver to maintain vehicle control and identify hazards. Significant features include lane width, alignment, sight distance, super-elevation, and pavement surface characteristics;
> 2. Influencing the number and types of opportunities that exist for conflict between vehicles. Significant features include access control, intersection design, number of lanes, and median;
> 3. Affecting the consequences of an out-of-control vehicle leaving the traveled lanes. Significant features include shoulder width and type, edge drop, roadside conditions, side slope, and guardrail; and
> 4. Affecting the behavior and attentiveness of the driver, particularly, the choice of travel speed. Driver behavior is affected by virtually all elements of the roadway environment. (p. 78)

Little (1968) noted that a "key technical problem in traffic safety measurements is how to quantify relationships in a highly interactive setting" (p. 11). Little further noted:

> There are two basic forms of loss incurred as a result of traffic accidents. First, there is the net loss in goods and services due to death, injury, and the expenditure of resources necessary to rectify where possible the effects of accidents. Under this category, we have such costs as lost net productivity of those injured and killed, the costs of medical treatment and repair to damaged property, and administration. These losses are referred to as economic losses and, at least in principle, are quantifiable. In addition to these, however, these

> are losses in the form of pain, fear, and suffering on the part of those involved in accidents. (p. 96)

The Transportation Research Board (1987) noted in its publication Designing Safer Roads that reconstructing crest curves to improve sight distance can be cost-effective under certain circumstances. For example, when a major hazard exists in this sight-restricted area, and the design speed of the existing curve is more than 20 miles per hour (MPH) below operating speeds at the sight-restricted area, and average daily traffic (ADT) is greater than 1,500, the project is probably cost-effective. The Transportation Research Board noted that "sight distance improvements at crest curves can provide user time and operating cost savings, but the savings are small in relation to the cost of these improvements and can usually be ignored in cost-effectiveness estimates" (p. 171). However, the Transportation Research Board noted that "highway user travel time and operating cost savings for flattening horizontal curves can be considerable. Taking these savings into account, along with safety benefits, strengthens the case for these improvements" (p. 171).

The Transportation Research Board (1987) attributed this unfortunate fact to inherent difficulties in the safety related research work which included:

1. Accidents are relatively infrequent so that it is difficult to undertake sound statistical studies which require consistent data collected over long periods of time.

2. Road geometry is not the only factor that impacts accidents. Included in these factors are the road environment, the driver, and the vehicle, which are dynamically interrelated and can contribute to occurrence and severity of accidents.

3. Reporting practices of non-fatal accidents are not 100%.

4. Additional factors such as vehicle performance and crash worthiness, change-over time, and certain relationships that are developed at one time, cannot be representative at another time.

The Transportation Research Board (1987) noted that "despite...long-term efforts, surprisingly little is known about the decrease in accident rates, the results from improvements in road design" (p. 78).

At the time roadways are improved, geometric and safety issues must be addressed. Safety is a primary responsibility of the public road agency.

Other Various Combinations

The information obtained from the data collection effort is analyzed and expressed in a number format and then converted to an index. There are several types of indexes which can be developed. These indexes allow the substantial amount of data assembled to be translated into an easy-to-use and readily-understandable management tool.

Haas and Cheetam (1982) noted that combining the various individual factors would result in a composite index known as the pavement quality index (PQI). The pavement quality index, on a scale of 0 to 10, has been found to be useful in programming rehabilitation projects. The pavement quality index uses the Canadian riding comfort index (roughness measure), a structural adequacy rating from deflection survey measurements, and a pavement condition rating.

Karan, Christison, Cheetham, and Berdahl (1983) found that the development of a pavement quality index (PQI) could encompass all the various aspects related to pavement performance into a single index for comparing different road segments. The PQI incorporates the riding comfort, structural adequacy determined from deflection survey measurements, and the pavement condition or distress. According to Haas and Cheetam (1982), all ratings are based on a scale of 0 to 10. The higher the score the better the road. Haas and Cheetam concluded that "although information on the individual data items should be retained, a composite 'pavement quality index' (PQI), on a scale of 0 to 10, has been found quite useful for rehabilitation programming" (p. 41).

Karan, Haas, Cheetam, Christison, and Khalil (1983) noted that their work in Alberta, Canada, included not only the development of the pavement quality index (PQI) and its components of structural adequacy, riding comfort, and visual condition ratings, but also included consideration for remaining service life (in structural or serviceability terms or both) for each road section. The use of the remaining service life concept provides the decision maker with information regarding the health and longevity of the road system.

Carmichael and O'Grady (1983) reported on information for the city of Arvada, Colorado. Arvada included in its data base specific pavement distresses (both extent and severity) and ride quality. Ride quality was considered as merely another distress factor that was subtracted from the road's overall rating. Arvada's goal was to select the most cost-effective projects. Cost effectiveness was determined by developing values of road improvements. Carmichael and O'Grady noted that pavements which have calculated the highest values

> are pavements that, for most cases, will have the highest cost with respect to the length of pavement to be rehabilitated (indicating the need for a major improvement), have a high traffic level (thereby making it an important street), and be in a poor condition as indicated by the condition rating score. (p. 42)

Benefits of Improved Roads for Users

The National Association of County Engineers (1992) noted that there is a relationship between the rate of pavement deterioration and the cost to rehabilitate the pavement. During the first 75% of the pavement's life there is a 40% quality drop of that pavement. In addition, after the pavement's life has reached 75% of its useful life, each $1.00 of renovation cost will dramatically increase to between $4.00 and $5.00 if another 40% decrease in the pavement's quality is allowed to occur. This additional 40% drop in quality will take only 3 to 4 years of additional time. It is important that the public receive the maximum benefit from each dollar expended on the roadway. The typical relationship between pavement condition (deterioration), time, and the cost of repairs is graphically depicted in National Association of County Engineers' 1992 publication NACE Action Guides' Volume III on page 1-1.

The users of roads pay a user fee in the form of a fuel tax whenever fuel is purchased. Pavements will last longer if they are properly maintained on a timely basis. This means that the user fee will not have to be increased in order to "catch up" when the roads cannot be properly maintained due to financial constraints.

D. M. Walker and Thiede (1987) noted that improving highway segments benefits highway users in three ways. There is a savings in travel time, a savings in vehicle operating costs, and a lowering of accident rates. Dunbar (1980) noted that the value of time saved is a function of the road users' income.

Research Hypotheses

The strategy for the ranking of projects can be based on a rating that reflects the physical condition of the pavement, a rating that reflects the pavement roughness, a rating that incorporates the combination of physical condition of the pavement and the pavement roughness, or a rating that takes into account the pavement's age and amount of traffic. It can be expensive to collect the data required to rate and rank the road segments. Is it possible that one type of data, whether based on surface distress, or pavement roughness, or the combination of road pavement's surface and pavement roughness, or the amount of traffic and the age of pavement, yields the same ranking order? Because if the ranking order does not change, considerable sums of money could be saved on the collection process and reallocated to a more worthwhile expenditure.

The research hypothesis for the study can be stated as follows. Is there a relationship between the ranking of each road segment based on that segment's:

1. surface distress rating and roughness rating?
2. surface distress rating and pavement serviceability rating?
3. surface distress rating and traffic/age rating?
4. roughness rating and pavement serviceability rating?
5. roughness rating and traffic/age rating?
6. pavement serviceability rating and traffic/age rating?

Summary

The various technical factors associated with the rational selection of road improvement projects have been reviewed in detail in this chapter. The pavement's physical condition and the pavement's roughness measures are the key factors in the ranking process. Typically these two factors are combined to create a composite index for ranking the priority improvement projects. The literature also suggests that two other technical factors, pavement age and traffic volume, could be combined to create an acceptable ranking for priority improvement projects at a minimal cost. The remaining technical factors are important, but they serve to offer supporting information for ranking projects. Geometric, safety, and structural capacity issues are incorporated in the individual road improvement projects design. Safety programs, such as hazard abatement, alignment, and skid resistance improvement projects, should be in addition to the pavement management process discussed in this project. This process for ranking improvement projects assumes that the agency has a process in place for addressing safety problems.

CHAPTER III

RESEARCH DESIGN

Introduction

Permission to complete this study was obtained from the Kalamazoo County Road Commission (KCRC). KCRC has a long history of employing various management tools to improve the budgetary process. KCRC supports the project.

The Kalamazoo County Road Commission primary road system consists of 434 miles. These roads have been segmented in accordance with the state of Michigan Highway Needs Study Program. The roads have been sectioned so that each individual segment is relatively uniform with regard to functional classification, cross-section, geometric, traffic, and physical condition. Segment breaks also occur at county lines, corporate limits, and major intersections. KCRC's primary road system has been divided into 410 segments.

Data

The Michigan Highway and Nonmotorized Needs Study inventory data are maintained by each Michigan road agency. The information on this inventory is an excellent source for historical and background attributes for each road segment. These attribute data for uses in this study will include the following descriptive information: (a) section number, (b) road name, (c) from limit, (d) to limit, (e) function classification, (f) section length, (g) pavement width, (h) 24-hour traffic count, (i) traffic count date, (j) percent commercial traffic, (k) pavement surface type, (l) pavement surface thickness, (m) base material type, (n) base material thickness, (o) sub-base material type, (p) sub-base material thickness, and (q) sub-grade material type.

These attribute data were determined from KCRC files including as-built records and road borings. In the few situations where neither records nor borings are available, the data were obtained from long-term KCRC employees who have first-hand knowledge of construction practices and techniques over the past 20 to 30 years. A sample copy of the Michigan Highway and Nonmotorized Needs Study - Inventory Data (Form 1716) can be obtained from the Michigan Department of Transportation, Post Office Box 30050, Lansing, Michigan 48909.

Surface Distress Rating Data

For each section of roadway, field data were collected to create a surface distress rating for each section of roadway. The surface distress rating is a single value representing the overall condition of each road segment surface. The surface distress rating incorporates the following types of surface distresses: (a) alligator cracking, (b) map cracking, (c) transverse cracking, (d) longitudinal cracking, (e) edge cracking, (f) distortion, (g) excessive crown, (h) rutting, (i) ravelling/streaking, (j) potholes, (k) bleeding/flushing, and (l) rippling/shoving.

These surface distresses have been recognized by research as visible and proper criteria which reflect the structural adequacy and condition of the roadway (American Public Works Association, 1985; Benson et al., 1988; Shufon & Hartgen, 1982; Van Gurp et al., 1984). It is this information, coupled with the type of material; composition of the road itself; and date of last resurfacing, reconstruction, or recondition, that allows for the development of prediction models or performance curves for the various maintenance and rehabilitation measures for each road section.

Each road segment was rated by a team of qualified, trained, and experienced team of raters under contract to KCRC. Pavement Management Systems, Ltd. of Amherst, New York, completed the collection of data during August and September 1991 and issued their report in December 1991. The team rated each road segment on the various surface distress factors, as noted earlier. This rating took place along the road segment at each 100 feet and incorporated the severity and density of the distresses. The ratings are accumulated and combined to give an overall rating from 0 to 10 for each road segment.

Roughness Rating Data

At the same time as the road's surface distress data were collected in 1991, the team developed a roughness or riding comfort rating for each road segment. The road roughness rating represents the roadway user's impression of the roadway. The subjective feeling of the road user can be rated using an objective mechanical device. Road roughness was measured using an electronic device called an Accelerometer. A value from 0 to 10 was determined representing a range of extremely rough to perfectly smooth.

Pavement Serviceability Rating Data

An overall pavement rating was developed for each segment. The pavement serviceability rating was derived from an average of the pavement condition and pavement roughness ratings.

Traffic/Age Rating Data

A traffic/age rating was developed for each segment. An equation weighted the age of the pavement as 75% of the rating and assigned the daily traffic volume as 25%

of the rating. The maximum allowed pavement age was 30 years. The maximum allowed daily traffic volume was 10,000 vehicles. Typically, on the county road system, roads carrying more than 10,000 vehicles per day are a four lane facility. The increased lanes decrease the amount of traffic per lane and thus the traffic impact is minimized.

A review of the attribute data determined that the county road commercial or truck traffic was consistently in the 3% to 5% range. Therefore, an additional factor weighting commercial traffic was not included. Since the heavier axle traffic is evenly distributed throughout the road system, validity concerns are addressed.

Analysis

Each road segment was rated based on surface distresses, roughness, pavement serviceability, and traffic/age factors. For each rating factor, the road segments were placed in order, from worst to best, to determine which roads should be repaired first.

The focus of this project is the allocation of limited funds on road improvement projects. Proper planning requires that, at a minimum, a 5-year road improvement plan be developed. Only the worst one-third of the road segments as determined by each ranking strategy will be included for evaluation. To compare the ranking by the four rating procedures of all segments does not provide useful information, from a practical point of view. The comparison of the ranking of worst one-third segments, which is all that is required for the 5-year plan, will be more worthwhile. It will offer the opportunity to test the correlation of just the most important portion of the project rankings. The ranking of the better two-thirds is not of any importance if the worse one-third are not improved first.

The research hypotheses for this project are as follows:

Hypothesis 1--Relationship Between Surface Distress Rating and Roughness Rating

Conceptual Hypothesis 1: There is a relationship between each road segment's surface distress rating and roughness rating.

Operational Hypothesis 1: There is a correlation of greater than zero between the rankings of each road segment's surface distress rating and roughness rating.

Null Hypothesis 1: There is a correlation of zero between the rankings of each road segment's surface distress rating and roughness rating.

Hypothesis 2--Relationship Between Surface Distress Rating and Pavement Serviceability Rating

Conceptual Hypothesis 2: There is a relationship between each road segment's surface distress rating and pavement serviceability rating.

Operational Hypothesis 2: There is a correlation of greater than zero between the rankings of each road segment's surface distress rating and pavement serviceability rating.

Null Hypothesis 2: There is a correlation of zero between the rankings of each road segment's surface distress rating and pavement serviceability rating.

Hypothesis 3--Relationship Between Surface Distress Rating and Traffic/Age Rating

Conceptual Hypothesis 3: There is a relationship between each road segment's surface distress rating and traffic/age rating.

Operational Hypothesis 3: There is a correlation of greater than zero between the rankings of each road segment's surface distress rating and traffic/age rating.

Null Hypothesis 3: There is a correlation of zero between the rankings of each road segment's surface distress rating and traffic/age rating.

Hypothesis 4--Relationship Between Roughness Rating and Pavement Serviceability Rating

Conceptual Hypothesis 4: There is a relationship between each road segment's roughness rating and pavement serviceability rating.

Operational Hypothesis 4: There is a correlation of greater than zero between the rankings of each road segment's roughness rating and pavement serviceability rating.

Null Hypothesis 4: There is a correlation of zero between the rankings of each road segment's roughness rating and pavement serviceability rating.

Hypothesis 5--Relationship Between Roughness Rating and Traffic/Age Rating

Conceptual Hypothesis 5: There is a relationship between each road segment's roughness rating and traffic/age rating.

Operational Hypothesis 5: There is a correlation of greater that zero between the rankings of each road segment's roughness rating and traffic/age rating.

Null Hypothesis 5: There is a correlation of zero between the rankings of each road segment's roughness rating and traffic/age rating.

Hypothesis 6--Relationship Between Pavement Serviceability Rating and Traffic/Age Rating

Conceptual Hypothesis 6: There is a relationship between each road segment's pavement serviceability rating and traffic/age rating.

Operational Hypothesis 6: There is a correlation of greater that zero between the rankings of each road segment's pavement serviceability rating and traffic/age rating.

Null Hypothesis 6: There is a correlation of zero between the rankings of each road segment's pavement serviceability rating and traffic/age rating.

Testing the Null Hypotheses

The strategies for the rankings for the priority improvement projects for the four ratings were compared. The samples are in ordinal data format. A nonparametric test statistic for ordinal data was used. According to Kerlinger (1986), a nonparametric test "depends on no assumptions as to the form of the sample population or the values of the population parameters" (p. 266).

The Spearman rho (ρ) was used to operationalize the relationship for each hypothesis. The Spearman rho (ρ) test statistic for ordinal data was used to determine if there is a correlation between the rankings. The alpha level, the probability of a Type I error, was set at .05.

Each road segment's rating was built into a data file. The file was downloaded onto Western Michigan University's VAX computer. The Statistical Package for the Social Sciences (SPSS) release 4.1 software for VAX/VMS was used for the analysis. By default, the NONPAR CORR command in SPSS computes two rank-order Spearman coefficients and provides the one-tailed significance level (SPSS, Inc., 1990). The significance level or exact probability was determined from the inferential test. The built-in defaults were used.

Summary

Information concerning development of the surface distresses, roughness, pavement serviceability, and traffic/age rating systems have been provided in detail in this chapter. The four ranking strategies were analyzed using SPSS on Western Michigan University's VAX system to test their relationships with each other.

Chapter IV contains the results of the hypothesis testing. Specifically included in Chapter IV are road segment characteristics and the findings pertinent to each hypothesis.

Provided in Chapter V are a summary of research problem, method, and findings; the conclusions drawn from the project; and the project's implications.

CHAPTER IV

FINDINGS

Introduction

Strategies for the ranking of projects can be based on a rating that reflects the physical condition of the pavement, a rating that reflects the pavement roughness, a rating that incorporates the combination of physical condition of the pavement and the pavement roughness, or a rating that takes into account the pavement's age and amount of traffic. It can be expensive to collect the data required to rate and rank the road segments. Is it possible that one type of data (whether based on surface distress, or pavement roughness, or the combination of road pavement's surface and pavement roughness, or the amount of traffic and the pavement's age) yield the same ranking order as another? Because if the ranking order does not change, considerable sums of money could be saved on the collection process and reallocated to a more worthwhile expenditure.

The research hypothesis for the study can be stated as follows. Is there a relationship between the ranking of each road segment based on that segment's:

1. surface distress rating and roughness rating?
2. surface distress rating and pavement serviceability rating?
3. surface distress rating and traffic/age rating?
4. roughness rating and pavement serviceability rating?
5. roughness rating and traffic/age rating?
6. pavement serviceability rating and traffic/age rating?

The Spearman rho (ρ) was used to operationalize the relationship for each hypothesis. The Spearman rho (ρ) test statistic for ordinal data determined whether there was a correlation between the rankings. The alpha level was set at .05.

This chapter contains the results of the hypothesis testing. Included in Chapter IV are road segment characteristics and the findings pertinent to each hypothesis.

Road Segment Characteristics

There were 410 Kalamazoo County primary road segments considered for this project. Each segment was rated and assigned a value between 0 and 10 for each of the four different approaches. The four rating approaches are (1) surface distress on a scale from 0 to 10, (2) roughness on a scale from 0 to 10, (3) pavement serviceability on a scale from 0 to 10, and (4) traffic/age rating systems on a scale from 0 to 10. The minimum, maximum, and mean value determined for each rating system for the 410 road segments are found in Table 1. Road segments rated 7.00 and less are at the point that surface distresses are considered to be significant (Pavement Management Systems, 1991). Hartgen (1984) noted that a roadway rated in the 5.00 to 7.00 range requires considerable attention by maintenance operations.

Since the focus of this project is the allocation of limited funds on road improvement projects, only the worst one-third of the road segments as determined by each ranking strategy were included for evaluation. To compare the ranking by the four rating procedures of all segments does not provide useful information, from a practical point of view. The comparison of the ranking of the worst one-third segments, which would be required for the 5-year plan, will be more worthwhile. It will offer the opportunity to test the correlation of just the most important portion of the project rankings. The ranking of the better two-thirds road segments is not of any importance if the worse one-third are not improved first.

Table 1

Minimum, Maximum, and Mean Values for Rating Systems for All Road Segments

Rating system	Segments	Minimum	Maximum	Mean
Surface distress	410	1.94	10.00	7.84
Roughness	410	3.75	9.27	6.96
Pavement serviceability	410	3.54	9.50	7.40
Traffic/age	410	0.19	9.39	6.23

Each segment was rated by each of the four rating procedures. Then the segments were ranked (sorted) from worst to best. All road segments which were ranked in the worst third by any of the four ranking procedures were retained for analysis. Through this process 188 segments were eliminated from further study. The remaining 222 road segments ranked in the worst third of all road segments by at least one rating system. See Table 2 for the range and average value for the worst third of the road segments as determined for each rating system. As expected, the values in Table 2 are worse than Table 1, documenting the road segments' tremendous needs.

Table 2

Minimum, Maximum, and Mean Values for Rating Systems for Worst Third Road Segments

Rating system	Segments	Minimum	Maximum	Mean
Surface distress	222	1.94	10.00	6.88
Roughness	222	3.75	9.00	6.27
Pavement serviceability	222	3.54	8.54	6.58
Traffic/age	222	0.19	8.90	5.04

Description of Findings Pertinent to Each Hypothesis

Hypothesis 1--Relationship Between Surface Distress Rating and Roughness Rating

Conceptual Hypothesis 1: There is a relationship between each road segment's surface distress rating and roughness rating.

Operational Hypothesis 1: There is a correlation of greater than zero between the rankings of each road segment's surface distress rating and roughness rating.

Null Hypothesis 1: There is a correlation of zero between the rankings of each road segment's surface distress rating and roughness rating.

Table 3 shows that the Spearman rho (ρ) statistical analysis determined that the correlation between the rankings is 0.06. The exact probability for this test is .20 which is greater than the selected alpha level of .05. There is no support for the correlation between the rankings of each road segment's surface distress rating and roughness rating being greater than zero.

Table 3

Spearman Correlation Coefficients and Exact Probability for Ranking of Road Improvement Projects for Worst 222 Road Segments

Rating system	Roughness	Pavement serviceability	Traffic/age
Surface Distress	0.06 ($p = .20$)	0.87* ($p = .00$)	-0.06 ($p = .19$)
Roughness		0.51* ($p = .00$)	0.28* ($p = .00$)
Pavement serviceability			0.09 ($p = .08$)

* $p < .05$.

<u>Hypothesis 2--Relationship Between Surface Distress Rating and Pavement Serviceability Rating</u>

Conceptual Hypothesis 2: There is a relationship between each road segment's surface distress rating and pavement serviceability rating.

Operational Hypothesis 2: There is a correlation of greater than zero between the rankings of each road segment's surface distress rating and pavement serviceability rating.

Null Hypothesis 2: There is a correlation of zero between the rankings of each road segment's surface distress rating and pavement serviceability rating.

Table 3 shows that the Spearman rho (ρ) statistical analysis determined that the correlation between the rankings is 0.87. It is positive and is greater than 0. Since the exact probability for this test is .00, the null hypothesis is rejected and the hypothesis that the correlation is greater than zero supported.

Hypothesis 3--Relationship Between Surface Distress Rating and Traffic/Age Rating

Conceptual Hypothesis 3: There is a relationship between each road segment's surface distress rating and traffic/age rating.

Operational Hypothesis 3: There is a correlation of greater than zero between the rankings of each road segment's surface distress rating and traffic/age rating.

Null Hypothesis 3: There is a correlation of zero between the rankings of each road segment's surface distress rating and traffic/age rating.

Table 3 shows that the Spearman rho (ρ) statistical analysis determined that the correlation between the rankings is -0.06. It is negative and is less than 0. Consequently, there is no support for the correlation between the rankings of each road segment's surface distress rating and roughness rating being greater than zero.

Hypothesis 4--Relationship Between Roughness Rating and Pavement Serviceability Rating

Conceptual Hypothesis 4: There is a relationship between each road segment's roughness rating and pavement serviceability rating.

Operational Hypothesis 4: There is a correlation of greater than zero between the rankings of each road segment's roughness rating and pavement serviceability rating.

Null Hypothesis 4: There is a correlation of zero between the rankings of each road segment's roughness rating and pavement serviceability rating.

Table 3 shows that the Spearman rho (ρ) statistical analysis determined that the correlation between the rankings is 0.51. It is positive and is more than 0. Since the exact probability for this test is .00, the null hypothesis is rejected and the hypothesis that the correlation is greater than zero is supported.

Hypothesis 5--Relationship Between Roughness Rating and Traffic/Age Rating

Conceptual Hypothesis 5: There is a relationship between each road segment's roughness rating and traffic/age rating.

Operational Hypothesis 5: There is a correlation of greater that zero between the rankings of each road segment's roughness rating and traffic/age rating.

Null Hypothesis 5: There is a correlation of zero between the rankings of each road segment's roughness rating and traffic/age rating.

Table 3 shows that the Spearman rho (ρ) statistical analysis determined a correlation between the rankings is 0.28. It is positive and is more than 0. Since the exact probability for this test is .00, the null hypothesis is rejected and the hypothesis that the correlation is greater than zero is supported.

Hypothesis 6--Relationship Between Pavement Serviceability Rating and Traffic/Age Rating

Conceptual Hypothesis 6: There is a relationship between each road segment's pavement serviceability rating and traffic/age rating.

Operational Hypothesis 6: There is a correlation of greater than zero between the rankings of each road segment's pavement serviceability rating and traffic/age rating.

Null Hypothesis 6: There is a correlation of zero between the rankings of each road segment's pavement serviceability rating and traffic/age rating.

Table 3 shows that the Spearman rho (ρ) statistical analysis determined that the correlation between the rankings is 0.09. The exact probability for this test was .08 which is greater than the selected alpha level of .05. There is no support for the correlation between the rankings of each road segment's surface distress rating and roughness rating being greater than zero.

Summary

Provided in this chapter are the compared results of the relationship of the selected strategies for allocating funds to improve county roads. The four strategies were based on the following rating approaches: (1) surface distress, (2) roughness, (3) pavement serviceability, and (4) traffic/age rating systems.

The comparison of the rankings using the Spearman rho (ρ) rank correlation coefficient is found in Table 3. All but one of the correlation coefficients are positive. However, only three of the six comparisons are statistically significant.

It was found that there is a relationship between the strategy of the ranking of each road segment based on that segment's surface distress rating and pavement serviceability rating; the ranking of each road segment based on that segment's roughness rating and pavement serviceability rating; and the ranking of each road segment based on that segment's roughness rating and traffic/age rating.

Based on the data and analysis no conclusions could be drawn between the ranking of each road segment based on that segment's surface distress rating and roughness rating, the ranking of each road segment based on that segment's surface distress rating and traffic/age rating, or the ranking of each road segment based on that segment's pavement serviceability rating and traffic/age rating.

Chapter V provides a summary of research problem, method, and findings; the conclusions drawn from the project; and the project's implications.

CHAPTER V

SUMMARY AND DISCUSSION

Summary of Research Problem, Method, and Findings

Summary of Research Problem

The county road manager is faced with choices in determining the allocation of limited road improvement funds. To assist in determining priorities for the rational expenditure of public funds for the various road improvement projects, it is necessary to use a strategy that employs technical factors to assist in the ranking of the projects to aid in project selection. This ranking procedure employs a pavement management system.

The ranking of projects can be based on a rating that reflects the physical condition of the pavement, a rating that reflects the pavement roughness, a rating that incorporates the combination of physical condition of the pavement and the pavement roughness, or a rating that takes into account the pavement's age and amount of traffic. It can be expensive to collect the data required to rate and rank the road segments. Is it possible that one type of data (whether based on surface distress, or pavement roughness, or the combination of road pavement's surface and pavement roughness, or the amount of traffic and the pavement's age) yields the same ranking order as another. Because if the ranking order does not change, considerable sums of money could be saved on the collection process and reallocated to a more worthwhile expenditure.

The research hypotheses for the study can be stated as follows. Is there a relationship between the ranking of each road segment based on that segment's:

1. surface distress rating and roughness rating?
2. surface distress rating and pavement serviceability rating?
3. surface distress rating and traffic/age rating?
4. roughness rating and pavement serviceability rating?
5. roughness rating and traffic/age rating?
6. pavement serviceability rating and traffic/age rating?

Summary of Research Method

Each road segment was rated on its surface distresses, roughness, pavement serviceability, and traffic/age. For each rating factor, the road segments were placed in order, from worst to best, to determine which roads should be repaired first.

Only the worst one-third of the road segments as determined by each ranking strategy were included for evaluation. The worst one-third segments would constitute the necessary information to develop a 5-year road improvement priority plan. This approach offers the opportunity to test the correlation of just the most important portion of the project rankings.

The segments are in ordinal data format. The Spearman rho (ρ), a nonparametric test statistic for ordinal data, was used to determine if there is a correlation between the rankings. To test the null hypotheses the alpha level was set at .05.

Summary of Research Findings

A relationship was found between the ranking of each road segment based on that segment's surface distress rating and pavement serviceability rating, the ranking of each road segment based on that segment's roughness rating and pavement serviceability rating, and the ranking of each road segment based on that segment's roughness rating and traffic/age rating.

Based on the data and analysis, no conclusions could be drawn between the ranking of each road segment based on that segment's surface distress rating and roughness rating, the ranking of each road segment based on that segment's surface distress rating and traffic/age rating, or the ranking of each road segment based on that segment's pavement serviceability rating and traffic/age rating.

Conclusions

The pavement's level of surface distress and the pavement's roughness are the two most frequently mentioned rating factors required for allocating road improvement funds for road projects (American Association of State Highway and Transportation Officials, 1990a; Elton & Juang, 1988; Hartgen, 1984; Karan, Christison, Cheetham, & Berdahl, 1983; Kulkarni, 1984a; Majidzadeh et al., 1982; Manubay et al., 1985; Martin, 1988; Maser et al., 1988; McHattie & Connor, 1983; Mercier & Stoner, 1988; Pedigo & Hudson, 1982; Shufon & Hartgen, 1982; Theberge, 1988; Turner et al., 1986; Van Gurp et al., 1984; D. M. Walker & Thiede, 1987; Way et al., 1982). Fernando and Hudson (1983) noted that an overall pavement rating is the combination of the surface distress and the pavement roughness factors.

With two major rating factors for selecting projects, does it make a difference if only one factor is used in the ranking of projects, and if so, what is the difference? And how does the ranking of road improvement projects based on the combination of the surface distress and the pavement roughness (i.e., pavement serviceability) compare to each rating factor separately? Or is there another approach that could be made in the office, such as ranking improvement projects using pavement age and traffic volume, which will yield the same results?

It is important that a rational basis be developed for the allocation of funds for improving roads. A pavement management system offers that rational approach. However, with inadequate funding, it is important that a cost-effective process of ranking road improvement projects be employed. The ranking approaches considered for this project were based on surface distress, roughness, pavement serviceability, and traffic/age ratings.

The research undertaken for this project showed that the strategies for the ranking of road improvement projects based on surface distress rating factors and roughness rating factors, surface distress rating factors and traffic/age rating factors, or pavement serviceability rating factors and traffic/age rating factors do not appear to be correlated. This means that it appears that the rankings would not yield the same results. A different priority for road improvement projects would result from each of the rankings and therefore a difference exists.

A relationship was found between the ranking of each road segment based on that segment's surface distress rating with pavement serviceability rating, and the ranking of each road segment based on that segment's roughness rating with pavement serviceability rating. The pavement serviceability rating was derived from an average of the pavement condition and pavement roughness ratings. It was therefore expected that a very high level of correlation would be found between the order of projects ranked for improvements by the surface distress rating and pavement serviceability rating systems, and between the order projects ranked for improvements by the roughness rating and pavement serviceability rating systems.

The comparison for the ranking of road projects to the traffic/age rating strategy yielded interesting results. The ranking of road projects based on traffic/age rating factors appeared to show that there was no correlation to the ranking of road projects by surface distress rating factors. And, although the ranking of road projects based on traffic/age rating factors also appeared to show no correlation to the ranking of road projects by pavement serviceability rating factors, the significance of the correlation was .08.

However, very interestingly, the strategy of the ranking of road projects based on traffic/age rating factors showed significant although low positive correlation to the ranking of road projects by roughness rating factors. Pavement deterioration is a function of pavement age and traffic. This is supported by Kulkarni's (1984b) research when he reported that traffic causes pavement surface distresses such as fatigue cracking and pavement roughness. In addition, Carmichael and O'Grady (1983) noted that a "substantial amount of pavement damage can be related to traffic" (p. 41). The older the road and the higher the volume of traffic, the sooner the pavement will need to be overlayed or the road will need to be reconstructed.

Implications

The understanding of fundamental engineering principles is critical in order to be able to explain the improvement strategy project to the public in terms that are understandable. But, before issues can be discussed, the leader must understand and appreciate the technical issues and their impact on decision making. In addition, individuals placed in leadership roles often manage individuals whose jobs are technical in nature. A good leader must be familiar with and understand the technical issues.

The results of this study provide a county road manager an opportunity for a better understanding of the allocation of limited public funds. The allocation of funds for road improvements is an important part of the county road manager's responsibility. The results of this study suggest that the elimination of certain data does change the rank of road improvement priorities. The additional expense to collect data is warranted depending on the organization's goals, objectives, and policies.

Baladi and Snyder (1990) noted that a prioritization of road improvement projects must be based on "an established priority concept/procedure that is compatible with the goals, objectives, and policy" (p. 17-63) of the road authority. This research suggests that if the goals, objectives, and policy of the road authority for road improvement projects were to stress surface distress rating factors instead of roughness rating factors, or to stress surface distress rating factors instead of traffic/age rating factors, or to stress pavement serviceability rating factors instead of traffic/age rating factors, the goals, objectives, and policy would be met.

Since no conclusion could be drawn between the strategy of ranking each road segment based on that segment's surface distress rating and roughness rating, it cannot be concluded that the one rating is a suitable substitute for the other. The collection of both surface distress rating and roughness rating appears not to be a duplication of ratings. Since economies of scale would be achieved by evaluating road segments simultaneously for both factors, it would appear to be worthy of the nominal additional expense to collect both surface distress and roughness data.

The strategy of selecting road projects based on traffic/age rating factors offers an inexpensive and quick way to determine the order for road project improvement. The research documented a significant although low positive correlation of .28 between ranking of projects using traffic/age rating factors and roughness rating data. The ranking of road projects based on traffic/age rating factors may offer an easy and simple way to compare the results determined by another approach.

Surfacing distress ratings offers a more objective approach to project selection. The pavement serviceability rating factors incorporate the objective findings with subjective considerations. The combination of these two ratings is commonly used throughout Michigan and the United States for road improvement project selection.

Final Comments

Each of the technical factors is important for rating pavements (Baladi & Snyder, 1990) and the conclusion that the order of improvement projects is different for most of the strategies leads the researcher to state that there is value in developing a composite factoring approach to rank road improvement projects. This composite or weighted ranking approach is in use throughout the industry.

There are additional opportunities. It is recommended that further research be undertaken to improve upon the traffic/age rating factor. Potential changes to the formula include a different weighting approach among factors; the use of additional factors, for example, type of base, construction material, or its all-season status; a rating of traffic volume based on light, moderate, or heavy; and urban versus rural traffic.

This has been a worthwhile and personally rewarding unique research project. This project tested several rational approaches to determine if there was a difference for the selection of road improvement projects. These rational approaches are generally accepted as the appropriate approach to prioritize improvement projects. The opportunity to study the relationships was appreciated by the investigator.

APPENDICES

Appendix A

Glossary of Terms

Glossary of Terms

Alligator Cracking: Alligator or fatigue cracking is a series of interconnection cracks caused by fatigue failure of the asphalt concrete cement under repeated traffic loading. Cracking begins at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The small pieces are generally ranging in size from one inch to approximately six inches. Alligator cracking occurs only in areas subjected to repeated traffic loading, such as wheel paths and very often also due to inadequate base or subgrade support. Therefore, it would not occur over an entire area unless the entire area were subjected to traffic loading. Alligator cracking is considered a major structural distress and is usually accompanied by rutting. Repair by excavating localized areas and replacing base and surface. Large areas require reconstruction. Improvements in drainage may often be required.

Alternatives: The various choices of treatments available for providing a solution to a pavement deficiency or problem.

Asphalt cement: Asphalt is a dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing. Asphalt cement or AC is a fluxed or unfluxed asphalt specially prepared as to quality and consistency for direct use in the manufacture of bituminous or flexible pavements.

Block cracking: Block cracking are interconnected cracks that divide the pavement into approximately rectangular pieces. Cracks usually intersect at nearly right angles. The blocks may range in size from approximately 1 by 1 ft. to 10 by 10 ft. Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling (which results in daily stress/strain cycling) and therefore indicating advanced age. It is not load-associated. Block cracking usually indicate that the asphalt has hardened significantly. Block cracking normally occurs over a large proportion of pavement area, but sometimes will occur only in nontraffic areas. This type of distress differs from alligator cracking in the alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike blocks, alligator cracks are caused by repeated traffic loadings, and are therefore found only in traffic areas (i.e., wheel paths). Repair with sealcoating during early stages to reduce weathering of the asphalt. Overlay or reconstruction required in the advanced stages.

Distortion: Shoving or rippling is surface material displaced crossways to the direction of traffic. It can develop into washboarding when the asphalt mixture is unstable because of poor quality aggregate or improper mix design. Repair by milling pavement smooth and overlaying with stable asphalt mix. Other pavement distortions may be caused by settling, frost heave, etc. Patching may provide temporary repair. Permanent correction usually involves removal of unsuitable subgrade material and reconstruction.

Flushing: The presence of excess asphalt cement on the pavement surface. Repair by blotting with sand or by overlaying with properly designed asphalt mix.

Joint reflection cracking (from longitudinal and transverse portland cement concrete slabs): The distress occurs only on asphalt-surfaced pavements which have been laid over a portland cement concrete slab. It does not include reflection cracks from any other type of base (i.e., cement- or lime-stabilized); such cracks are mainly caused by thermal- or moisture-induced movement of the portland cement concrete slab beneath the asphalt cement surface. This distress is not load-related; however, traffic loading may cause a breakdown of the asphalt cement surface near the crack. If the pavement is fragmented along a crack, the crack is said to be spalled. A knowledge of slab dimensions beneath the asphalt cement surface will help to identify these distresses.

Longitudinal cracking: Longitudinal cracks are parallel to the pavement's centerline or laydown direction. They may be caused by:

1. A poorly constructed paving lane joint.

2. Shrinkage of the asphalt cement surface due to low temperatures or hardening of the asphalt and/or daily temperature cycling.

3. A reflective crack caused by cracking beneath the surface course, including cracks in portland cement concrete slabs (but not portland cement concrete joints).

Longitudinal cracking in the wheelpaths indicates fatigue failure from heavy vehicle loading. Longitudinal cracks with one foot of the edge are caused by insufficient shoulder support, poor drainage, frost action. Cracks usually start as hairline or very narrow and widen and erode with age. Without crack filling they can ravel, develop multiple cracks and become wide enough to require patching. Filling and sealing longitudinal cracks will reduce moisture penetration and prevent further subgrade weakening. Multiple longitudinal cracks in the wheel path or pavement edge indicate a need for strengthening with an overlay or reconstruction.

Network level: The level at which key administrative decisions that affect programs for road networks or systems are made. Sometime referred to as the program level.

Network level analysis: Evaluation of pavement to enable the selection of candidate projects, project scheduling, and budget estimates.

Nondestructive Deflection Testing: Also known as NDT involves the application of a surface load onto the pavement structure with the simultaneous measurement of resulting surface deflections. The measured surface deflections can be inputs for a complete structural evaluation of the pavement.

Patching and utility cut patching: A patch is an area of pavement which has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress. Patches with cracking, settlement or distortions indicate underlying causes still remain. Recycling or reconstruction are required when extensive patching shows distress.

Pavement condition: A quantitative representation of distress in pavement at a given point in time.

Pavement distress: The physical manifestations of defects in a pavement.

Pavement maintenance: All routine actions, both responsive and preventative, which are taken to preserve the pavement structure, including joints, drainage, surface, and shoulders as necessary for its safe and efficient utilization.

Pavement structural capacity: The maximum accumulated traffic loads that a pavement can withstand without incurring unacceptable distress.

Performance: Ability of a pavement to fulfill its purpose over time.

Physical distress: Physical distress is a measure of the road surface deterioration caused by traffic, environment and aging.

Polishing: A smooth slippery surface caused by traffic polishing off sharp edges of aggregates. Repair with sealcoat or thin bituminous overlay.

Portland cement concrete: Also known as PCC consists of four major components: portland cement, aggregates, water, and air. Portland cement derives its name from the Isle of Portland, off the southern coast of England where a natural stone was quarried which had the same appearance as the rock used in the cement patented in 1824. Currently, portland cement is the product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates with calcium sulfates added specially prepared as to quality and consistency for direct use in the manufacture of concrete or rigid pavements.

Potholes: Holes and loss of pavement material caused by traffic loading, fatigue and inadequate strength. Often combined with poor drainage. Potholes are small (usually less than 3 ft. in diameter), bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free moisture collection inside the hole. Potholes are produced when traffic abrades small pieces of the pavement surface. The pavement then continues to disintegrate because of poor surface mixtures, weak spots in the base or subgrade, or because it has reached a condition of high-severity alligator cracking. Potholes are generally structurally related distresses and should not be confused with ravelling. Repair by excavating or rebuilding localized potholes. Reconstruction required for extensive defects.

Present serviceability: The current condition of a pavement (traveled surface) as perceived by the general public.

Project level: The level at which technical management decisions are made for specific projects or pavement segments.

Project level analysis: Evaluation of pavement to select the type and timing of rehabilitation or maintenance.

Ravelling: Progressive loss of pavement material from the surface downward caused by: stripping of the bituminous film from the aggregate (sometimes known as weathering); asphalt hardening due to aging; poor compaction, especially in cold weather construction; or insufficient asphalt content. Slight to moderate ravelling has loss of fines, severe ravelling has loss of course aggregate. Ravelling in the wheel paths can be accelerated by traffic. Repair the dry weathered surface with a sealcoat, or a thin overlay if additional strength is required.

Reconstruction: Construction of the equivalent of a new pavement structure which usually involves complete removal and replacement of the existing pavement structure including new and/or recycled materials.

Reflective cracking: Cracks in overlays reflecting the crack pattern in the pavement underneath. Difficult to prevent and correct. Thick overlays or reconstruction is usually required.

Rehabilitation: Resurfacing, restoration, and rehabilitation (3R) work undertaken to restore serviceability and to extend the service life of an existing facility. This may include partial recycling of the existing pavement, placement of additional surface materials or other work necessary to return an existing pavement, including shoulders, to a condition or structural or functional adequacy.

Ride quality: Based on the principle that the prime function of a pavement is to serve the traveling public. In turn, ride quality was used as a measure of how well pavements could serve the public.

Roughometer: A road meter that measures the unidirectional vertical movement of damped, leaf-sprung wheel relative to the road meter's trailer frame during travel to yield a measure of roughness.

Rutting: A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but, in many instances, ruts are noticeable only after a rainfall when the paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrades, usually by consolidated or lateral movement of the materials due to traffic load. Significant rutting can lead to major structural failure on the pavement. Repair minor rutting with overlays. Severe rutting requires milling the old surface or roadbed reconstruction before resurfacing.

Serviceability: The ability of a specific section of pavement to serve traffic in its existing condition.

Slippage cracking: Slippage cracks are crescent or half-moon shaped cracks. They are produced when braking or turning wheels cause the pavement surface to slide or deform. This distress usually occurs when there is a low-strength surface mix or a poor bond between the surface and the next layer of the pavement structure. Repair by removing the top surface and resurfacing using a tack coat.

Transverse cracking: Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. Often regularly spaced. Transverse cracks are not usually load-associated. These may be caused by:

1. Shrinkage of the asphalt cement surface due to aging or hardening of the asphalt and/or daily temperature cycling.

2. A reflective crack caused by cracking beneath the surface course, including cracks in portland cement concrete slabs (but not portland cement concrete joints).

Transverse cracking will initially be widely spaced (over 50'). Additional cracking will occur with aging until they are closely spaced (within several feet). These usually begin as hairline or very narrow cracks; with time they widen. If not properly sealed and maintained, secondary or multiple crack develop parallel to the initial crack. The crack edges can further deteriorate by ravelling and eroding the adjacent pavement. Prevent water intrusion and damage by sealing cracks which are more than 1/4 inch wide.

Appendix B

Kalamazoo County Road Commission Summary of Primary Roads
by Classification, Surface Type, and Length in Miles

Kalamazoo County Road Commission Summary of Primary Roads
by Classification, Surface Type, and Length in Miles

Surface Type: / Classification:	Urban 2 lanes	Urban 3 lanes	Urban 4 lanes	Urban 5 lanes	Rural 2 lanes	Total
Thin Bituminous Pavement (0.5 to 2.5 inches)					55.00	55.00
Typical Bituminous Pavement (over 2.5 inches)	51.00		3.00		193.00	247.00
Bituminous Pavement over Bituminous Base	17.00	1.00	7.00	8.00	51.00	84.00
Portland Cement Concrete					4.00	4.00
Bituminous Pavement over Portland Cement Concrete	7.00	2.00	6.00	4.00	25.00	44.00
Total Miles	**75.00**	**3.00**	**16.00**	**12.00**	**328.00**	**434.00**

Appendix C

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
038010	E MICHIGAN AVE	END OF PCC	0.24MI E OF 40TH ST	6.84	8.26	7.55	5.81
002010	Y AVE	PORTAGE	24TH ST	5.97	4.51	5.24	7.28
002020	Y AVE	24TH	27TH	5.47	3.26	4.37	1.62
002030	27TH ST & YZ AVE	Y AVE	28TH ST	6.67	5.96	6.32	1.87
002040	YZ AVE	28TH	32ND ST	6.26	4.34	5.30	1.90
004010	Y AVE	42ND ST	48TH ST	5.74	6.27	6.01	4.88
005010	W AVE	VANKAL AVE	2ND ST	5.91	5.60	5.76	5.58
005020	W AVE	2ND ST	4TH ST	6.20	6.47	6.34	5.47
005030	W AVE	4TH ST	8TH ST	5.58	9.36	7.47	2.87
005040	W AVE	8TH ST	SCHOOLCRAFT TWP LINE	5.31	8.59	6.95	0.58
006010	W AVE	US131	14TH ST	6.06	6.44	6.25	3.68
006020	W AVE	14TH ST	PORTAGE RD	4.44	5.84	5.14	3.67
006030	W AVE	PORTAGE RD	GT RR	5.24	4.78	5.01	3.34
006040	W AVE	GT RR	0.80MI E PORTAGE RD	5.78	7.45	6.62	3.59
006050	W AVE	0.80MI E PORTAGE RD	W VICKSBURG LT	5.25	5.14	5.20	3.59
008020	W AVE	E VICKSBURG LIMITS	31TH ST	5.08	5.87	5.48	5.19
008030	W AVE	31TH ST	36ST	4.58	5.67	5.13	4.59
008040	W AVE	36TH ST	BEGIN FULTON'S 4LANE	6.69	7.04	6.87	2.66
008050	W AVE	BEGIN FULTON'S 4LANE	42 ND ST	8.26	6.35	7.31	7.91
008060	W AVE	42 ND	END FULTON'S 4LANE	7.72	6.21	6.97	8.15
008070	W AVE	END FULTON'S 4LANE	48TH ST	6.32	4.35	5.34	2.41
009020	U AVE	2ND ST	8TH ST	8.79	7.18	7.99	7.93
011010	29TH ST	W AVE	U AVE	6.23	4.46	5.35	4.83
011040	U AVE	32TH ST	34TH ST	7.46	7.03	7.25	8.41
011050	U AVE	34TH ST	36TH ST	7.68	7.27	7.48	8.45

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
012020	TU AVE & 27TH ST	26TH ST	T AVE	6.54	3.88	5.21	2.89
012030	T AVE	27TH ST	29TH ST	6.20	3.74	4.97	3.75
012040	29TH ST	T AVE	S AVE	6.47	4.62	5.55	2.91
014010	S AVE	SPRINKLE RD	26TH ST	5.22	8.68	6.95	1.97
014020	S AVE	26TH ST	27TH ST	5.98	8.91	7.45	2.08
014030	S AVE	27TH ST	29TH ST	5.56	9.05	7.31	2.08
015050	QR AVE	25TH ST	0.75MI E OF 25TH ST	6.49	4.30	5.40	5.64
015060	QR AVE	0.75MI E OF 25TH ST	29TH ST	5.80	4.20	5.00	5.63
016010	R AVE	36TH ST	43RD ST	6.12	3.62	4.87	2.60
016020	R AVE	43RD ST	E COUNTY LINE	6.55	5.39	5.97	2.65
017010	Q AVE	VANKAL AVE	3RD ST	5.43	5.99	5.71	2.96
017020	Q AVE	3RD ST	8TH ST	4.73	5.68	5.21	4.08
018010	Q AVE	8TH ST	0.50MI W OF 12TH ST	6.18	6.32	6.25	6.43
018020	Q AVE	0.50MI W OF 12TH ST	12TH ST	6.64	6.74	6.69	4.68
018030	CENTRE AVE	12TH ST	0.25MI E OF 12TH ST	6.46	9.01	7.74	4.25
018040	CENTRE AVE	0.25 MI E OF 12TH ST	OAKLAND DR	7.41	6.69	7.05	4.00
018050	CENTRE AVE	OAKLAND DR	0.80MI E OF OAKLAND	6.10	6.84	6.47	2.68
018060	CENTRE AVE	0.80MI E OAKLAND DR	SHAVER RD	7.07	8.19	7.63	4.18
018070	CENTRE AVE	SHAVER RD	WESTNEDGE AVE	6.07	8.69	7.38	5.25
018090	CENTRE AVE	CURRIER DR	PORTAGE RD	8.29	7.56	7.93	4.40
018100	CENTRE AVE	PORTAGE RD	SPRINKLE RD	5.93	7.21	6.57	3.05
019020	Q AVE	34TH ST	36TH ST	5.71	4.13	4.92	1.44
021010	P AVE	SPRINKLE RD	E PORTAGE LIMITS	5.13	5.97	5.55	4.59
022020	PQ AVE	36TH ST	38TH ST	6.57	4.55	5.56	2.64
022040	O AVE	38TH ST	1.0MI E OF 38TH ST	9.00	6.91	7.96	2.97

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
022050	O AVE	1.0MI E OF 38TH ST	42ND ST	6.21	4.50	5.36	2.97
026020	34TH ST & MN AVE	N AVE	35TH ST	6.02	8.44	7.23	7.28
026040	MN AVE	36HT ST	38TH ST	6.61	7.11	6.86	6.75
026050	MN AVE	38TH ST	MERCURY DR	7.29	7.14	7.22	6.75
026060	MERCURY DR	MN AVE	E MICHIGAN AVE	6.94	6.68	6.81	7.13
028010	STADIUM DR	VANKAL AVE	0.40MI E OF VANKAL	5.06	5.80	5.43	4.21
028020	STADIUM DR	0.40MI E OF VANKAL	0.40MI E OF 1ST ST	5.38	5.84	5.61	4.10
028030	STADIUM DR	0.40MI E OF IST ST	4TH ST	5.51	5.87	5.69	3.60
028040	STADIUM DR	4TH ST	8TH ST	5.83	6.55	6.19	3.25
029010	STADIUM DR	8TH ST	9TH ST	5.22	7.19	6.21	6.00
029020	STADIUM DR	9TH ST	0.83MI E OF 9TH ST	5.31	7.18	6.25	6.00
029030	STADIUM DR	0.83MI E OF 9TH ST	U S 131	5.13	7.46	6.30	6.00
031010	ML AVE (MILLER RD)	SPRINKLE RD	0.19MI E OF SPRINKLE	6.40	9.32	7.86	5.70
031020	ML AVE (MILLER RD)	0.19MI E OF SPRINKLE	26TH ST	6.88	9.36	8.12	5.70
033010	LAKE ST	E KALAMAZOO CITY LT	BL I-94	4.63	7.45	6.04	3.33
033020	LAKE ST	B L I-94	OLMSTEAD DR	6.11	6.72	6.42	5.58
033040	LAKE ST	0.17MI N OF OLMSTEAD	SPRINKLE RD	7.64	7.41	7.53	6.68
033060	COMSTOCK AVE	0.10MI E OF SPRINKLE	RIVER ST	6.21	7.81	7.01	6.45
034010	E MICHIGAN AVE	E KALAMAZOO CITY LT	0.71 MI E OF CITY LT	6.16	7.61	6.89	6.93
034020	E MICHIGAN AVE	0.71MI E OF CITY LT	1.14 MI E OF CITY LT	7.10	6.74	6.92	6.93
034030	E MICHIGAN AVE	1.14MI E OF CITY LT	E KALAMAZOO TWP LINE	7.10	6.76	6.93	6.93
034040	E MICHIGAN AVE	E KALAMAZOO TWP LIN	0.18MI E OF SPRINKL	7.08	6.97	7.03	6.80
034050	E MICHIGAN AVE	0.18MI E OF SPRINKLE	RIVER ST	7.24	6.76	7.00	6.80
034060	E MICHIGAN AVE	RIVER ST	KING HWY (M-96)	6.59	7.24	6.92	6.80
036010	E MICHIGAN AVE	McCOLLEM	START OF PCC	5.68	6.28	5.98	5.44

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
037010	FORT CUSTER DR	E MICHIGAN AVE	40TH ST	5.34	6.56	5.95	5.60
038020	E MICHIGAN AVE	0.24MI E 40TH ST	0.21 MI E OF 46TH ST	6.20	6.51	6.36	5.78
038030	E MICHIGAN AVE	0.21MI E 46TH ST	MERCURY DR	5.12	4.93	5.03	5.78
041010	HUMPHREY AVE	E KALAMAZOO CTY LT	E MAIN ST	6.70	2.38	4.54	4.90
042010	E MAIN ST	E KALAMAZOO CITY LT	0.12MI W OF NAZARETH	6.34	7.06	6.70	5.75
042020	E MAIN ST	0.12MI W OF NAZARETH	E KALAMAZOO TWP LINE	5.74	6.45	6.10	6.00
042030	E MAIN ST	E KALAMAZOO TWP LINE	SPRINKLE RD	5.65	7.35	6.50	6.00
042040	E MAIN ST	SPRINKLE RD	0.37 MI W OF 26TH ST	7.43	8.45	7.94	6.00
043030	H AVE	10TH	0.35MI E OF 10TH ST	7.30	6.72	7.01	7.20
043040	H AVE	0.35MI E OF 10TH ST	12TH ST	6.59	5.30	5.95	7.20
044010	BARNEY RD	NICHOLS RD	0.25MI E OF NICHOLS	6.35	8.27	7.31	6.26
044020	BARNEY RD	0.25 MI E OF NICHOLS	0.65MI W OF DOUGLAS	5.41	4.97	5.19	6.26
044030	BARNEY RD	0.65MI W OF DOUGLAS	DOUGLAS AVE	6.25	4.16	5.21	6.36
044050	MOSEL AVE	WESTNEDGE AVE	PITCHER ST	5.58	6.45	6.02	4.70
044060	MOSEL AVE	PITCHER ST	0.35MI E OF PITCHER	5.93	7.54	6.74	4.51
044070	MOSEL AVE	0.35MI E OF PITCHER	UPPER RIVERVIEW DR	6.14	10.00	8.07	7.01
045040	G AVE	25TH ST	GULL RD (M-43)	7.05	6.64	6.85	6.84
046020	G AVE	32ND ST	36TH ST	6.19	8.32	7.26	4.21
046030	G AVE	36TH ST	38TH ST	6.15	9.34	7.75	4.36
046040	G AVE	38TH ST	0.1MI W OF M-96	6.91	9.93	8.42	4.50
046050	G AVE	0.1MI W OF M-96	M-96	5.26	8.78	7.02	4.50
047010	FORT CUSTER DR	M-96	48TH ST	6.79	6.67	6.73	2.35
048010	D AVE	W COUNTY LINE	6TH ST	8.03	9.05	8.54	2.80
048040	D AVE	W RAMP US 131	12TH ST	6.00	9.38	7.69	4.63
048050	D AVE	12TH ST	DOUGLAS AVE	5.84	9.35	7.60	4.64

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
048060	D AVE	DOUGLAS AVE	WESTNEDGE AVE	5.43	9.15	7.29	4.83
048070	D AVE	WESTNEDGE AVE	RIVERVIEW DR	6.10	9.37	7.74	4.83
048080	D AVE	RIVERVIEW DR	24TH ST	6.65	7.36	7.01	5.13
048090	24TH ST	D AVE	DE AVE	6.47	7.06	6.77	4.63
049010	DE AVE	24TH ST	26TH ST	6.70	4.61	5.66	5.87
050030	D AVE	28TH ST	W RICHLAND VILLAGE L	7.23	7.05	7.14	7.55
053010	VANKAL AVE	STADIUM DR	0.20MI N /STADIUM DR	5.30	3.34	4.32	6.54
053020	VANKAL AVE	0.20MI N /STADIUM DR	ALMENA DR	5.53	3.69	4.61	6.89
054040	2ND ST	D AVE	B AVE (E)	5.78	3.83	4.81	6.11
054050	2ND ST	B AVE (E)	1ST ST	5.78	3.98	4.88	5.38
054060	1ST ST	AB AVE (W)	N COUNTY LINE	3.75	3.33	3.54	5.46
055010	5TH ST	Q AVE	PQ AVE	5.79	8.32	7.06	2.08
055020	PQ AVE	5TH ST	6TH ST	6.14	6.15	6.15	2.09
055050	6TH ST	0.24MI N OF O AVE	0.47MI S OF N AVE	5.91	7.57	6.74	8.35
059030	O AVE	8TH ST	9TH ST	6.12	5.94	6.03	6.23
059040	9TH ST	O AVE	I-94	5.24	6.26	5.75	3.59
059050	9TH ST	I-94	N AVE	7.23	8.96	8.10	2.46
059060	9TH ST	N AVE	ATLANTIC AVE	7.46	7.45	7.46	3.38
059070	9TH ST	ATLANTIC AVE	STADIUM DR	4.68	7.54	6.11	2.50
059080	9TH ST	STADIUM DR	MERIDIAN AVE	4.90	9.11	7.01	4.32
059090	9TH ST	MERIDIAN AVE	KL AVE	4.62	8.95	6.79	3.24
059100	KL AVE	8TH	9TH	7.80	6.89	7.35	3.20
060010	RAVINE RD	F AVE	D AVE	7.00	7.27	7.14	7.28
060020	RAVINE RD	D AVE	BASELINE	5.67	7.91	6.79	7.35
061010	12TH ST	U AVE	PRAIRIE RONDE TWP LY	5.38	4.90	5.14	6.62

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/AGE
061020	12TH ST	PRAIRIE RONDE TWP LT	0.50MI S OF Q AVE	5.23	3.60	4.42	6.61
061030	12TH ST	0.50MI S OF Q AVE	Q AVE	6.20	6.06	6.13	6.13
061040	12TH ST	Q AVE	MILHAM AVE	8.30	6.37	7.34	6.95
062010	W MICHIGAN AVE	STADIUM DR	11TH ST	4.62	5.61	5.12	5.36
062020	W MICHIGAN AVE	11TH ST	0.35MI W OF 12TH	4.46	4.44	4.45	4.76
062030	W MICHIGAN AVE	0.35MI W OF 12TH	12TH ST	5.00	4.85	4.93	4.76
064020	DRAKE RD (12TH ST)	0.48MI S OF W MAIN	W MAIN ST(M-43)	5.46	7.54	6.50	2.00
065020	12TH ST	F AVE	D AVE	8.19	7.28	7.74	8.07
066010	SHAVER RD	END OF PCC	S PORTAGE CITY LTS	5.83	7.76	6.80	6.83
068010	KENDALL	CITY LIMITS	0.11MI S OF M-43	8.15	6.91	7.53	5.01
068020	KENDALL	0.11MI S OF M-43	M-43	8.15	6.62	7.39	5.34
069010	NICHOLS RD	W MAIN ST(M-43)	ALAMO AVE	6.57	9.37	7.97	5.33
069020	NICHOLS RD	W MAIN ST(M-43)	NICHOLS RD	6.10	8.82	7.46	5.33
069030	NICHOLS RD	ALAMO AVE	RAVINE RD	5.61	7.12	6.37	5.30
069040	NICHOLS RD	RAVINE RD	BARNEY RD	6.43	7.29	6.86	5.49
071030	DOUGLAS AVE	MOSEL AVE	G AVE	7.20	8.91	8.06	5.45
071040	DOUGLAS AVE	G AVE	F AVE	7.96	8.81	8.39	5.90
072010	DOUGLAS AVE	F AVE	D AVE	7.48	8.67	8.08	5.90
072020	DOUGLAS AVE	D AVE	BASELINE	7.40	8.29	7.85	5.88
073030	PORTAGE RD	W AVE	VW AVE	5.43	9.38	7.41	6.49
073040	PORTAGE RD	VW AVE	V AVE	5.86	9.30	7.58	6.49
073050	PORTAGE RD	V AVE	U AVE	6.18	9.03	7.61	6.05
073060	PORTAGE RD	U AVE	T AVE (MANDIGO)	6.03	9.03	7.53	6.05
074010	PORTAGE RD	T AVE (MANDIGO)	OSTERHOUT AVE	5.82	9.03	7.43	4.88
074040	PORTAGE RD	AMES DRIVE	ZYLMAN RD	5.79	8.90	7.35	4.50

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
074060	PORTAGE RD	PLEASANT DR	CENTRE ST	5.82	8.99	7.41	4.50
074070	PORTAGE RD	CENTRE ST	0.20MI N OF CENTRE	5.03	8.74	6.89	5.00
074080	PORTAGE RD	0.20MI N OF CENTRE	0.47MI N OF CENTRE	6.18	8.08	7.13	5.00
074090	PORTAGE RD	0.47MI N OF CENTRE	0.65MI N OF CENTRE	5.21	7.49	6.35	5.00
074100	PORTAGE RD	0.65MI N OF CENTRE	0.78MI N OF CENTRE	5.44	6.88	6.16	5.00
074110	PORTAGE RD	0.78MI N OF CENTRE	BISHOP RD	5.46	7.36	6.41	5.00
074120	PORTAGE RD	BISHOP RD	LANSING AVE	5.34	7.78	6.56	2.25
074130	PORTAGE RD	LANSING AVE	MILHAM AVE	5.26	7.84	6.55	2.25
076010	N. BURDICK ST	KALAMAZOO CITY LT	MOSEL AVE	7.73	7.32	7.53	7.14
081010	24TH ST	Z AVE	Y AVE	5.05	4.50	4.78	8.90
081020	24TH ST	Y AVE	S VICKSBURG VILLAGE	6.84	5.24	6.04	8.31
081030	24TH ST	S VICKSBURG LTS	W AVE	5.61	5.91	5.76	8.56
083020	SPRINKLE RD	CENTRE ST	KILGORE RD	7.57	8.63	8.10	0.75
083040	SPRINKLE RD	0.15MI N OF KILGORE	CORK ST	7.43	9.01	8.22	1.00
083070	SPRINKLE RD	E MAIN ST	H AVE	5.37	7.68	6.53	2.25
083080	SPRINKLE RD	H AVE	GULL RD(M-43)	5.76	8.08	6.92	2.25
083090	SPRINKLE RD	GULL RD(M-43)	G AVE	5.55	8.45	7.00	2.25
085010	OLMSTEAD RD	B L I-94	LAKE ST	7.13	9.08	8.11	4.96
088010	28TH ST	S COUNTY LINE	YZ AVE	5.39	6.06	5.73	7.44
089020	31ST ST	X AVE	W AVE	7.63	7.07	7.35	7.84
090020	29TH ST	Q AVE	0.1MI N OF Q AVE	6.14	6.67	6.41	4.39
090030	29TH ST	0.1MI N OF Q AVE	OP AVE	4.35	7.32	5.84	4.30
090040	29HT ST	OP AVE	O AVE	5.05	6.96	6.01	4.30
090050	29TH ST	O AVE	N AVE	5.29	7.89	6.59	4.23
090060	29TH ST	N AVE	MN AVE	5.42	4.13	4.78	2.21

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
090070	MN AVE	29TH ST	0.2MI E OF 28TH ST	5.78	4.21	5.00	4.99
090080	MN AVE	0.2MI E OF 28TH ST	28TH ST	5.58	5.03	5.31	4.99
090090	28TH ST	MN AVE	ML AVE	6.01	4.47	5.24	5.12
091030	RIVER ST	COMSTOCK AVE	KING HWY(M-96)	5.44	7.58	6.51	0.19
091040	RIVER ST	KING HWY(M-96)	E MICH AVE	5.71	7.68	6.70	3.39
092040	26TH ST	E MAIN ST	H AVE	7.29	5.74	6.52	1.57
093010	28TH ST	GULL RD(M-43)	F AVE	7.06	6.36	6.71	7.76
093020	28TH ST	F AVE	D AVE	6.87	5.84	6.36	7.80
094010	36TH ST	W AVE	T AVE	6.01	8.88	7.45	2.23
094020	36TH ST	T AVE	0.33MI N OF R AVE	6.75	9.02	7.89	2.19
096010	35TH ST	MN AVE	M AVE	6.59	6.99	6.79	1.55
096020	35TH ST	M AVE	ML AVE	6.23	5.28	5.76	1.55
096030	35TH ST	ML AVE	I-94	7.75	9.26	8.51	1.31
101040	38TH ST	L AVE	MILLER DR	6.52	4.44	5.48	7.55
102030	37TH ST	S ROSS TWP LINE	G AVE	7.33	7.09	7.21	7.62
104010	37TH ST	M-89	D AVE	6.03	9.71	7.87	7.19
104020	D AVE	37TH ST (S)	37TH ST (N)	6.05	8.64	7.35	7.15
104040	GULL LAKE DR W	CD AVE	BC AVE	6.32	9.98	8.15	7.75
105010	42ND ST	Z	FULTON S LIMITS	7.80	4.35	6.08	8.00
105020	42ND ST	0.15MI S OF W AVE	W AVE	7.80	4.28	6.04	7.97
105030	42ND ST	W AVE	0.15MI N OF W AVE	8.00	4.32	6.16	8.09
105040	42ND ST	FULTON N LIMITS	N TWP LINE	7.80	3.44	5.62	8.11
105050	42ND ST	N TWP LINE	0.4MI S OF TS	7.50	3.60	5.55	8.11
109010	40TH ST	M-89	BASELINE	6.00	1.94	3.97	1.73
110010	GULL LAKE DR E	C AVE	B AVE	6.17	9.98	8.08	7.85

Data Set of the Worst Third Kalamazoo County Road Commission Roads by Road Segment

SECT NO.	STREET NAME	FROM	TO	RCI	SDI	PSR	TRAFF/ AGE
110020	GULL LAKE DR E	B AVE	0.30MI N OF B AVE	6.29	9.99	8.14	7.70
110030	GULL LAKE DR E	0.30MI N OF B AVE	BASELINE	5.87	9.99	7.93	7.82
112010	AUGUSTA DR	N AUGUSTA LT	E COUNTY LINE	7.98	8.10	8.04	2.80
113010	GRAND PRAIRIE RD	DRAKE RD	NICHOLS RD	6.56	8.24	7.40	3.45
114010	KL AVE	4TH ST	0.45MI E OF 4TH ST	7.00	2.73	4.87	6.98
114020	KL AVE	0.45MI E OF 4TH ST	8TH ST	6.80	4.05	5.43	6.98
115010	KL AVE	9TH	11TH	8.00	6.34	7.17	6.11
115020	KL AVE	11TH	12TH	7.55	5.92	6.74	4.83
116010	10TH ST	M-43	0.50MI S OF H AVE	7.12	7.41	7.27	6.73
116020	10TH ST	0.50MI S OF H AVE	H AVE	7.11	7.36	7.24	7.36
117010	25TH ST	G AVE	F AVE	4.63	6.96	5.80	4.06
117020	25TH ST	F AVE	DE AVE	4.79	6.60	5.70	4.06
118010	H AVE	SPRINKLE RD	26TH ST (S)	5.30	7.28	6.29	3.00
120010	11TH ST	M AVE (PARKVIEW)	STADIUM DR	5.98	9.86	7.92	6.60
120020	11TH ST	STADIUM DR	KL AVE	5.95	7.02	6.49	6.50
121010	NAZARETH RD	E MAIN ST	GULL RD (M-43)	5.95	9.86	7.91	4.34
121020	NAZARETH RD	GULL (M-43)	G AVE	6.45	9.97	8.21	6.42
124010	SOLON ST	KALAMAZOO CITY LT	0.15MI S OF W MAIN	8.48	8.21	8.35	5.38
124020	SOLON ST	0.15MI S OF W MAIN	W MAIN ST (M-43)	7.85	7.03	7.44	5.38
125010	24TH ST	D AVE	C AVE	7.95	9.07	8.51	5.55
125020	24TH ST	C AVE	M-89	5.78	7.69	6.74	5.71
129010	H AVE	GULL (M-43)	SPRINKLE RD	7.30	3.51	5.41	3.33

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