ROADSOFT-GIS, A TRANSPORTATION ASSET MANAGEMENT SOLUTION FOR COUNTIES AND CITIES IN MICHIGAN AND ITS APPLICATION TO AGENCIES IN AFRICA

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Abstract

In 2002, Michigan legislation required state and local transportation agencies to adopt an asset management approach to managing their road networks. The legislation laid the foundation for both state and local roadway managers to break away from the traditional "tactical" approach of concentrating on the immediate and most severe problems—fixing the Worst First. Instead, agencies can move forward to a strategic and system-wide approach—keeping the good roads good by applying the Correct Fix, in the Correct Place, at the Correct Time.

The majority of Michigan's counties and cities have adopted the RoadSoft-GIS Integrated Roadway Management System as their roadway management and data collection tool. The system provides a wide variety of inventory and management modules for road surfaces, signs, crash data, culverts, guardrails, pavement markings and traffic counts. The asset management analysis tools in RoadSoft create deterioration curves for individual road segments, generate maintenance and reconstruction strategies, optimize strategies and budgets, and provide the engineer with a wealth of information for use when communicating with elected officials and the public.

In cooperation with the Mozambique Road Fund and the International Focus Group on Rural Roads, a graduate student from Mozambique is spending 6 months at Michigan Tech University learning the RoadSoft-GIS system. The objective is to evaluate RoadSoft as a roadway management tool that can be implemented within Mozambique's basic constraints. He will also develop the skills that will allow him to provide training and technical assistance throughout the roadway establishment and assist agencies with implementation.

Introduction

Michigan is located in the center of the Upper Midwest Region of the United States. It has a population of just over 10 million in an area of 147,121 Km^2. Michigan has the fourth largest road network in the United States. State and local highways, roads, and streets total 192,000 Km. The distance from the far north-western corner of the Upper Peninsula to the southeast corner of the Lower Peninsula is 1025 Km. The entire state experiences a four season environment, with winter having the most significant impact. Areas in the Upper Peninsula have experienced annual snowfall as high as 10 m and individual storms bringing as much as 1.2 m. Areas in the southwest experience freezing rain storms that coat cars, buildings and roadways with 3 cm of ice. In the summer, temperatures can reach 37^o C.

Road authority is unique in Michigan. The State of Michigan, through the Michigan Department of Transportation (MDOT) is responsible for federal and state routes. Cities and villages are responsible for all the streets within the city or village boundary except the federal and state routes passing through the city. County Road Commissions are responsible for all the remaining county and township roads within the county except the federal and state routes passing through the county.

The road commissions are established through legislation as independent bodies, some elected, some appointed, to manage and operate the transportation system within the counties. They are technically separate from county government. The townships that comprise the counties (10 to 18 per county) do not have any road authority, but are encouraged to work with their county road commission to develop transportation improvement plans.

There are 83 counties and over 500 municipalities (cities and villages) in the state. These "Local" agencies are responsible for more than 141,000 Km (73%) of the total road network, of which approximately 70,000 Km is unpaved. A wide range exists between rural and urban counties. For example: Keweenaw County, located on the Upper Peninsula, has a population of 2200 in an area of 1400 Km^2 and a county road network of 280 Km. Wayne County, located around the City of Detroit, has a population of 2,000,000 in an area of 1590 Km^2 and a county road network of 2500 Km.

Michigan faces the same shortfall in transportation funding that is being experienced worldwide. Fuel taxes (per gallon, paid at the pump) and road millages (applied as local property tax) are inadequate considering the continuous expansion of development in rural areas, increasing traffic load and accelerating deterioration of aging road surfaces. The road commissions do not have taxation authority, therefore county, city, village or township government must place supplemental tax propositions before the voters. Intense scrutiny by public interest groups has prompted agencies to adopt asset management principles as a way to spend revenues in the most effective way possible and then use the analysis from the management system to justify increases in revenue.

Transportation Asset Management in Michigan

In 2002, Public Act 499 was signed into law defining asset management as "an ongoing process of maintaining, upgrading, and operating physical assets cost-effectively, based on a continuous physical inventory and condition assessment" [5]. The act also created a Transportation Asset Management Council (TAMC) [7]. The Council was charged with "advising the commission on a statewide asset management strategy and the processes and necessary tools needed to implement such a strategy beginning with the federal-aid eligible highway system, and once completed, continuing on with the county road and municipal systems, in a cost-effective, efficient manner" [6].

The Council consists of ten representatives, 2 from the County Road Commission Association, 2 from the Michigan Municipal League (cities and villages), 2 from MDOT, 2 from the regional planning and development authorities, 1 from the Township Association, 1 from the County Government Association. The diverse composition of the Council insures that a statewide approach to asset management will serve all the constituents—large and small, urban and rural. The Council developed a series of goals and objectives with the expected outcome being "an asset management process that is easily used and communicated, and leads to a network that is managed by function" [6].

The law also requires that each year, MDOT, every county road commission, and all cities and villages would prepare a multi-year improvement program developed through the use of asset management principles that are consistent with the goals and objectives of the road agency's long-range plan for federal aid eligible streets and roads.

The legislation laid the foundation for roadway managers to break away from the traditional, "tactical" approach of concentrating on the immediate and most severe problems—*Fixing the Worst First*. They can instead adopt a strategic and system wide approach. Keeping the *Good Roads Good* and applying the *Correct Fix, in the Correct Place, at the Correct Time*.

To make the strategic approach a reality, road agencies need current condition data and analysis tools that can generate the required optimization of repair strategies and budgets. There are currently 218 agencies in Michigan using *RoadSoft-GIS* (the Integrated Roadway Management System for Counties, Cities and Villages in Michigan) in some capacity [9]. The *RoadSoft Laptop GPS Data Collector* has been adopted by the TAMC to collect condition data on 44,000 miles of federal aid highway. This collection effort is currently in its fifth year.

The *RoadSoft* Initiative

The development of *RoadSoft* began in 1992, after the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). ISTEA mandated the use of transportation management systems throughout the United States. Although this mandate was later rescinded in 1995, Michigan's local agencies, together with MDOT, realized that management systems were the future of good roadway management practice and that these systems needed to be available to local agencies. The Michigan Local Technical Assistance Program (LTAP) at Michigan Tech University was involved in these early discussions and was asked to identify an appropriate road surface rating system and later to develop prototype software that would satisfy the pavement management needs of Michigan's counties and cities [6]. *RoadSoft* software was introduced in 1993, and since that time, yearly development funding from MDOT has enabled *RoadSoft-GIS* to become a fully featured asset management application and the premier tool for local agencies in Michigan interested in state-of-the-art analysis.

The *RoadSoft* initiative is unique for a variety of reasons, all of which have been critical to the success of the program and its implementation by local agencies.

a) Software design, functionality and development is driven by county and city users (the *RoadSoft* Users Group) and civil engineers on the development staff, not by software engineers or application programmers.
b) Development, support and training are completely handled by the Technology Development Group (TDG) and the Michigan LTAP. Both are units of Michigan Technological University, hence not-for-profit organizations.
c) The software, GIS base map, and agency crash data are provided to all local agencies at no cost. Distribution includes all necessary run-time licenses. The agency simply supplies the computer.
d) The PASER condition rating system is time efficient, cost effective, explainable to non-professionals, and most of all, thoroughly adequate for network level analysis.

Pavement Surface Evaluation and Rating System (PASER). Local agencies using *RoadSoft-GIS* collect road surface condition data using the Pavement Surface Evaluation and Rating (PASER) methodology. [See Figure 1] PASER is a visual assessment system that rates the road surface on a scale of 1-10. Where 10 is new construction and 1 is totally failed. This system was formalized by the Transportation Information Center (Wisconsin LTAP) at the University of Wisconsin [1]. PASER condition ratings are based on the data collector's assessment of visible distress, its severity and extent, and needed maintenance or reconstruction. PASER rating manuals include extensive pictures and descriptions that guide the data collector through the rating process. The system is easily understood by engineers, technicians and support staff alike, and can be explained by local agency staff to elected officials and constituents. PASER is being used for the fifth year in the Transportation Asset Management data collection that is underway on 71,000 Km of federal aid paved streets and highways throughout Michigan.

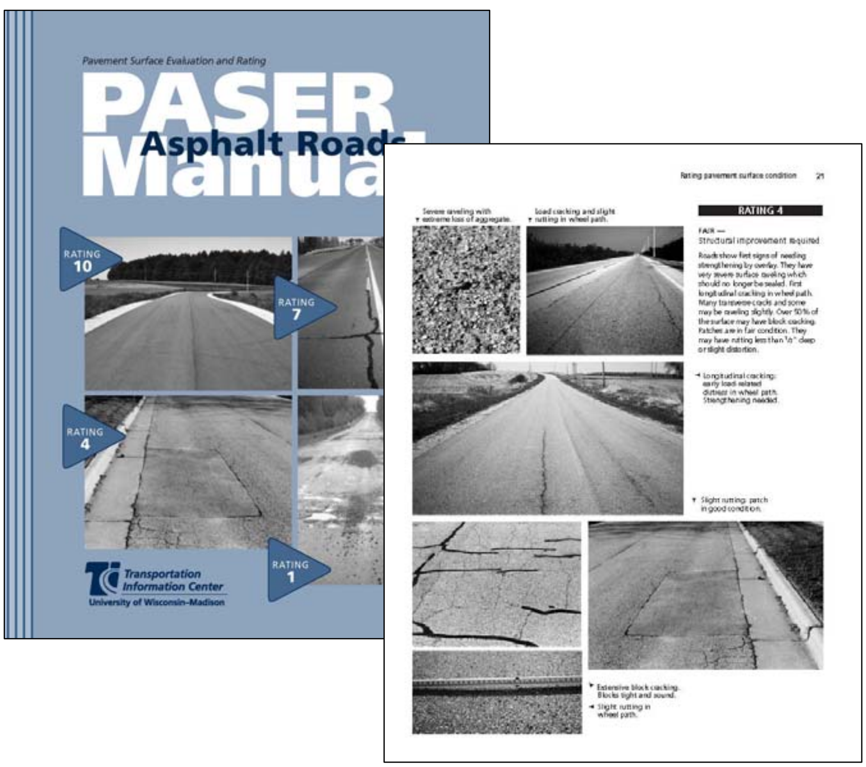

Figure 1. PASER Asphalt Manual

The PASER methodology is time efficient and cost effective, making it particularly useful for counties and cities with limited resources. Data collection is conducted by the engineering and non-engineering staff of counties and cities, regional planning organizations and state departments of transportation—not by highly paid consultants. These attributes make it a system especially attractive for use by developing countries.

Quality Control of Collected PASER Data. In 2004, 2005, and 2006, TAMC conducted a quality control (QC) review on 1% of the road miles from which data was collected. In 2006 the TAMC sponsored a study to develop a more rigorous and statistically sound QC process [3]. The QC monitoring plan recommended in that study uses a different methodology for selecting QC segments than the method used in previous years. The proposed monitoring plan focuses on absolute sample size and the number of decision events, and selects random, disassociated segments, rather than randomly selecting routes comprised of multiple contiguous and similar segments.

The proposed monitoring plan consists of approximately 250 road segments in each of the 14 planning regions, for a total of 3500 road segments throughout the State. Because of the random, disassociated selection, this plan may yield as many as 5 times the decision events as the previous method. The selected road segments will be distributed among all 83 counties.

The proposed sampling plan will be sufficient to analyze agreement on a statewide and regional level and will be adequate to identify changes of 10% or more in rating agreement and to detect systematic disagreement among the rating data. Agreement among the rating data is used as a proxy to determine whether the TAMC regional teams are implementing the process in a complete and appropriate manner. The above assumes that the data collected by the QC team is truth—the so-called "gold standard" by which other ratings are compared.

The *RoadSoft GIS* System

The *RoadSoft GIS* system is comprised of a variety of roadway inventory, management, and analysis modules accessed through a geographic information system (GIS) interface and a "Road Traveler" interface.

RoadSoft-GIS modules include:

Roadway Inventory & Management	Sign Inventory & Management
Culvert Inventory & Management	Safety Management (Crash Data)
Guardrail Inventory	Pavement Marking Inventory (linear & point)
Traffic Counts	Road Network Builder

Standardized reports are fully integrated across the various modules. Data mining tools allow for unlimited creativity in analysis and generating persuasive management presentation materials. All user collected data, as well as the GIS base map, can be exported in standard GIS format for use in other GIS software.

GPS Laptop Data Collection System (LDC). Data collection in the field is simplified through the LDC. This system uses a GIS and database export from the version of *RoadSoft-GIS* in the engineer's office and a low cost GPS device to allow real time data collection while driving down the road. Collected data is simply imported back into the agency's version of *RoadSoft-GIS*.

Map Reference Generation System (MRGenS). The newly implemented MRGenS was designed specifically for agencies outside of Michigan. It enables an agency with or without a referenced GIS base map or linear referencing system to create the necessary files needed by *RoadSoft-GIS*. This process can use a variety of existing GIS line maps or digital ortho photos to establish the base map reference. This map data is then combined with user-defined roadway attributes [See Figure 2].

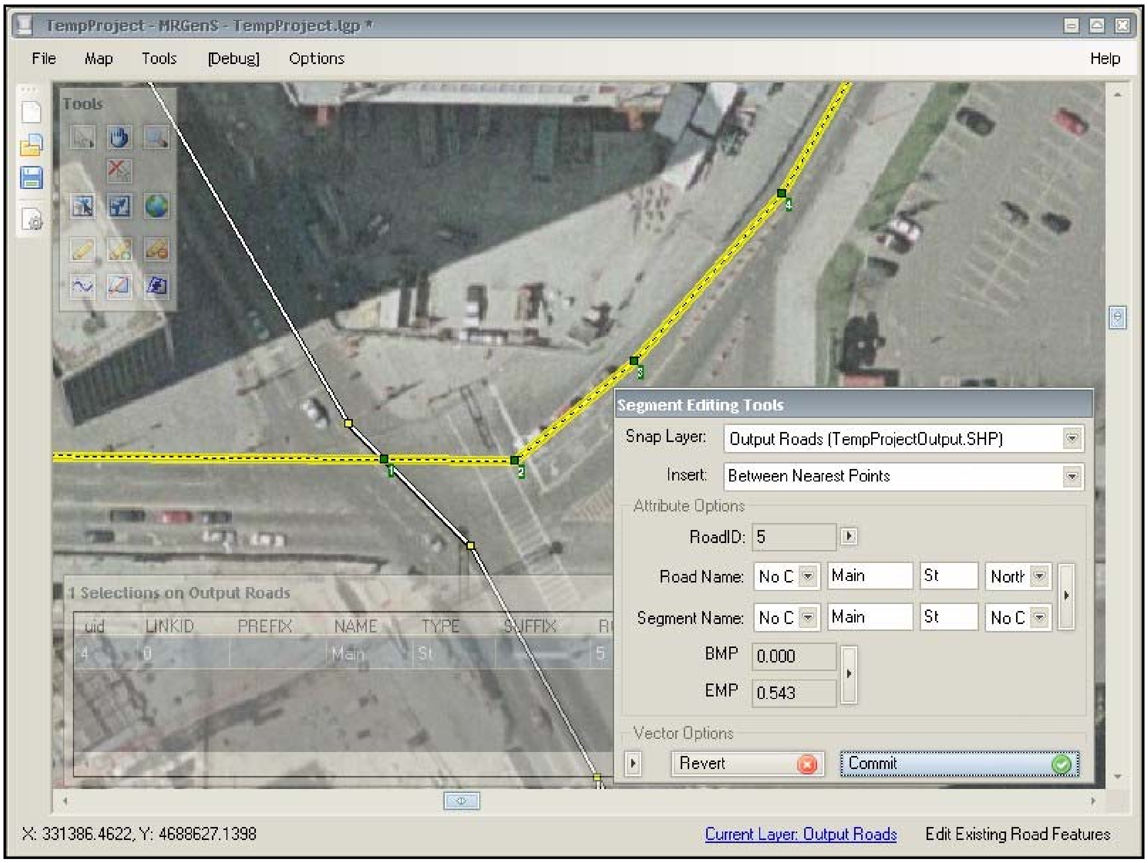

Figure 2. Map Reference Generation System

Pavement Strategy Evaluation and Optimization. Strategy evaluation and optimization is the core of the *RoadSoft* system and allows users to define pavement treatment preferences, and then evaluate effectiveness on a particular road network over a number of years. [See Figure 3] The strategy evaluation tool gives users the ability to quickly determine if a particular treatment strategy or investment level will succeed or fail on the road network. This analysis removes the guess work and speculation when the pavement engineer is charged with choosing treatment types.

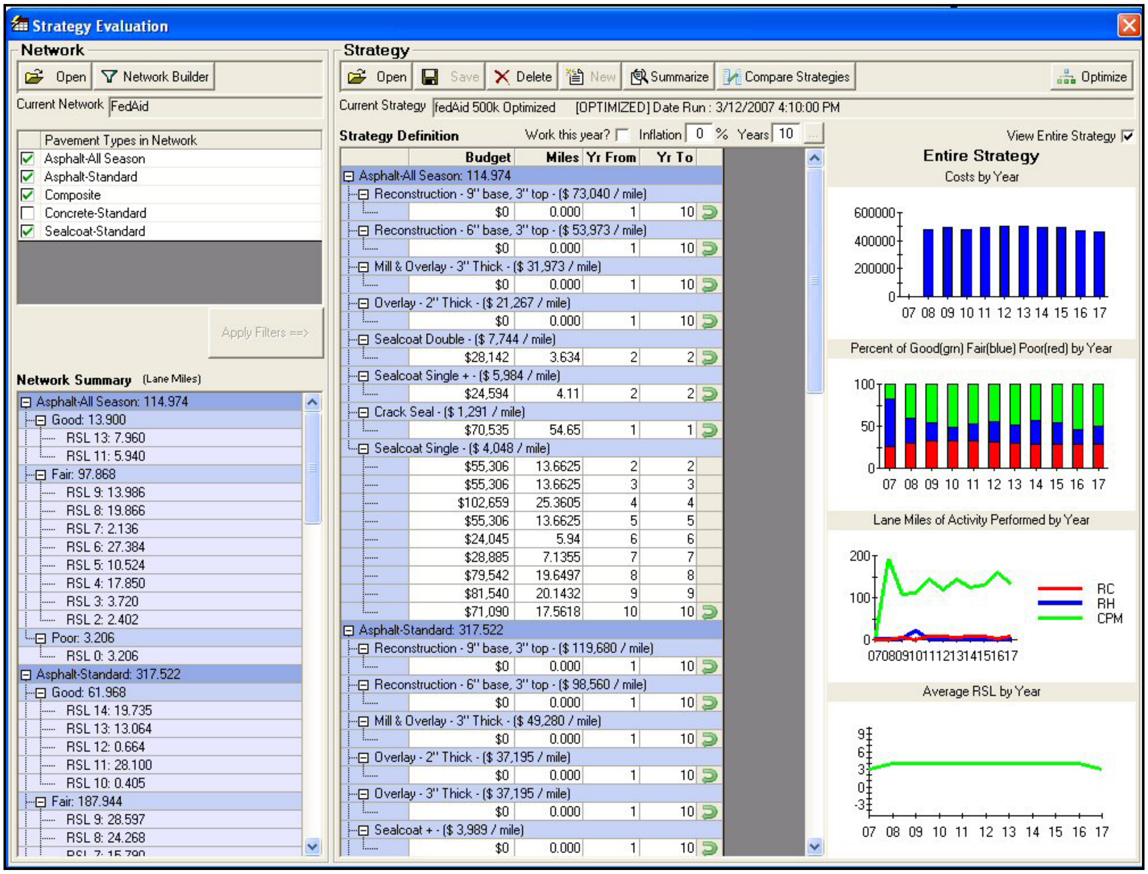

Figure 3. RoadSoft Strategy Evaluation Interface with RSL "Tree"

The *RoadSoft-GIS* strategy evaluation tool first determines the Remaining Service Life (RSL) of all of the road segments within a particular road network. RSL is calculated by developing discrete deterioration curves from historical PASER condition rating information. The system has six curve-fitting models available for building deterioration curves. Once the RSL has been developed, road segments with similar RSL are grouped together as a "tree" with mileage recorded as an aggregate in each RSL category [See Figure 2, lower left corner]. From this point on, the strategy evaluation tool is strictly a network level analysis tool.

The engineer can define a pavement treatment strategy using either custom pavement maintenance treatments or the default treatments defined in the program. He then defines the number of lane miles of each type of treatment that he would like to conduct during each year of the analysis period (usually 5 or 10 years). When the strategy analysis is run, the selected treatments are applied to the miles of road in the appropriate RSL category for that treatment [See Figure 4]. For each year of the simulation the entire road network is degraded by one RSL year. Road segments that are treated (maintained or reconstructed) are then moved to a higher RSL category that is specified by the treatment type.

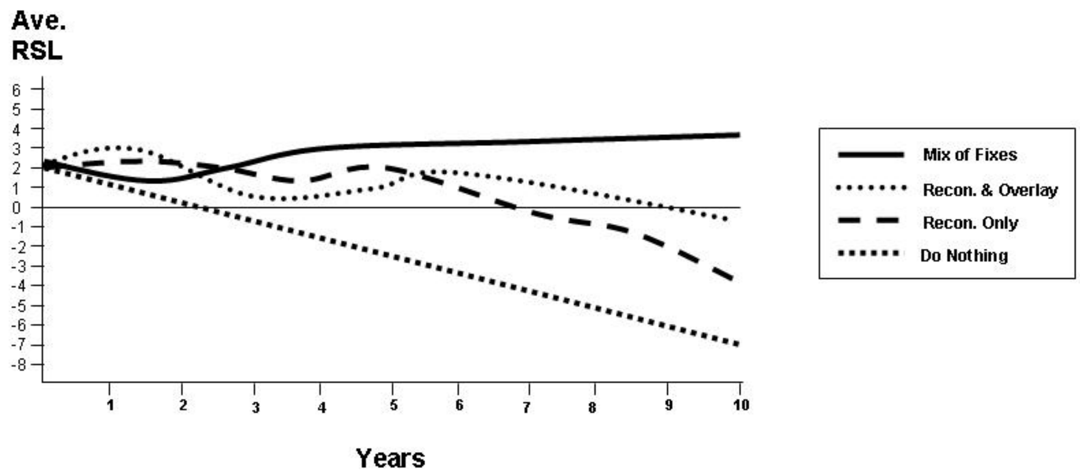

Figure 4. RoadSoft Strategy Evaluation Output

The *RoadSoft-GIS* strategy evaluation tool provides output that allows the engineer several different methods of determining the relative success of various strategies or determining preference between competing strategies. The engineer can evaluate each treatment strategy on the basis of the average network RSL produced over the life of the treatment simulation. The average network RSL quickly reveals if the strategy will produce a net increase or decrease in the condition of the road network. Resulting strategies can also be evaluated on the change in the distribution of roads needing no maintenance, preventative maintenance or reconstruction. Cost data associated with each proposed strategy can be evaluated by looking at anticipated yearly costs for each treatment option as well as determining which treatment option results in the largest rating improvement per dollar spent. The cost calculations allow inflation to be included as a factor, as well as variable costs for emergency projects or legislated spending programs.

The strategy optimization tool helps the engineer determine optimum strategies and develop budgets. He can set a maximum annual budget, select preferred treatments to be applied to the road network, and then optimize those selections to get a variety of solutions. The optimizer will attempt to find solutions that are the most cost effective when maximizing average network RSL. The resulting optimized strategies can then be saved and evaluated in the strategy evaluation tool.

Validation of the RoadSoft Deterioration Models. The deterioration models used in *RoadSoft* to support the strategy analysis process are based on two growth models—the Gompertz and the Logistic. The application of growth models to pavement deterioration was first introduced by Wen Kuo in 1995 [4]. If pavement condition can be described by a score (a rating), this score would change as the pavement deteriorates over time. This score then becomes the population size in the growth model and allows the model to be used to describe the deterioration process of pavements. How well these models fit the actual deterioration process of pavement directly influences the accuracy of pavement performance predictions, and therefore, the repair strategies generated.

A study funded by the Midwest Regional University Transportation Center and the TAMC investigated the use of the growth model approach and validated its appropriateness using historical condition data from five Michigan counties [2]. This report has shown that the original application of the Gompertz and Logistic growth models for pavement management achieved the desired results, but the analysis did not completely satisfy the assumptions made during the model's development. As part of the study, new Gompertz and Logistic growth models were introduced, thereby restoring validity to the common assumptions and meaning to the model parameters. The new models were compared with the original models both theoretically and through the study of the five-county data set. It was found that the new models have a slightly larger r^2, meaning that the variation of the deterioration process of a pavement can be explained better when using the new models.

Local Agency Asset Management Case Examples

City of Big Rapids, Michigan. The City of Big Rapids is located in the west-central portion of Michigan. The city has a population of 10,800 and is responsible for 42 miles of city streets. Ann Miller, DPW Administrative Assistant and co-chair of the Northern *RoadSoft* User Group, has been using *RoadSoft-GIS* for the past 5 years as a tool to assess citywide road conditions and prescribe specific types of maintenance. Together with the Director of Public Services and the Street Supervisor, they develop pavement repair strategies within the *RoadSoft-GIS* Asset Management module as a way to direct their roadway maintenance and rehabilitation program. "The analysis tools in *RoadSoft-GIS* avoid selecting specific projects. Instead you get a collection of road segments that meet the city's repair criteria," says Miller. "At that point, I sit down with my Director and Street Supervisor to assess all the other factors that weigh in on our repair program, such as business and residential development, water and sewer upgrades, etc. The decisions are made by decision makers, not by a computer."

Alcona County, Michigan. The Alcona County Road Commission is a local government agency that is responsible for a county road network consisting of 1165 Km of low to medium volume roads. Alcona County is a very rural county, even by Michigan standards, with a population of 11,570 in an area of 1,745 Km^2. The road network consists of approximately 690 Km of paved roads, 344 Km of gravel roads and 711 Km of unimproved earth roads. Alcona County Road Commission has an annual construction and maintenance budget which generally ranges between $1,350,000 USD to $1,600,000 USD per year. Similar to many of the rural counties in Michigan, the Alcona County Road Commission has a relatively large road network to maintain with relatively little funds. Likewise the county is sparsely populated and does not have a strong tax base from which to draw revenues from. In short, they are an agency trying to accomplish a substantial amount of work with a relatively small amount of funding.

As an early adopter, Alcona County Road Commission began using basic asset management principles and *RoadSoft 1.0* in the mid 1990's. They have accumulated one of the most fully developed data sets in Michigan for an agency of their size. They currently maintain data on pavement condition, signs, culverts and guard rails, and are in the process of adding pavement markings. They use the *RoadSoft-GPS Laptop Data Collection System* as part of an active annual data collection effort during the time when winter has ended, but when construction and maintenance cannot yet begin.

The Michigan LTAP conducted training at the Alcona County Road Commission for their township and county elected officials on the principles of asset management and pavement management. This training educates elected officials on the technical matters that they lack background in and gives them the ability to understand issues related to pavement management. An additional benefit of the training is that it provides a common language that can be used between technical personnel and the elected officials. During the annual PASER condition data collection, many of the elected officials ride along with the rating teams to observe and participate in the rating process.

The Alcona County Road Commission's use of an asset management system has improved the way it does business in a variety of ways, the most striking being the county's use of the analysis capabilities in *RoadSoft-GIS.* The County Engineer used the output of that analysis to work with elected officials in the townships when selecting future construction and maintenance projects. When the County Engineer meets with the township elected officials, he can use the GIS mapping features in *RoadSoft-GIS* to show surface type, current conditions, or the history of construction and maintenance activities, for either individual segments, functional classifications, political classifications, or any user-defined network (commercial routes, school bus routes, all season roads, etc.) These resources help direct the discussion of elected officials towards applying the correct fix in the correct place at the correct time. By keeping the discussion centered on the network-wide impact of their decisions, decision makers stay focused on the greater objective at hand; which is to provide for the overall health of the road network, rather than on politically driven projects that do not meet appropriate criteria.

The successful implementation of *RoadSoft-GIS* in Alcona County benefits the Road Commission in the following areas:

a) Assists engineering staff in communicating with elected officials.
b) Keeps elected officials focused on "network level" analysis and treatment of their road system, rather than focusing on constituent driven projects.
c) Aids in the selection of maintenance and reconstruction candidates by assuring the correct segments of road are selected for a particular treatment.
d) Gives the County Engineer a forum to educate the elected officials in his county on technical matters relating directly to pavement management.
e) Gives the elected officials an assurance that their roads are being maintained and reconstructed based on sound engineering and planning principles.
f) Allows elected officials to better understand the technical process involved in managing roadway assets, which in turn allows them to better respond to their constituents.
g) Aids the County Engineer in answering questions relating to roadside assets and their upkeep.

Mozambique Pilot Project with Michigan Tech University

Mozambique is a located in the southern east coast of Africa, bordered by Tanzania to the north, the Kingdom of Swaziland and the Republic of South Africa to the south, by Zambia, Zimbabwe, and Malawi to the west, and by the Indian Ocean on the east. The country is divided into 10 Provinces, with each Province divided into Districts. The country has a population of 19 million people distributed in an area of 801.590 km^2 (309.475 square miles). Mozambique's classified road network consists of almost 30,000 kilometers of roads, of which less than 20% (5,649 kilometers) are paved. Almost half of the unpaved roads are in poor condition, and only 57% are fully drivable by normal (non-four-wheel drive) traffic.

In the late 1990's after the 16 years of civil war and on behalf of a World Bank plan to improve the road sector, reforms were made that led to the establishment of new institutions that would improve the financing and management of the country's road network. The Roads Fund Board (FE) was established to manage roadway financing, while the National Roads

Authority (ANE) was established to manage both the Trunk highways (Primary) and Regional roads (Secondary and Tertiary).

Based on the new Road Strategic Plan developed by the Government of Mozambique, a new approach is being implemented in the management of roads [8]. A management system should be implemented in order to better prepare repair and budget strategies for a network with limited funding and a significant number of unimproved roads. This management system should be capable of the following: "It should be able to finance paved and unpaved road network such that roads entering the Annual Program would be maintained according to principles of optimal maintenance interventions based on sound engineering and economic principles." The goal is to provide a realistic approach for the management of paved and unpaved roads and improve the Road Authority budget process, thereby providing accurate and timely response to the needs of the Mozambican road network.

The system should take into account the sustainability of the road network and ensue that maintenance and reconstruction are planned in such a way so as to preserve the current investment and reduce total life-cycle costs. Basically the system must provide the following:

Sustainability. The most fundamental principle of NSRMP is to assure the sustainability of the road network and to ensure that resources invested in the sector yield long-term benefits to the economy.

Asset Preservation. Minimize the long-term life-cycle costs of maintaining the road network; prevent the high costs of neglected maintenance by ensuring that technically appropriate maintenance is carried out in a timely fashion.

Maintainability. Ensure that the design and construction of roads takes into consideration the limited resource capacity for maintenance. At the same time this does not mean that inadequate, low-cost maintenance programs should be used, but rather focus on realistic life-cycle costs analysis of keeping roads in good or at least drivable condition.

In order to address this issue, the International Focus Group in Rural Roads (IFG) and the Roadways Fund Mozambique are supporting an investigation of *RoadSoft-GIS* and the PASER rating process. In cooperation with the Road Fund, a civil engineer is spending six months at Michigan Technological University working with the *RoadSoft GIS* developers and trainers. His objective is to evaluate the capacity of the *RoadSoft-GIS* as one option for the implementation of roadway management in Mozambique.

This effort consists of:

a) Defining desirable geometric design and maintenance standards for each class of road in the network.
b) GIS/mapping to produce an accurate inventory and dataset of roads and road characteristics in *RoadSoft GIS.*
c) Assessment of the PASER rating system in the evaluation of the road network.
d) Long-range plan to assure the continuity of the process and training of qualified personnel within Mozambique.
e) Working with *RoadSoft* developers to accommodate meaningful analysis of the unpaved road network.

Summary

The adoption of transportation asset management practices among local agencies in Michigan is much more than simply passing legislation and increasing the data analysis performed. The changes brought about to organizational behavior will have impacts far beyond the rating of roadways and development of repair strategies. The experience of counties and cities in Michigan show this to be true.

The greatest challenge to the implementation of local agency asset management is getting the agencies to take the first step. That first step is eased by providing a management system that that these local agencies can understand, can explain, and can afford to use—both in the acquisition of the software and the collection of data. The *RoadSoft-GIS* Integrated Management System and the PASER Rating System meets those requirements.

Complex and exotic systems that a common engineer does not understand and cannot explain to a constituent have very little chance of long-term implementation success. Data collection processes that incur excessive costs or the need for specialized consultants are short-lived—one time only, until the budget gets cut, or until the champion of the system leaves the agency. The proof of implementation is in the numbers of agencies that adopt a system and engage the principles of asset management. Not just as a way to analyze data, but as a way to involve agency staff, elected officials, and constituents in the transportation planning process.

The pilot project at Michigan Tech is facilitating the investigation by Mozambique in the use of *RoadSoft-GIS*. This project will provide a unique opportunity for the Road Fund to consider a time-efficient and cost-effective system that may also have application in other developing countries. An important aspect of the pilot is that the visiting engineer will return to Mozambique prepared not only to operate the management system, but also prepared to explain the system to decision makers and to train technical personnel to operate the system.

References

1. Asphalt—PASER Manual, Wisconsin Transportation Information Center, University of Wisconsin, Madison, WI. (1987).

2. Dong, J. McNinch, T. *Validation of the Pavement Performance Models Used In Michigan's RoadSoft GIS Integrated Infrastructure Management System.* Michigan Technological University, Houghton, MI. (2006).

3. Drummer, T., McNinch, T, Colling, T. *Analysis of PASER Rating Quality Control Agreement & Development of a Quality Control Data Sampling Plan*. Michigan Technological University, Houghton, MI. (2006).

4. Kuo, W.H. *Pavement Performance Models for Pavement Management System of Michigan Department of Transportation.* Internal Report. Michigan Department of Transportation, Lansing, MI. 1995.

5. MI PA 499, Michigan Public Act 499, MCL 247.659a(1)(a) http://www.michigan.gov/documents/MDOT_AMC_AM_LAW_122436_7.pdf

6. Michigan's Local Technical Assistance Program. http://www.MichiganLTAP.org

7. Michigan Transportation Asset Management Council http://www.michigan.gov/mdot/0,1607,7-151-9623_10697_27106---,00.html

8. Mozambique Road Sector Strategy 2007 – 2011. Final Report—Autoridade Nacional de Estadas, Fundo de Estradas. August 2006.

9. RoadSoft-GIS. http://www.roadsoft.org

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