Implementation of a Pavement Management System for Municipally Maintained Roads in Rhode Island

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An attempt has been made to implement a pavement management system (PMS) for municipally maintained roads in Rhode Island. The primary objectives of the project were to select the most appropriate microcomputer-based PMS software and to implement the selected system in cities and towns throughout the state. A questionnaire survey distributed to all 39 Rhode Island municipalities revealed that only one community was actually instituting a functional PMS when the project began. Micro PAVER was identified as the most appropriate microcomputer-based PMS for municipally maintained roads, primarily because it is one of the simplest menu-driven programs. A workshop manual was prepared that used Micro PAVER as the core of the PMS procedure, and statewide implementation of this developed procedure was conducted through a series of training workshops for the technical staffs of the municipalities. Visual observation of surface distress was the only procedure used for pavement condition evaluations because of the need for a simple, objective, and repeatable survey methodology and the prioritization was based on the derived pavement condition index (PCI). During the standardization process, a 10 percent sampling technique was recommended for pavement condition surveys. At least 16 Rhode Island municipalities have decided to implement Micro PAVER, and several other communities may begin implementation in the near future. Potential enhancements to the municipal-level PMS were also identified and recommended.

In September of 1986, the Rhode Island League of Cities and Towns (RILOCAT) published a report indicating that Rhode Island ranked at the bottom of all states on state highway aid to cities and towns and near the bottom on per capita highway spending (*1*). Unlike most other states, Rhode Island has not used its fuel tax revenue directly for road improvement projects. Almost all major work has been financed through federal highway aid matched by bond revenues, obligating the Rhode Island Department of Transportation (RIDOT) to costly annual appropriations.

The shortage of funds to maintain the highway system is not limited to the state level. Local governments are also faced with the problem of deteriorating roads and reduced funding. Public funds that have been designated for pavements must therefore be used as effectively as possible. One proven method to mitigate the effects of depleted finances is through the use of a pavement management system (PMS) (*2*). A PMS is a set of tools or methods that assist decision makers in finding optimum strategies for providing and maintaining pavements in a serviceable condition over a given period of time (*3,4*). Without such a routine pavement maintenance program, roads require more frequent reconstruction, thereby costing the state and local governments millions of dollars.

Municipal highway agencies throughout the country are adopting PMSs for a variety of reasons: to develop a physical inventory; to justify maintenance budget increases; to preferentially rate maintenance needs; and, most important, to attain the best possible road network for the least amount of money. In 1987, state transportation officials identified the absence of a systematic and rational method to manage municipally maintained pavements. Although the RIDOT has a budget for snow plowing, pothole repair, and other related maintenance activities, a comprehensive pavement management program did not exist.

Recognizing the problem of pavement maintenance, Governor Edward D. DiPrete proposed a 3-year, $8 million pavement management program in September 1987 (*5*). The program was designed to rehabilitate the main streets and roads in cities and towns throughout the state with improvements such as resurfacing, striping, signing, sealing, and sidewalk and curb repairs. The program would be funded through the state's general fund, and would be phased over a 3-year period. In July of 1988, the governor's program also supported a research team from the Department of Civil Engineering at the University of Rhode Island (URI) to implement an appropriate PMS at the municipal level. This initial research program was jointly coordinated with the governor's office, the RIDOT, the Rhode Island Department of Administration (RIDOA), and the RILOCAT. The objectives of this project were to evaluate available PMSs, to identify the most appropriate PMS for municipally maintained roads in Rhode Island, and to implement the selected system by providing training and support.

STATEWIDE INVENTORY OF MUNICIPAL-LEVEL PAVEMENT MANAGEMENT PRACTICES

One of the initial tasks of this project was to conduct a questionnaire survey of the status of municipal pavement management programs in Rhode Island's 39 communities. The purposes of this survey were threefold:

1. To identify the existing pavement maintenance practices,
2. To identify the use and availability of computers within the municipalities' public works and highway maintenance departments, and
3. To develop an interest in the implementation of a computerized PMS.

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In July 1988, the RIDOT and URI distributed a pavement management program questionnaire to each of the state's 39 municipalities. By May 1989, all 39 cities and towns had responded to this survey. The reaction by the communities confirmed the need for statewide implementation of a microcomputer-based PMS in Rhode Island (*6*).

The questionnaire results indicated that Rhode Island communities maintain an average of 130 mi of road. Included in this total is an average of 98 mi of municipally maintained asphalt concrete pavements. Only one community identified maintenance responsibilities for portland cement concrete (PCC) road surfaces (a total length of only 2 mi). The size of municipal maintenance staffs ranged from 3 to 60 people with an average of 14 people. In addition, two towns reported that maintenance work was contracted, and consequently maintenance personnel were not employed.

The written responses to deciding the most cost-effective method for spending limited resources were more varied. Eleven communities reported the use of some type of inspection or survey method, and two municipalities are currently using a condition ranking system. Priority or available budget is the decision factor in six municipalities, and a comprehensive road and drainage plan is used by one town. Unfortunately, the remaining 19 responses were either inappropriate or blank.

According to the survey, 33 communities (85 percent) use a regular maintenance program. These programs are conducted annually in 15 communities, semiannually in 1 community, and seasonally in 6 communities. Six municipalities considered their maintenance program as something other than those mentioned. Only 11 of the 39 communities (28 percent) actually use computers within the public works departments. However, 18 of the remaining 28 communities have access to computers at another location. Since the survey was conducted, at least four municipalities have either purchased or obtained access to computers. Of the types of computer available, 9 communities possess IBM PCs, 11 communities use IBM compatible, and 9 communities have some other type of computer. Only 10 municipalities do not have access to a computer.

Although all 39 communities expressed concern about the deterioration of their municipally maintained pavements, an overwhelming majority of the communities (92 percent) do not have a computerized PMS in use. Further investigation of the three towns that claimed to have PMSs revealed that one of the municipalities actually had a computerized PMS, but with limited capabilities; another had a computerized budget management system; and the third had hired an engineering consulting firm to implement its PMS. Not including the town with the PMS installed by the consultant, at least 22 municipalities have indicated an interest in implementing a computerized PMS while 4 other communities may be interested. Only four towns actually expressed no desire to install a PMS; the eight remaining communities did not respond to this question.

EVALUATION AND SELECTION OF A PMS FOR MUNICIPALLY MAINTAINED ROADS

The reactions by the communities to the pavement management program questionnaire confirmed the lack of rational, systematic methods for the upkeep of municipally maintained pavements throughout the state. The diversity of the responses also established the primary requirements for a municipal level PMS: the system must be low cost, microcomputer based, simple to maintain, and easy to operate.

System Evaluation

The process of evaluating the multitude of pavement and infrastructure management systems was simplified by performing the procedure in two phases. The first phase of the evaluation involved a preliminary review of available literature and software. The second phase consisted of a more detailed comparison of the most promising programs identified in the first phase.

The first phase of the evaluation assessed the programs' general features, operations, costs, developer support, degree of completeness, simplicity, and capabilities. Although ratings or rankings were not assigned to each category, the following general guidelines were considered essential for the programs:

1. The overall operation and implementation of the system must be simple. The most desirable PMS would be user friendly, with menu-driven software using an on-line self-help feature, which the municipal engineering staffs can maintain with minimal outside assistance.
2. The initial cost and annual maintenance fees should be minimal. The ideal program would be nonproprietary, with little or no development costs imposed on the users.
3. The system should be based on visual observations of pavement distresses and possibly overall riding quality.
4. The collected data should be converted into an index number that indicates the pavement performance condition. The employed distress survey methodology must be objective and repeatable, and the derived index must allow preferential rating of road sections for maintenance.
5. The system should, as a minimum, have capabilities for storing pavement condition data, developing an objective pavement condition index, preferentially rating pavement sections for maintenance needs, providing maintenance alternatives, performing life cycle cost analysis, and providing annual budget requirements to keep pavements in acceptable condition.

After the preliminary review in the first phase, the most promising computer programs were selected for the more thorough investigation of the second phase. The nonquantified examination addressed seven specific characteristics:

1. Ease of program use,
2. Clarity and completeness of documentation,
3. Accessibility and quality of support and updating procedures,
4. Program costs,
5. Data management components,
   - A. Data base,
     - Condition rating data,
     - Cost data,
     - Maintenance history,
     - Inventory information,
   - B. Retrieval methods,
     - File flexibility,
     - Output flexibility,

C. Data analysis methods,
6. Pavement management levels (network and project), and
7. Feasibility of interim and long-term use.

Table 1 presents the programs and compares their major features.

Most of the programs appeared to be fairly easy to learn and use. Documentation for most of the software was explicit; some packages included detailed examples and applications. The accessibility and quality of support appeared to be adequate; most developers identified contact individuals who were familiar with the product, while others provided newsletters or electronic bulletin boards. The programs with larger numbers of users experience significant input about problems and potential improvements, which facilitates updating procedures. The costs of the programs were reasonable; the consultant-developed packages with customized software options generally cost more and require annual or periodic support fees.

The quality of the data management components depended on the limitations of the data base manager used in its development. Most of the packages were deficient in terms of file flexibility, especially those that used coding methods other than the American Standard Code for Information Interchange (ASCII) or did not allow files to be printed to disk. ASCII files contain standard text characters that may be read by different computer operating systems; ASCII appears in a readable form when displayed on the screen. The degree of output flexibility was fairly standard among the programs; in most of the packages, specific information can be generated by selecting the appropriate options, and then the reports can be sent to a disk file, screen, or printer. The data analysis methods of most of the programs were similar. A numeric pavement condition index or rating is derived from the quantity and severity of pavement distress. The distress data and pavement condition index are then used in other analysis routines within the program.

Most of the programs allowed both network and project level analyses, although some of the programs included capabilities for only one level of analysis. All of the packages were suitable for municipal use, but only a few appeared adaptable for site-specific modifications at a future time.

Selection of Micro PAVER

The PMS evaluation process identified several excellent microcomputer-based programs. Some useful functions were unique to certain programs; thus no single program included all the necessary capabilities of the ideal PMS. The features of Micro PAVER, however, distinguish it as the most appropriate PMS software for Rhode Island municipalities.

Micro PAVER is one of the simplest menu-driven microcomputer-based programs that features an objective and repeatable visual distress survey methodology. Because it was developed by a government agency, Micro PAVER is nonproprietary and does not require any development costs. Continuous support is provided by the American Public Works Association (APWA), and periodic updates are furnished to its users. Most recently, Version 2.1 was released in October 1989, and the next Micro PAVER upgrade will be released in May 1991. Accordingly, Micro PAVER is one of the most widely used programs; more than 110 users are organized as a nonprofit user group to assist each other and facilitate program updates (*6–8*).

The Micro PAVER system provides the user with a practical design approach for identifying cost-effective maintenance strategies for roads and streets. Micro PAVER's interface programs provide report generation capabilities for critical information that allows objective input to the decision-making process. Other important capabilities include data storage and retrieval, pavement network definition, pavement condition index rating, project rating, inspection scheduling, determination of present and future network condition, de-

TABLE 1 MAJOR FEATURES OF PROMISING PMS SOFTWARE

Software Name (Source)	Type of Developer	Relative Cost	Developer Support	Survey Method	Pavement Inventory	Condition Assessment	Pavement History	Maintenance Policy	Estimate of Quantities and Costs	Project Maintenance Costs	Overall Condition Frequency	Budget Planning Analysis	Future Inspection Scheduling	Alternative Strategy Evaluation
Flexible PMS (Caltrans)	State	Low	No	Visual	Yes	Yes	No	Yes	Costs Only	Yes	No	No	No	No
Metro Pavement Management (Metropolitan Transportation Commission)	Agency	Moderate	Yes	Visual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Micro PAVER (APWA)	Agency	Low	Yes	Visual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pavement Management System (Vanasse Hangen Brustlin)	Consultant	High	Yes	Visual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road Manager (Christman Associates)	Consultant	Moderate to High	Yes	Visual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RSMMS (Wilbur Smith Associates BTML Division)	Consultant	High	Yes	Visual	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
STAMMP (Pennsylvania Department of Transportation)	State	Low	No	Visual	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No

termination of needs for maintenance and repair (M&R), performance of economic analysis, and budget planning (*9–12*).

PRELIMINARY IMPLEMENTATION OF Micro PAVER ON PILOT NETWORKS

During the evaluation process of available microcomputer-based PMSs, two pilot networks were created. The road system of the URI Kingston campus was established primarily to investigate the adaptability of promising computer programs to an actual street layout. The larger road network of the town of South Kingstown was instituted to test the suitability of the selected computer program in a typical community. This section summarizes the preliminary implementation of Micro PAVER on these two-pilot networks, and also recommends municipal implementation guidelines that were recognized during these trial installations.

University of Rhode Island Campus

The URI Kingston campus roadway network is representative of most municipal networks in the state, but only at a smaller scale. The roadways on the campus are primarily two-lane streets with asphalt concrete surfaces with functional classifications ranging from service roads (seldom-used) to circulators (heavily traveled).

The characteristics of the campus roadway network allowed it to serve many functions:

1. The suitability of Micro PAVER and other promising computer programs could be examined,
2. Municipal personnel could be trained in pavement condition survey procedures,
3. The repeatability and reproducibility of the pavement condition index (PCI) methodology could be tested,
4. Condition survey techniques could be calibrated, and
5. Micro PAVER could be continuously evaluated and tested.

Most important, a PMS was established for the Kingston campus roadways.

Town of South Kingstown

The town of South Kingstown began implementation of Micro PAVER in June 1988. The implementation was administered by an engineering technician, with assistance from an engineering intern during summer months. An average of 10 person-hours per week were expended for collection of pavement condition data, background research of construction and major maintenance records, and data entry into the computer. These tasks were completed for the 110-mi paved municipal roadway network in July 1989. The pavement condition surveys disclosed that the average town-maintained roadway section is in good condition.

With data currently collected for the entire network, the Engineering Division plans to use Micro PAVER for routine applications. South Kingstown currently does not use life cycle cost analysis in the selection of maintenance and rehabilitation strategies. The selection of individual projects and the treatment strategies for these projects are based on factors such as available funds, citizen complaints, political considerations, utility information, and future development plans. With the Micro PAVER system operational, maintenance strategies can be related to the PCI and a more rational strategy selection process can be developed. For example, the Engineering Division has noticed that the service lives of higher-volume road surfaces treated with stone seals are not as long as expected. Engineering Division personnel can now analyze the collected data to determine which roads would be more cost-effectively treated with rehabilitation strategies other than stone sealing.

Although the Micro PAVER program is not yet being used to its full potential, the town of South Kingstown is pleased with the progress and the results of the implementation thus far. The Micro PAVER program itself was easily adapted to fulfill the pavement management requirements of the town. The town will continue with its implementation and expects to perform pavement condition assessments on an annual basis for approximately one-fourth of the road network. With network condition data updated every year, the town will be able to establish a realistic long-range objective.

Recommended Implementation Guidelines

Before data can be collected, a municipality must first identify its pavement network components. A zone is the largest subdivision within a network. Zone boundaries are usually defined by permanent or physical obstructions (such as natural or seminatural barriers, or state or major local roads), or less common, by administrative divisions (such as voting wards or school districts). The zone layout of South Kingstown is shown in Figure 1. A branch is any identifiable part of the network

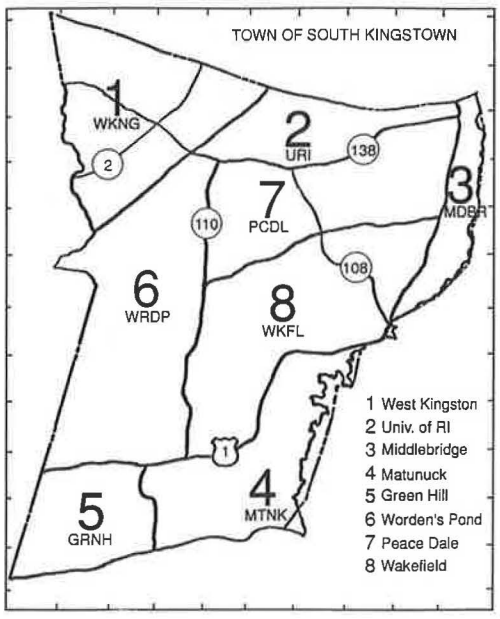

FIGURE 1 Micro PAVER zones in the town of South Kingstown.

that is a single entity and has a distinct function, such as an individual street. Ideally, each branch should be contained within one individual zone, but occasionally, branches may be components of two or more zones. Sections are those portions of branches that are uniform in pavement structure composition, traffic, construction history, pavement rank, drainage facilities, and shoulders. Other factors to be considered in defining sections include management, data availability, costs, and whether the section limits can be changed. Because no formal length restrictions are imposed upon sections, a branch may consist of a single section. For example, minor residential streets and dead-end roads typically have identical characteristics throughout, and therefore consist of only one section. Samples are the smallest component of the network. The sample is the portion of the section that is actually inspected; therefore the samples must be representative of the entire section. For sections with asphaltic surfaces, the sample units consist of 2,500 ± 1,000 ft². Figure 2 shows a typical application of sections and sample units for a branch on the URI Kingston campus road network.

Accurate section PCIs are essential to both network and project level decisions. However, inspection of every sample unit within a pavement section would involve considerable time and effort. Such a practice would require more manpower, funds, and time than are available to most municipalities. Because sections have been defined as having common characteristics (including surface type, structure, maintenance history, traffic conditions, and about the same level of deterioration), statistical extrapolation is applied to reduce the collection effort of distress data. Thus, only selected sample units are inspected and the PCI for the entire section is extrapolated. For initial network implementation, a 10 percent sampling level should be sufficient, as presented in Table 2.

A municipality should select its sampling level according to the desired level of accuracy. In fact, because additional sampling can always be performed in the future, a community's first-time sampling needs could be underestimated without jeopardizing this previously collected data. All subsequent inspections should always include the previously surveyed samples. Periodic inspection of the same sample unit ensures the repeatability and reproducibility of the PCI methodology and also yields a more accurate deterioration rate for the pavement section.

TABLE 2 RECOMMENDED SAMPLING STRATEGY FOR INITIAL IMPLEMENTATION OF Micro PAVER ON MUNICIPAL NETWORKS

Number of Sample Units per Section	Recommended Sample(s) to Inspect (if representative)
1 - 10	2nd
11 - 20	2nd, 12th
21 - 30	2nd, 12th, 22nd
31 - 40	2nd, 12th, 22nd, 32nd
.	.
.	.
.	.

PMS WORKSHOPS AND STATEWIDE IMPLEMENTATION STATUS

The installation of Micro PAVER on the pilot networks allowed the system to be tested for widespread municipal use throughout Rhode Island. Because the program worked adequately during this trial period, the URI PMS team began the effort to implement Micro PAVER statewide. This task was accomplished through three separate informational workshops.

The RIDOT/URI PMS workshops were one-and-one-half-day informational and instructional sessions open to all 39 municipalities. For each of the three workshops, letters of invitation were sent to the individuals designated by the communities on the returned questionnaires. Where applicable, additional personnel and previous attendees were notified with invitations, schedules, and instructions.

A total of 26 communities, exactly two-thirds of Rhode Island's 39 municipalities, attended at least one of the workshops (Figure 3). As a precaution against future implementation problems, the 13 nonparticipating municipalities were asked if a particular reason existed for not attending any of the workshops. The two most common responses were per-

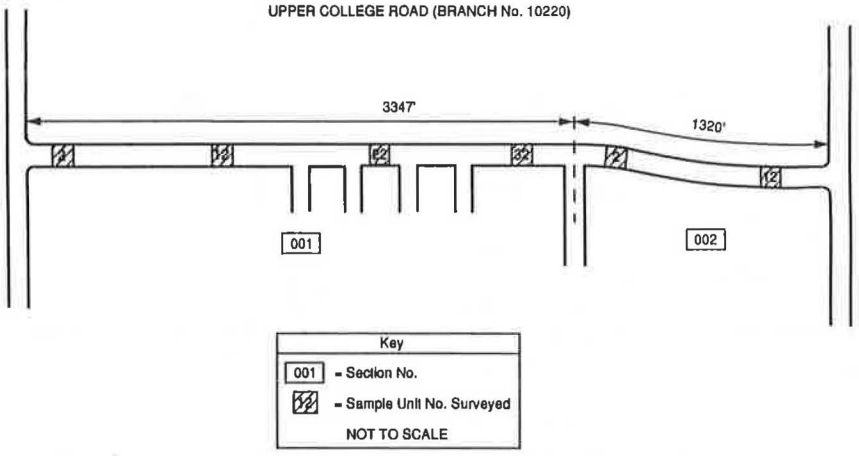

FIGURE 2 Typical branch, section, sample unit application on the URI campus.

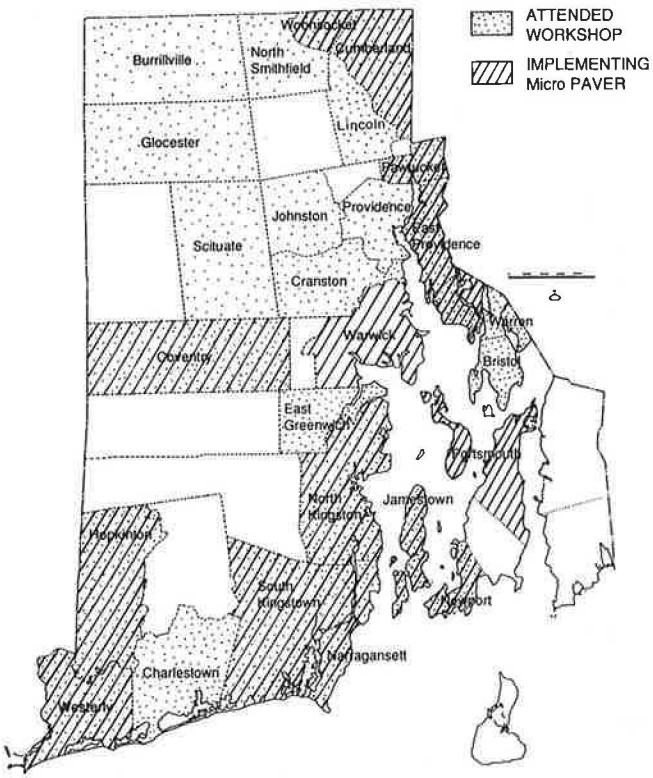

FIGURE 3 Rhode Island municipalities implementing Micro PAVER.

sonnel shortages or scheduling conflicts. However, according to the questionnaire responses, none of these 13 public works departments uses computers. Figure 3 also shows that at least 16 municipalities have decided to implement Micro PAVER. A more detailed description of the status of these 16 municipalities is presented in Table 3.

POTENTIAL ENHANCEMENTS TO THE MUNICIPAL-LEVEL PMS

Substantial progress has been achieved in the implementation of a PMS in Rhode Island municipalities. Although Micro PAVER Version 1.0 was the most appropriate microcomputer-based pavement management program for statewide use at that time, it may not be a perfect or complete system. In fact, several opportunities to enhance the system exist.

The most obvious enhancement to the overall system will be the implementation of Micro PAVER Version 2.1 by the individual municipalities. This revised program includes many additions and new features. General changes include a utility program to convert Version 1.0 data bases to Version 2.1; an unsurfaced road condition index; and extended memory to increase the speed of report generation.

Another short-term enhancement will be to continue the process of confirming the approaches, methods, data, and costs used by both the URI PMS team and the town of South Kingstown. Some of this information was acquired from other areas of the country and may not be appropriate for Rhode Island.

TABLE 3 STATUS OF PMS IMPLEMENTATION WITH Micro PAVER IN RHODE ISLAND MUNICIPALITIES

Municipality	Workshop Attended	Computer Available	Possess Micro PAVER	Established Network/Branch Numbering System	Method of Data Collection	Percent Data Collection Completed	Data Collection Completion Date (Actual or expected)
Barrington	1st	Yes	Yes	No	Students	0%	1990
Coventry	1st, 3rd	Yes	Yes	Yes	Students	100%	July 1989
Cranston	2nd	Yes	Yes	No	Inhouse	0%	N.A.
Cumberland	1st	Not yet	Yes	Yes	Students	0%	1990
East Providence	2nd	Yes	Yes	No	Students	0%	1990
Hopkinton	2nd	Yes	Yes	No	Inhouse	0%	1990
Jamestown	2nd	Yes	Yes	Yes	Inhouse	60%	1991
Lincoln	1st	Yes	Yes	Yes	Students	10%	1990
Narragansett	2nd	Yes	Yes	Yes	Consultant	100%	1989
Newport	1st	Yes	Yes	Yes	Inhouse/students	1%	1991
North Kingstown	1st,2nd,3rd	Yes	Yes	Yes	Consultant	98%	1990
Pawtucket	1st,3rd	Yes	Yes	Yes	Students	70%	1990
South Kingstown	1st	Yes	Yes	Yes	Inhouse/students	100%	June 1989
Warwick	1st	Yes	Yes	N.A.	N.A.	N.A.	N.A.
Westerly	1st	Yes	N.A.	N.A.	N.A.	N.A.	N.A.
Woonsocket	2nd,3rd	Yes	Yes	Yes	Students	N.A.	1990

Note: N.A. indicates that the information is not available at this time.

Similarly, collection of more accurate costs for construction and maintenance activities will require time for several municipalities to become more proficient using the Micro PAVER procedures. Once this happens, a type of user's group may develop from which the URI PMS team may compile maintenance and repair policy information, construction and maintenance costs, and other useful information. Statewide averages or default values may then be established and shared among users.

A comparison of in-house and hired-consultant data collection services will also benefit the municipalities, especially those who have not yet begun implementation. With time and cost information available for both approaches, the most cost-effective method may be determined for the combined schedule and budget requirements anticipated by the individual municipalities.

Logically, the most critical modifications to the PMS are of an inherent nature; that is, they focus on ways to improve the contents or effectiveness of the Micro PAVER program itself. However, the PMS as a whole will be subject to improvements from outside sources as well. These activities may be longer range in scope and may merge or combine the PMS with other larger systems or data bases.

Some Rhode Island communities may integrate the Micro PAVER PMS with a public works management system. These systems usually include programs or modules that are relevant to pavement management. The typical street or pavement inventory program directly incorporates the numeric pavement condition rating from the PMS and generates inventory reports virtually identical to Micro PAVER's. Other typical programs, such as maintenance management, cost accounting, planning, and budgeting, generate information similar to the Micro PAVER report routines. Public works management systems normally include other computer programs that would complement a PMS: automated complaint tracking, public works cost accounting, and equipment management information. Used in connection with a PMS, these computer programs form a comprehensive public works maintenance system. The option to combine the PMS with a public works management system must be decided on by the individual communities.

Integration of the pavement management system with a geographic information system (GIS) has the most potential. A GIS allows users to capture, edit, and display geographic data as well as perform geographic analysis and create topographical maps. A GIS not only stores the traditional elements of a street inventory (street name, pavement width, pavement length, surface type, pavement condition, curbs, gutters, sidewalks, striping, shoulders, ditches, culverts, streetlights, traffic signs, signals, etc.), but displays the information in practically endless combinations. The data base can be expanded to include any information essential to pavement management: street surface area, measurements of missing curbs and gutters, completed or scheduled utility work, unit costs for various rehabilitation processes, costs to perform rehabilitation, and recommended rehabilitation strategies (*13–16*).

A GIS can be used for daily routine maintenance scheduling. The system can also be very helpful in answering the public's questions on street conditions and expected repair dates. However, the greatest aid of a GIS may be its ability to indicate to elected officials and public administrators the condition of streets. Plots of streets in poor condition are useful at city or town council meetings, budget meetings, and neighborhood organization meetings. The ability to point out to decision makers the plots of poor-condition roads can only result in a positive impact on the funding and repair process (*13–16*).

A PMS combined with a GIS is clearly one of the most powerful tools for preparing municipal-level pavement maintenance programs. The city of Cranston has already expressed a strong interest in implementing a combined GIS-PMS.

CONCLUSIONS

1. Thirty-three of the 39 municipalities in Rhode Island (85 percent) used regular maintenance programs for their highways; however, the statewide absence of a systematic and rational method to manage municipally maintained roads was evident. Only one of the communities was using a computerized PMS, a proven technique to economically administer highway M&R.
2. Micro PAVER was selected as the most appropriate microcomputer-based PMS for municipally maintained roads in Rhode Island. Micro PAVER is one of the simplest menu-driven programs that provides users with a practical decision-making tool for identifying cost-effective M&R alternatives for roads and streets.
3. A Micro PAVER–based PMS was successfully implemented on two trial networks: the URI Kingston campus and the town of South Kingstown. Through these initial installations, several critical functions were established:

- A preliminary procedure for field crew training;
- Data bases to check the reproducibility of PCI values;
- A standard network (the URI road network) that will allow for future study, training, and calibration; and
- A model municipal network (South Kingstown) to encourage statewide implementation.

4. Twenty-six Rhode Island municipalities (represented by 62 participants) attended at least one of the pavement management workshops jointly offered by the RIDOT and URI. At least 16 municipalities have decided to implement Micro PAVER. Several other communities that originally expressed little or no interest in a PMS are now recognizing the importance of a systematic and rational method for maintaining their municipal pavements.
5. The integration of GIS technology with a PMS was identified as one of the most promising and logical applications to enhance the capabilities of a municipal-level PMS.

RECOMMENDATIONS

1. The URI PMS team should continue to assist all interested municipalities with the implementation of the developed PMS, and update a list of pavement repair and rehabilitation strategies, costs, and service lives of all municipal pavement maintenance practices typically used in Rhode Island.
2. Implementation and research on the town of South Kingstown model network should be continued, and all other

municipalities should consider using or adapting the results of this pilot network.

3. All systems installed with Micro PAVER Version 1.0 or 1.2 should be upgraded to Version 2.0 or later. These updated programs include several new features including an unsurfaced road condition index, storage of traffic data, and a combined budget planning and PCI frequency report.

4. Each municipality should consider incorporating their PMS into a total public works management system.

5. Integration of the PMS with a GIS should be considered at the municipal level.

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