TRANSPORTATION RESEARCH
CIRCULAR
Number E-C127
February 2008

Implementation of an Airport Pavement Management System

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH CIRCULAR E-C127

Implementation of an Airport Pavement Management System

Prepared by
Susan Tighe
University of Waterloo, Ontario, Canada
and
Margaret Covalt
Applied Pavement Technology
Urbana, Illinois

for the
Pavement Management Systems for Airports Subcommittee
Pavement Management Systems Committee
Transportation Research Board

February 2008

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

TRANSPORTATION RESEARCH CIRCULAR E-C127
ISSN 0097-8515

The **Transportation Research Board** is one of six major divisions of the National Research Council, which serves as an independent adviser to the federal government and others on scientific and technical questions of national importance. The National Research Council is jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal.

The **Transportation Research Board** is distributing this Circular to make the information contained herein available for use by individual practitioners in state and local transportation agencies, researchers in academic institutions, and other members of the transportation research community. The information in this Circular was taken directly from the submission of the authors. This document is not a report of the National Research Council or of the National Academy of Sciences.

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

Jennifer Correro. Proofreader and Lavout

Contents

Executive Summary

This circular discusses the implementation of an Airport Pavement Management System (APMS). The role of an APMS, as well as the data requirements for the implementation and update of an APMS, are explained. It also reviews the benefits and costs associated with the implementation of an APMS, as well as the challenges commonly faced by those agencies implementing an APMS.

The primary steps involved in implementing an APMS include identifying the APMS users and their needs, conducting a pavement inventory, evaluating pavement condition, customizing APMS software as needed, analyzing data, generating reports and other outputs, and obtaining training on the APMS process and software. After an APMS has been implemented, continued support and update of it is critical.

The major issues identified in the implementation of an APMS are adequate training, sufficient funding, satisfying diverse needs, and maintaining the database. In order to surmount these obstacles, APMS requires commitment from all levels of management before implementation. This commitment consists of resources in terms of personnel to maintain the database and finances to continue supporting the APMS. Additionally, it is essential that adequate training is available and provided to all personnel connected with the APMS in terms of data collection, developing models, or understanding program outputs. Finally, the APMS should be flexible to accommodate future user needs and expansion.

This circular is an initiative of the Airport Pavement Management Subcommittee. The subcommittee mandate is concerned with the development, evaluation, integration, and application of existing and new systems of airfield pavement management and the component concepts and models for all types of airfield pavements. This includes the development, assessment, and application of new and existing methods and procedures directed toward a better understanding and description of airfield pavements as a whole and the interrelationships among all factors that influence airfield pavement behavior and performance and that must be taken into consideration in making pavement management decisions, including such factors as loads, environment, strategy alternatives, economics, construction, and maintenance. In addition, this subcommittee is concerned with the transfer of knowledge and technology as it relates to airfield pavement management systems and their components.

This circular was reviewed and approved by the Pavement Management Systems for Airports Subcommittee. It was produced under the auspices of the Pavement Management Systems Committee and has been approved by the parent committee.

—Susan Tighe
Chair, TRB Airport Pavement Management Subcommittee
Canada Research Chair and Associate Professor
University of Waterloo, Waterloo, Ontario

—Margaret Covalt
Immediate Past Chair, TRB Airport Pavement Management Subcommittee
Vice President
Applied Pavement Technology, Inc., Urbana, Illinois

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Leanne Whiteley, James Smith, Patrick Leong, and Ken Huen, University of Waterloo, and of Laura Raczkowski, Applied Pavement Technology.

Overview of Airport Pavement Management

Today's airport sponsors and aviation agencies are tasked with the difficult job of making limited fiscal resources address an often-growing backlog of pavement rehabilitation needs. This is especially true as funding levels become more restrictive and the competition for pavement rehabilitation project funding heightens. Airports and state aviation agencies are better able to address these issues if they have tools at their disposal to assist in (*a*) determining their pavement needs, (*b*) optimizing the selection of projects and treatments over a multiyear period, and (*c*) evaluating the long-term impacts of their project priorities.

Historically, most agencies responsible for managing airport pavements have made decisions regarding maintenance and rehabilitation (M&R) based on experience and best engineering practices. However, since 1985 the number of airport agencies using APMS to help them manage this critical asset has grown dramatically. In fact, 84% of state aviation agencies in the United States use APMS (Broten 2004*a*). This is partially due to the passage of Public Law 103-305 in 1995. This law states that for an airport agency to be eligible for federal funding, it must be able to show that it has an effective pavement maintenance management system in place (FAA 2004).

The role of an APMS is to assist decision makers in developing economically viable strategies to maintain the pavements in a serviceable condition over a given period of time. APMS provides a consistent, objective and systematic procedure for determining priorities, schedules, and allocating resources. It can also quantify information and provide specific recommendations to maintain a pavement network at an acceptable level of service while minimizing pavement-related expenditures.

Network-Level and Project-Level Airport Pavement Management

Airport pavement management can be applied at the network and project level. The network level takes into consideration all the pavement assets being managed by an agency. The project level is specific to a given pavement area that has been identified for potential rehabilitation.

NETWORK-LEVEL MANAGEMENT

At the network level, questions concerning short- and long-range budget needs and the overall condition of the network (both current and future) are answered. In addition, network-level management assists in prioritizing which pavement sections should be rehabilitated, reconstructed, or have maintenance performed on them. The level of inspection utilized in this type of evaluation is generally basic, consisting mainly of a visual inspection of a portion of the surface of each of the pavement sections contained within the network.

PROJECT-LEVEL MANAGEMENT

At the project level, management decisions are made regarding to the most cost-effective M&R alternative for a given pavement section. The evaluation at the project level is typically more analyzed in detail than at the network level. The pavements that were triggered as candidates for M&R actions during the network-level analysis are further assessed. A higher sampling rate for the pavement inspection is often used. In addition, supplementary testing methods such as deflection testing (or nondestructive testing), friction testing, roughness testing, and core sampling may be conducted based on specific needs.

Benefits and Costs of Airport Pavement Management

BENEFITS

There are numerous benefits that may be realized through the use of an APMS. First of all, an APMS can be used to provide improved documentation of the inventory and condition data available for the pavements in a given system. Also, because the information pertinent to the pavements is stored in a single computerized database, it becomes significantly easier to access. Thus, a major benefit of an APMS is that it can provide a more efficient way to monitor the condition of the pavement system and to also outline any plans for M&R.

Another benefit of an APMS is that it can be used to examine deterioration trends of various pavement sections within the system. This capability leads to the ability to predict future pavement conditions. With this in mind, an APMS can assist an airport or agency in making cost-effective decisions about specific M&R treatments and their optimal timing while also understanding the long-term impacts of the decisions being made. This ability can lead to the eventual improvement of the condition of the pavement system due to a more efficient method of allocating available funding. In fact, an analysis of several state APMS databases has shown a slow but steady increase in pavement condition since the APMS were implemented (Broten 2004*a*).

COSTS

The costs associated with an APMS include the costs to collect inventory data, to assess the condition of the pavements, to establish a pavement management database, and to analyze the collected data. These are not one-time costs since the database must be updated to remain current. There are also costs associated with computer hardware and software as well as labor costs associated with those operating and maintaining the APMS. Training, both initial and refresher, is another cost associated with an APMS.

Implementation of an Airport Pavement Management System

The implementation and maintenance of an APMS requires a large investment and commitment of time and resources. Larger airports may choose to obtain training in the APMS process and then implement and maintain the APMS using internal staff. Another common approach is to have a consultant set up the initial APMS and provide training to the airport staff so that the agency can take over the management and maintenance of the system.

IDENTIFICATION OF POTENTIAL USERS AND DETERMINATION OF THEIR NEEDS

When the APMS is initially designed, it is of extreme importance that all potential users of the system are identified and that their individual needs are determined so that everyone can be satisfied with the end product (Broten 2004*b*). These potential users of an APMS differ depending on the implementing agency: individual airport, state, regional planning agency, or branch of the military. The following are some of the typical users of an APMS.

Many larger airports have an engineering department. This group requires the most detailed and technical information out of the APMS. Typically, the engineering department plans ahead for any M&R actions that may become necessary in the future to keep the pavement in good condition. The type of information required is detailed and comprehensive data regarding the pavement infrastructure and the options for its long-term M&R. A pavement management software program that can provide geographic information systems (GIS) capabilities is also important to this group.

Also, larger airports often have a maintenance department; they are another key user of the information that an APMS can provide. The type of information that is useful to them is the specific types and locations of distresses so that the proper maintenance activity can be planned and implemented when necessary. Software programs with the capability to employ a Global Positioning System (GPS) are of use to this group.

Furthermore, some airports have a finance department. They are mainly interested in the cost of the APMS and how it will be funded. However, after the APMS is in place, they would want the cost information on the various recommended M&R actions and how these would be funded. An APMS can also provide the finance department with assistance in determining the pavement system's current value and an estimated cost to maintain the pavement at a given condition value.

Commercial service airports have several groups of potential users of the APMS whose primary concern is not about the M&R of the pavement. These groups are the operations department, the upper airport management, and the airline companies. These groups are most concerned with keeping the pavements open for use, as this is the most profitable for them. Highly detailed and technical information is ideal, as maps and graphs have generally worked well for them.

APMS implemented at the state or regional level in the United States is used by the state, the regional planning commission, the individual airports, and FAA. APMS implemented by military agencies are used by the individual bases and at the federal level.

SELECTION OF SOFTWARE

Once the users of the APMS have been identified and their needs determined the APMS software must be selected. The first two issues that are addressed in the selection process are how much money is available to develop or purchase the software and what type of software is desired. If the agency elects to purchase existing off-the-shelf software, they must decide between software that is available for purchase to anyone and proprietary software that is sold by the software company on a restricted basis.

In addition to the cost and type of software, there are other factors to consider when selecting the optimal pavement management software program for use in the APMS process. One example is the type of user interface: some software programs are easy to navigate and some offer a graphical interface. Another important feature is the capability to employ GIS linking. If this feature is necessary to an agency in the future, it is important to choose from the beginning a software program that can accommodate this need. Also, the comparison of the type of outputs that each software program generates will also aid in the selection process. Finally, the comparison of the type of analysis that best fits the type of output the agency is needed. The selection of an analysis type will narrow down and often determine the type of software program that can be employed.

RECORDS REVIEW

Before initiating the evaluation of pavements, a comprehensive review of existing records is undertaken to collect data needed to conduct the APMS analysis. The data collected during a standard records review include the construction and maintenance history of each pavement within the system. This information varies from the initial pavement construction date and the materials used to any M&R actions that have been performed to the pavement section since its original construction. Other types of data that are collected include condition data from previous inspections, climatic data such as temperature and precipitation ranges, and any information of the types of traffic utilizing a particular pavement.

There are two important guidelines in determining the extent of historical information to include in the inventory. First, it is essential to have accessible data so that time will not be wasted in a records search. Second, the collected information should serve a purpose.

Available records include construction drawings, geotechnical reports, FAA records, state records, aerial photographs, airport records, and master planning and system planning documents. The information collected is often supplemented by interviews with various personnel including state aviation staff, FAA, airport managers, air traffic personnel, airport operations staff, airline personnel, and fixed base operators.

NETWORK DEFINITION AND MAP GENERATION

Dividing the pavement in the system up into smaller, more controllable units is an important component in the APMS process. As specified in FAA AC 150/5380-6A (FAA 2003) and ASTM Standard D 5340 (ASTM 2003), the definition of network is comprised of four main divisions: network, branch, section, and sample unit.

The largest unit within an APMS is the network. A network is defined as a group of pavements that will be managed and maintained together. A network is usually an individual airport.

The network is then divided up into branches. As a general rule, a branch is a section of pavement that serves a specific purpose within the network. Examples of branches that are common to APMS are runways, taxiways, and aprons or ramps.

Next, the branches are broken up into smaller units called sections. According to ASTM D5340, each section must have uniform design, construction history, traffic, and condition. Sections are the management units for the selection of potential M&R projects. To decide where section breaks are located, it is useful to think of the section as a "repair unit," or a portion of the pavement that will be managed independently and evaluated separately for pavement M&R.

During the actual survey, it may be necessary to define additional section divisions if there is a definite change in pavement condition or surface. Pavement sectioning takes account of utilization in materials, traffic loading, etc., that will affect pavement performance over time. In order to make the survey process more sensitive to load-related distress on airports receiving heavy loads, it is important to separate heavily trafficked areas from lightly trafficked or nontrafficked areas. It is extremely important to have correct pavement sections since poor sectioning can lead to erroneous results.

The final step in the network definition process is to split each section up into sample units. This step is mainly completed for the purposes of pavement condition inspections. As stated by the ASTM Standard D 5340, the sample unit size for airfield pavements are

- Jointed portland cement concrete (PCC) pavement = 20 ± 8 slabs and
- Asphalt concrete (AC) pavement = 5000 ± 2000 ft^2 of area.

It is important to note that if the joint spacing on a PCC section is greater than 25 ft, the concept of imaginary slabs is to be used to make the slabs of an appropriate length for evaluation.

The practices used when establishing sample unit divisions are extremely important as they can directly affect the accuracy of the pavement evaluation results. Sample unit sizes must be within the allowable range stated in the ASTM Standard D 5340 and the size of the sample units within a section should be as consistent as possible (Broten 2001).

Maps for all pavement areas to be inspected are prepared and included in the APMS. The maps illustrate important pavement dimensions, display pavement sections and sample units, and identify specific sample units to be inspected. These maps are prepared to scale and presented in a format that is easy to access by field personnel conducting the survey. These maps are often generated using a computer-assisted drafting (CAD) package. The computer-generated maps are flexible and contain great amounts of information. Furthermore, most CAD packages possess a powerful layering capability. Once a base map is created, layers can be generated that use the base map to show the location of any desired feature such as lighting, landing systems, and drainage structures.

PAVEMENT EVALUATION

Different methods of pavement evaluation lead to different pavement management decisions. Therefore, the method selected to evaluate pavement condition is extremely important because it is the basis of all recommendations. For this reason, it is critical to select an objective and repeatable procedure so that APMS recommendations are reliable and condition ratings do not vary among inspectors.

Evaluation of airport pavement involves four key components: surface condition (or distress measurements), strength, roughness, and skid resistance. Typically, network-level pavement management involves only the visual assessment of pavement condition. Project-level pavement management may involve strength, roughness, and skid resistance evaluation. Destructive testing (e.g., coring and boring) also may be required.

Most aviation agencies use the pavement condition index (PCI) methodology developed by the U.S. Army Corps of Engineers. The PCI procedure is described in FAA AC 150/5380-6A and ASTM Standard D5340. The PCI value is a rating of the pavement's condition based on a visual survey of the types of distress, severities, and quantities present on the pavement surface. It can range from 0 (failed) to 100 (excellent). It serves as a means to express the condition of the pavement in a consistent and clear manner that others can readily understand and use to compare with other pavements.

The sampling rate, the number of sample units that must be inspected during the PCI survey based on the total number of sample units within a given section, is generally determined based on the agency's needs. Examples of different types of sampling rates that are commonly used include surveying 100% of the pavement surface or surveying only the number of sample units that will obtain a 95% confidence interval around the PCI value.

When surveying, it is important to select sample units that extend over the entire section so that the whole section is properly represented when the PCI value is calculated. If any additional sample units that are not characteristic of the pavement section's condition or contain types of distresses not typical to the section as a whole are identified during the pavement survey, they should be identified accordingly before the PCI value is calculated. This is done to prevent the distresses in the additional sample unit from being extrapolated throughout the entire section. When surveying all the sample units within a pavement section, it is important to note that there can be no additional sample units identified, as the survey is taking into account 100% of the pavement surface without extrapolating distresses. During a PCI survey, photographs are often taken. These photographs provide an overview of typical conditions and cover any unusual or severe distress identified in the field.

DATABASE DEVELOPMENT

Database development consists of entering the collected information that is pertinent to the pavement sections into a common database file. This includes all information that was collected during the records review process and during the pavement evaluation. Quality control measures should be used to ensure that the integrity of the database is maintained.

Many APMS software options permit the user to define many database fields to meet specific requirements. It is important to investigate the options available prior to entering data into an APMS database.

SOFTWARE CUSTOMIZATION

During the APMS customization, the policies, practices, and procedures of the agency using it must be taken into account in order for the final product to reflect the decision process used by the agency. The customization involves activities such as the development of pavement performance models, the development of prioritization guidelines, the identification of maintenance policies, and establishment of unit costs for various M&R activities.

Performance Models

The development of pavement performance models is an important part of APMS software customization. The performance models are used within an APMS to predict pavement performance over time, and assist in determining the appropriate time to apply maintenance or rehabilitation to a section so that the benefits obtained from the expenditure are maximized. In addition, by projecting the rate at which the pavement condition will change over time, a meaningful life-cycle cost analysis can be performed to compare the costs of different rehabilitation alternatives.

There are several methods that can be employed to create pavement performance models. The selection of which method an agency should use is greatly dependent upon the amount of data that are available and the APMS software being used.

One method that can be employed is known as the expert modeling approach (Zimmerman 1999). This technique is generally used when there are not enough data to create an appropriate deterioration model. These performance models are based primarily on the opinions of engineers that are familiar with the way different pavement surface types deteriorate over time.

Regression analysis, either linear or nonlinear, is another common method used to create performance models. These models may need to be constrained so that the condition of the pavement section does not increase after it has deteriorated. One common type of the regression analysis approach that can be utilized to create performance models is known as family modeling. The main concept of family modeling is to divide pavements up into groups (or families) that are expected to perform in comparable ways (Shahin 2001). Typical characteristics such as pavement surface types (AC, PCC, etc.) and functional classifications (runways, taxiways, aprons or ramps, etc.) are utilized when creating the pavement families. Performance models are then created based on the available condition data to show a typical deterioration curve for all of the pavement sections within each family.

Markov modeling and mechanistic modeling are two other methods for developing pavement performance models. Historically, neither of these modeling approaches has been used in APMS.

Maintenance and Rehabilitation Policies and Associated Treatment Costs

APMS software can usually be customized to include the M&R polices that an agency will consider for use on their pavements. In some APMS software, the user can specifically define what factors should trigger the consideration of different pavement repair types such as overall condition level, type of distress present, rate of deterioration, and so on. Also, the costs for each treatment can be established in most APMS software.

Prioritization Guidelines

The development of prioritization guidelines is another aspect of APMS software customization. Prioritization guidelines act as a sort of ranking system for the pavement projects identified during the analysis as needing some sort of M&R action when the available funds are limited. These guidelines are based on the practices of the agency; examples of factors that can be employed are the pavement condition and the use of the pavement.

DATA ANALYSIS

APMS data analysis can be separated into three main activities: condition analysis, needs analysis, and impact analysis.

Condition Analysis

Condition analysis involves determining the current condition of the pavement network in terms of overall condition, cause of deterioration, and rate of deterioration. An overall condition value or rating provides a sense of overall pavement condition and can be an indicator of the magnitude of work that will be required to rehabilitate the pavement. It also provides the means for comparing the condition of one pavement section to another.

The types of distresses identified during an inspection provide insight into potential causes of the pavement deterioration. The cause of pavement deterioration can be broken down into structural, climate, materials, age, or a combination of those factors. Examples of load-related distresses include alligator cracking and rutting on AC pavements and corner breaks in PCC pavements. Examples of climate- and materials-related distresses are block cracking and weathering or raveling for AC pavements and joint sealant deterioration for PCC pavements. By knowing the causes of the pavement deterioration, more appropriate repair and rehabilitation alternatives can be identified.

The loss in condition over time (i.e., the pavement's rate of deterioration) is another factor of interest in evaluating the performance of a pavement. Pavements exhibiting a higher-than-normal rate of deterioration warrant close monitoring in the future.

Needs Analysis

Needs analysis involves developing an M&R schedule for the pavements being managed. A needs analysis requires that appropriate M&R activities be selected for each pavement based on predicted pavement performance. Budget constraints are considered during the development of a needs analysis, so M&R activities must be prioritized. The output of a successful needs analysis is a list of annual, prioritized M&R projects and associated costs.

Impact Analysis

Impact analysis involves comparing different M&R plans to determine the impact that different decisions will have on the pavement network. By assessing condition trends over time, an agency can quickly determine whether the overall health of the network is improving or deteriorating

under certain funding levels. Another type of impact analysis is to determine M&R backlog. In other words, an agency can track the amount of pavement that requires M&R, but because of budget constraints is not being repaired. The most important benefit of an impact analysis is the ability to contrast the different impacts that different budget levels or rehabilitation strategies have on the network over time. The use of an APMS facilitates this type of analysis by providing the tools necessary to perform the analysis as well as the graphics necessary to visualize the impacts on the network over time.

GEOGRAPHIC INFORMATION SYSTEMS

The use of GIS at airports in the United States has increased in the last few years. As airports realize the benefits and recognize the gains from implementation of various GIS applications, additional applications are being added. One of the new practices in state-of-the-art airport infrastructure management is the combination of maintenance management with GPS and GIS technology for better management of airport resources and better coordination with operations (McNerney 1995).

APMS OUTPUTS

Results of planning analyses are useful only if the information provided can be easily conveyed. There are a number of different methods for presenting the results of the analyses discussed previously including tables, reports, graphs, and maps.

Often, engineers prefer seeing detailed information in the form of comprehensive reports. However, because of the volume of information contained in these types of reports they might not be effective for quickly conveying information to managers or airport sponsors. Instead, graphical reports are often more effective for people who need to quickly evaluate large amounts of data.

There are several types of reports and other various outputs that can be generated directly from the pavement management software program. These depend greatly on the software type that is selected. Some APMS software allows for the creation of a user-defined report that enables the user to create a report that contains the information of their choosing. Also, if the software program selected has GIS capabilities, a GIS report can typically be generated as well.

TRAINING

An important consideration in the APMS implementation process is proper training of the individuals who will be using this system. At the completion of the training process, the agency should have all the skills necessary to operate the program efficiently and effectively. Training typically includes formal sessions that cover topics such as pavement evaluation, APMS concepts, and the use of APMS software. Best results have been reported when training is ongoing throughout the implementation process and arrangements are made for periodic follow-up training.

FOLLOW-UP

The usefulness of the information obtained from an APMS is dependent on the quality of the data being used. It is of extreme importance, therefore, that a follow-up plan be created as part of the APMS implementation process. This plan outlines the information that needs to be updated, whether employees or consultants will be responsible for the collection and updating of each of the items listed, and with what frequency each item needs to be collected. The following is a partial list of the items in an APMS that will require periodic revision.

The condition data must be current and reflect existing conditions. The frequency of re-inspections is dependent upon the agency, available manpower (if performed by agency staff), funding, and the facility use. If funding does not permit this cycle at the larger facilities, one approach is to inspect the runways annually and the remaining pavements every 2 to 3 years.

If rehabilitation projects alter the pavement management sections, or if new sections are added to the network, the following will likely need to be adjusted:

- Maps,
- Database network definition,
- Last construction dates,
- Surface types,
- Performance family assignments, and
- Section areas.

Challenges

There are four basic challenges that an airport agency may encounter during the implementation of an APMS depending on the type and size of the agency and airport being managed:

- Obtaining support for the APMS;
- Funding the APMS;
- Managing the APMS; and
- Meeting needs of diverse groups of users.

OBTAINING SUPPORT FOR THE APMS

The first challenge is to obtain support for the APMS. Often, a person familiar with APMS and the benefits it can offer to the airport or agency leads the charge. At the state level, it is often a member of the state aviation engineering staff that serves this role. At a large commercial airport, the effort is often initiated within either the maintenance division or the engineering division. At a small airport, the airport sponsor or manager would most likely initiate the effort. The champion must go about the process of informing others about the value of APMS and why the agency should consider implementing an APMS.

One successful approach to obtaining the needed support for an APMS is to identify potential users of the system and form a committee that includes representatives from each group. A facilitator is selected to interview each user group to identify their needs. The APMS committee should be involved throughout the implementation process. The group is then responsible for providing guidance during the installation.

FUNDING THE APMS

Obtaining the necessary funding for the implementation and upkeep of an APMS is another challenge that must be taken into account before the implementation process is begun. Funding is necessary for all areas of the APMS including the software, hardware, training, collection of data, and the analysis of data. It also includes funding for the personnel that will be responsible for operating and maintaining the system.

MANAGING THE APMS

Before an APMS is implemented, it is very important that the airport agency determine which division within the organization will manage the program. The managing and updating of the APMS must be continued on a regular basis; however, it may prove to be a difficult process due to the typically limited staff available to complete this task. To address this problem, the APMS should be designed from the beginning for continual growth (Broten 2004*b*). A follow-up plan

should be created during the APMS implementation so that it is easier to determine what data need to be updated, by whom, and at what frequency (University of Illinois 2003).

Various groups within an organization require different types of information from an APMS and with different levels of detail. Upper management requires less detailed information, mainly in graphical and mapping formats. Engineering staff use the data to make plans for the long-term rehabilitation of the pavement infrastructure; therefore they need detailed and comprehensive data regarding the condition of the pavements and available M&R options. Maintenance departments must setup day-to-day and annual maintenance program; therefore, they need detailed distress information. To meet everyone's needs the APMS must be user friendly at all levels and have a mechanism to share the APMS results throughout the agency.

Conclusions

Historically, most agencies responsible for managing airport pavements have made decisions regarding M&R based on experience and best engineering practices. However, since 1985 the number of airport agencies using APMS to help them manage this critical asset has grown dramatically.

The role of an APMS is to assist decision makers in developing economic viable strategies to maintain the pavements in a serviceable condition over a given period of time. APMS provides a consistent, objective, and systematic procedure for determining priorities, schedules, and allocating resources. It can also quantify information and provide specific recommendations to maintain a pavement network at an acceptable level of service while minimizing pavement-related expenditures.

The primary steps involved in implementing an APMS include identifying the APMS users and their needs, selecting APMS software, conducting a pavement inventory, evaluating pavement condition, customizing APMS software as needed, analyzing data, generating reports and other outputs, and obtaining training on the APMS process and software. After an APMS has been implemented, continued support and update of the APMS is critical.

The major challenges associated with the implementation of an APMS include adequate training, sufficient funding, satisfying diverse needs, and maintaining the database. In order to surmount these obstacles, the APMS needs to receive commitment from all levels of management before implementation. This commitment consists of resources in terms of personnel to maintain the database and finances to continue supporting the APMS. Additionally, it is essential that adequate training is available and provided to all personnel connected with the APMS either in terms of data collection, developing models, or understanding program outputs. Finally, the APMS should be flexible to accommodate future user needs and expansion.

References

ASTM D 5340, Standard Test Method for Airport Pavement Condition Index Surveys., 2003.

Benedetto, A. A Decision Support System for the Safety of Airport Runways: The Case of Heavy Rainstorms. *Transportation Research Part A: Policy and Practice*, Vol. 36, No. 8, 2002, pp. 665–682.

Broten, M., and M. Wade. How to Sustain a Pavement Management System at a Commercial-Service Airport. Presented at 6th International Conference on Managing Pavements, Queensland, Australia, 2004b.

Broten, M., and R. De Sombre. The Airfield Pavement Condition Index (PCI) Evaluation Procedure: Advantages, Common Misapplications, and Potential Pitfalls. Presented at 5th International Conference on Managing Pavements, Seattle, Washington, 2001.

Broten, M., C. Comer, and A. Muntasir. State Airport Pavement Management Practices and the Impact on Pavement Condition. Presented at 6th International Conference on Managing Pavements, Queensland, Australia, 2004a.

Broten, M., D. Peshkin, M. Wade, and A. Wolters. Prioritization of Airfield Pavement Rehabilitation Projects. Presented at ASCE Airfield Pavement Specialty Conference, 2002.

Broten, M., G. Schwandt, and S. McNeely. Airport Condition Assessment. *ASCE Proceedings*, Denver, Colorado, 1993.

Broten, M., G. Schwandt, and R. Blanco. Adapting an Automated Data Collection Devise for Use on Airports. *Proc., ASCE Infrastructure Management Specialty Conference*, 1997.

Calautti, J., and S. Murrell. Roughness Assessment in Pavement Management at New York Metropolitan Area Airports. Presented at FAA Worldwide Airport Technology Transfer Conference, Atlantic City, N.J., 2004.

Chee, K. GTAA Pavement Management System Status Update. Public Works and Government Services of Canada Workshop, February 12–13, 2003.

Chu, C.-P., and W.-Y. Huang. Analysis of Maintenance Needs for Improving Runway Skid Resistance. Presented at 5th International Conference on Managing Pavements, Seattle, Washington, 2001.

Comer, C., and M. Broten. Leveraging the Use of Pavement Management Results, 5th International Conference on Managing Pavements, Seattle, Washington, USA, 2001.

FAA. Authorization Act of 1004 (Public Law 103-305).

FAA. *Guidelines and Procedures for Maintenance of Airport Pavements*. Advisory Circular 150/5380-6A. FAA, Washington, D.C., 2003.

FAA. *Pavement Management System*. Advisory Circular 150/5380-7. FAA, Washington, D.C., 1988.

Feighan, K., and A. Reynolds-Feighan. An Application of Damage Cost Allocation for Airport Services in Ireland. Presented at 6th International Conference on Managing Pavements, Queensland, Australia, 2004.

Fonseca, O. A. A Network-Level Approach for Simultaneously Managing Pavement of a Set of Airports. Presented at 5th International Conference on Managing Pavements, Seattle, Washington, 2001.

Gadallah, A. A., H. S. Mahgoub, and S. M. El-Gioshy. Development of an Airfield Pavement Management System. 3rd Transportation Specialty Conference, Canadian Society for Civil Engineers, London, Canada, 2000.

Gartin, R. S., C. A. Chow, and H. Zubeck. Alaska Airports Pavement Management Program: Case Study of Implementing Micro-PAVER at 48 Airports in Alaska. Presented at 80th Annual Meeting of the Transportation Research Board, Washington, D.C., 2001.

Gendreau, M., and P. Soriano. Airport Pavement Management Systems: An Appraisal of Existing Methodologies. *Transportation Research Part A: Policy and Practice*, Vol. 32, No. 3, 1998, pp. 197–214.

Haas, R., W. R. Hudson, and J. Zaniewski. *Modern Pavement Management*. Krieger Publishing Company, Malabar, Florida, 1994.

Hayes, F. O., W. C. Greer Jr., D. J. Molloy, S. R. Kuchikulla, and Q. B. Watkins. Hartsfield–Jackson Atlanta International Airport: Pavement Evaluation Program.

Hede, J. C. H., and J. Andersen. Airpave Management—An Innovative Integrated Pavement Management System for Airport Pavements. Presented at 5th International Conference on Managing Pavements, Seattle, Washington, 2001.

Hossain, M., and S. Uddin. Evaluation of General Aviation Airport Condition in Kansas—Results and Implications. Presented at 5th International Conference on Managing Pavements, Seattle, Washington, 2001.

Huang B., T. F. Fwa, W. T. Chan, and S. B. Liu. Implementation of GIS/GPS-Based Airport Pavement Management System: A Case Study. Presented at 6th International Conference on Managing Pavements, Queensland, Australia, 2004.

McNerney, M. T. Airport Infrastructure Management Using Geographical Information System: State of the Art. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1703*, TRB, National Research Council, Washington, D.C., 2000, pp. 58–64.

McNerney, M. T., and R. Harrison. Full-Cost Approach to Airport Pavement Management. *Handbook of Airline Economics* (D. Jenkins, ed.), McGraw-Hill, 1995, pp. 121–130.

Ollerman, F., and A. Varma. Development and Visualization of Airport Pavement Management Information: Lessons Learned. Presented at 77th Annual Meeting of the Transportation Research Board, Washington, D.C., 1997.

Papaleo, S. Airport Pavement Maintenance Management Systems. 1998 Frank Magee Scholarship, Airport Planning Pty Ltd., 1998.

PWGCS. *A Best Practice for the Implementation of a Pavement Management System for Small and Medium Airports*. ATR-045. Public Works and Government Services Canada, Ottawa, 2002.

Shahin, M. Y. Pavement Management–MicroPAVER Update. Presented at 5th International Conference on Managing Pavements, Seattle, Washington, 2001.

Shahin, M. Y., J. A. Burkhalter, and K. A. Keifer. Airport Pavement Management: Enhancements to MicroPAVER. Presented at FAA Technology Transfer Conference, 2002.

Shahin, M. Y., J. Schmidt, J. A. Burkhalter, and K. A. Keifer. Pavement Management–PAVER Update. Presented at 78th Annual Meeting of the Transportation Research Board, Washington, D.C., 1999.

Sun, L., S. Kan, and Y. Ji. Evaluation and Rehabilitation Models of Airport Pavement Management System: A Case Study of Shanghai Pudong International Airport. Presented at 6th International Conference on Managing Pavements, Queensland, Australia, 2004.

University of Illinois. CEE 498 Pavement Management Systems Textbook, 2003.

Zimmerman, K. *NCHRP Synthesis of Highway Practice 222: Pavement Management Methodologies to Select Projects and Recommend Preservation Treatments*. TRB, National Research Council, Washington, D.C., 1995.

Zimmerman, K., and M. Broten. Development of Performance Models for PMS. Presented at 24th International Air Transportation Conference, ASCE, 1996.

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

TRB

TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001

THE NATIONAL ACADEMIES™
Advisers to the Nation on Science, Engineering, and Medicine

The nation turns to the National Academies—National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council—for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org