AIRPORT PAVEMENT MANAGEMENT SYSTEMS (PMS)

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ABSTRACT

This paper provides an overall view of airport PMS components and presents the experiences of different world airports in PMS implementation, use, and benefits. The primary components described in the paper include pavement inventory, pavement inspection, condition assessment, condition prediction, condition analysis, and work planning. The use of Geographical Information Systems (GIS) is also presented. Experience using PMS from different countries including Unites States, Norway, Sweden, Holland, Denmark, and Finland is presented. The PMS inventory component is for defining the management sections of the airfield pavements. Inspection is primarily based on distress but may also include structural, skid, and roughness surveys. Condition assessment is the reduction of the inspection data into condition indexes that are useful for pavement functional and structural evaluation. Condition prediction is the ability to predict the derived condition indexes in the future and to be able to perform maintenance and repair (M&R) budget consequence analysis. Condition analysis is the ability to view past and future conditions assuming no major M&R is performed. Work planning is the ability to determine the condition and M&R backlog consequence of a given budget. Alternatively, work planning is the ability to determine budget requirements for a desired condition level or M&R requirements. Inventory, condition, and analysis data can also be presented on airport maps using GIS technology. The primary requirement is to link the pavement inventory management sections to the GIS map polygons. There are several different computerized PMSs currently in use by airport authorities around the world. The pavement management components of selected systems will be presented. Also presented will be a description of how these various systems are being used and benefits derived by the airport authorities.

KEY WORDS

PAVEMENT MANAGEMENT SYSTEM / CONDITION PREDICTION / CONDITION ANALYSIS / PAVEMENT CONDITION INDEX

1. INTRODUCTION

Airfield pavement management has been in use by many civil and military airport agencies around the world for many years. In the past, the main difficulty facing the pavement engineer was to convince upper management that the benefits of implementing a pavement management system (PMS) far exceeds the implantation cost. Today, this is no longer an issue. Rather, the issue is how to best implement a PMS and use it to serve the agency and users.

The main objective of this paper is to briefly present the essential components of a PMS for airfield pavements and to provide different airport agencies experience with:

- PMS initiation
- Data update procedures including inspection
- How the PMS is being integrated in the agency's current business practices
- Summary of the most beneficial aspects of having the system in place

The airport agencies participating in this paper include: The U.S. Ohio Department of Transportation, Office of Aviation; Avinor in Norway; Swedish Civil Aviation Administration; and Civil Aviation Administration, Finland.

2. AIRFIELD PAVEMENT MANAGEMENT COMPONENTS

2.1. Inventory definition

The airfield pavement network is broken into branches and sections. A branch is an easily identifiable entity with one use, i.e. a runway, taxiway, or apron. Each branch is divided into uniform sections based on construction, condition, and traffic channelization. A section can only be of the same pavement type, i.e. asphalt or concrete. A section can also be viewed as the smallest pavement area where major M&R, such as overlay or reconstruction, will be scheduled.

Section identification is normally performed using AutoCAD. This allows easy conversion of the drawing into a GIS shape file using tools such as ArcView. Shape files are useful to display pavement data on airfield maps.

2.2. Pavement inspection

At a minimum, airfield pavement inspection consists of a distress survey every 1 to 5 years. Skid resistance measurement and Non-destructive Deflection Testing (NDT) are normally performed every 5 to 10 years. Runway longitudinal profile measurement is usually not performed unless there is a pilot complaint about pavement roughness.

2.3. Condition assessment

The inspection results are reduced to condition indicators that can be used for pavement management. A widely used distress index is the Pavement Condition Index (PCI). The PCI, Figure 1, is a score from 0 to 100 that measures the pavement structural integrity (not capacity) and surface operational condition. It correlates with the needed level of M&R and agrees closely with the collective judgment of experienced pavement engineers.

The skid resistance data is reduced to a friction index for the runway. The NDT data is reduced to a structural index such as the Aircraft Classification Number/ Pavement classification Number (ACN/PCN).

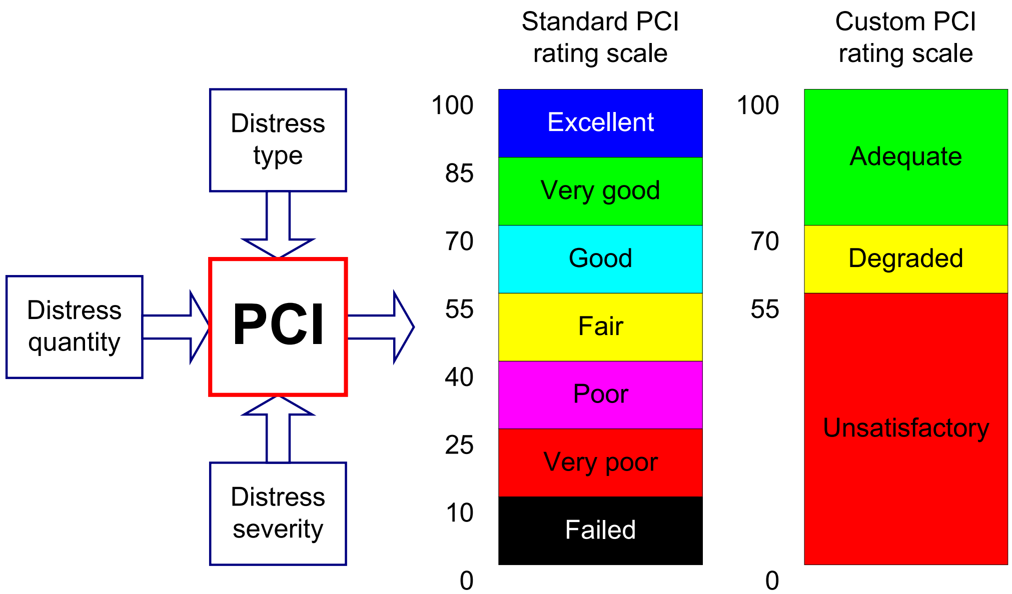


Figure 1: Pavement Condition Index standard and custom rating scales.

2.4. Condition prediction

There is no such thing as one prediction model that will work for all locations and conditions. Therefore, it is important that the PMS include a prediction modeling engine that can be used to formulate different models for different locations and conditions. Figure 2 is an example model developed for asphalt taxiways for a general aviation airport. Such a model is used to predict the future deterioration of the asphalt taxiway pavement sections assuming that the traffic will continue to be the same as in the past. An accurate condition prediction is also important for the analysis of different budget consequences.

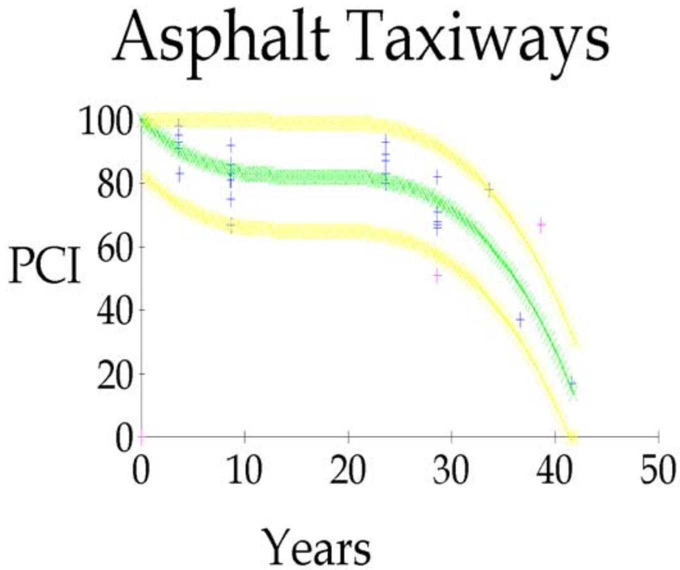


Figure 2: Prediction model for asphalt taxiways at a general aviation airport.

2.5. Condition analysis

A condition analysis routine should allow the airport managers to see past conditions and where is it going to be in the future assuming no major M&R is performed. This condition analysis allows managers the ability to assess the consequence of past budget decisions and the value of having a PMS especially if the PMS has been in place for several years.

2.6. Work planning

The work-planning module should answer two categories of questions. First, for a given budget, what is the most economic M&R strategy and what is the consequence of that action on the future network condition and backlog of M&R. Alternatively, given a desired condition objective, how much should my budget be. Typical objectives include maintaining current network condition, reaching a certain condition in x years, or eliminating all backlog of major M&R in x years. Figure 3 shows the results of performing such analysis on a general aviation airport.

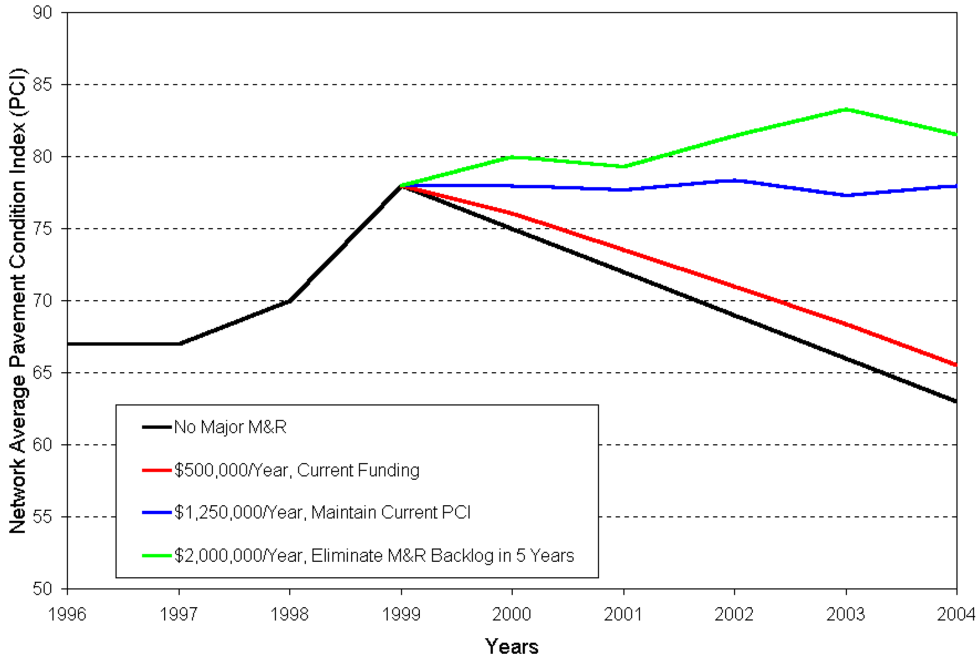
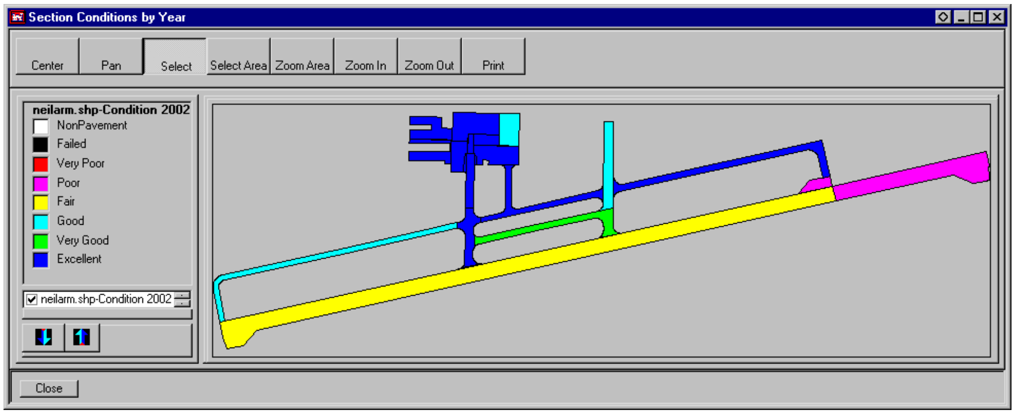


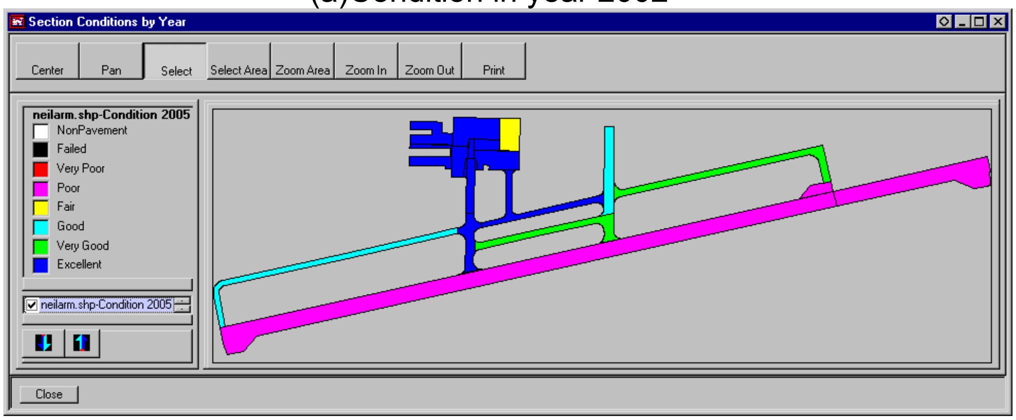
Figure 3: M&R work plan scenarios based on different funding options.

2.7. GIS linkage

The results from all the above components can best be presented in color using an airport map, which can be easily achieved if the PMS allows for easy linkage to GIS, i.e. each pavement section is linked to the corresponding GIS polygon. Figure 4 shows the airfield pavement condition at the time of survey and projected condition if no major M&R is performed.



(a)Condition in year 2002



(b) Condition in year 2005

Figure 4: a) Condition of the airfield at time of survey (2002), b) Projected condition of the airfield in 3 years (2005).

3. U.S. OHIO DEPARTMENT OF TRANSPORTATION, OFFICE OF AVIATION AIRPORT PAVEMENT MANAGEMENT AND GIS

Why PMS? A PMS provides the most cost effective, non-biased grant selection process for maintaining airport pavements in Ohio.

3.1. History

Ohio built 60 new general aviation airports between 1960 and 1971 to boost state and local economies. By the early 1980's, the pavements were in need of repairs and overlays. The Ohio Department of Transportation (ODOT) implemented an airport grant program for major M&R with a maximum $50,000 per grant. (In 2003, state funding provides a maximum of $175,00 per grant.) Grants were used to offset the cost of construction for local governments. In each fiscal year, all publicly owned public-use airports sent a grant request for pavement work. The ODOT Office of Aviation would fly to each airport to review the grant requests. Once the reviews were complete (which took up to a month), grants were issued. This process of grant selection was used from 1980-1986.

In 1986, ODOT airport engineer Mark Justice P.E. reviewed the grant allocation process and found it to be costly in time and state assets. In an effort to save time and money, a pavement management system (Micro PAVER) was purchased.

3.2. Airport pavement inspection setup

Airports are broken into branches (runways, taxiways, and aprons), sections (based on construction history and pavement structure), and finally into sample units (5000 sq. ft. areas for AC pavements). Between 1986-1994, all inspection data collection was completed on paper inspection forms and manually entered into the computer. Research found that with the expanding computer technology and practicality of tablet computers, the amount of time spent on generating paper inspection sheets and entering computer data manually could be reduced enough to recoup the computer cost within two years of inspections.

3.3. Current inspection practice: 1994-2003

At present, there are 97 General aviation airports in the ODOT pavement management system ranging from small (3000 ft. x 65 ft. runways) to larger corporate/military facilities (9000 ft. x 150 ft. runways). One-third of these airports are inspected each year. A pen-based tablet computer is used for inspection data entry in the field. Inspections are completed in all types of weather due to the ruggedness and durability of the tablet computer. With Micro PAVER installed on the tablet computer, data is entered directly into the PMS, Figure 5. A GIS program (ArcView) is used to guide the pavement inspector around the airport to the sample units to be inspected using the airport AutoCAD drawing, Figure 6. The PMS program and GIS program are used in the field by toggling between the two programs on the tablet computer. Images of the airport can also be stored in the Micro PAVER database. However, the GIS program is used since it allows the inspector to use a measuring tool on the airport drawings. Once the inspection data is collected, the data is downloaded to the desktop PC through the Micro PAVER import routine.

Figure 5: Pen computer set up for field data entry. Keypad is used to enter data.

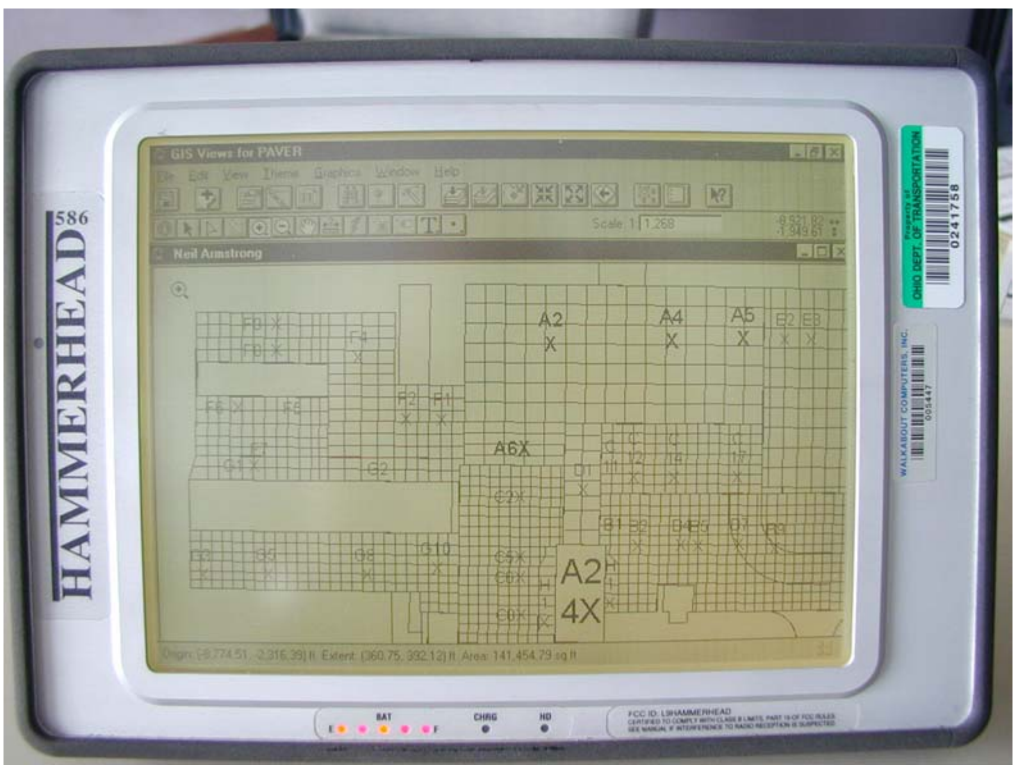


Figure 6: Pen computer with ArcView airport project used during inspections.
Note: sample to be inspected designated with an (X).

3.4. Grants

ODOT primarily uses the PMS for the selection of the annual $2,000,000 pavement maintenance grant program in the state of Ohio. The PMS system is also used to provide input for the Federal Aviation Administration (FAA) State apportionment $8,000,000 grants.

Each airport sends their five-year Airport Capital Improvement Plan (ACIP) to the FAA regional office. The FAA regional office then sends this ACIP to the State of Ohio to select the grant aid projects. State side aid is limited to pavement M&R, while the federal side aid can be used for other airport projects that are eligible in the FAA grant program such as runway extension, land acquisition, etc.

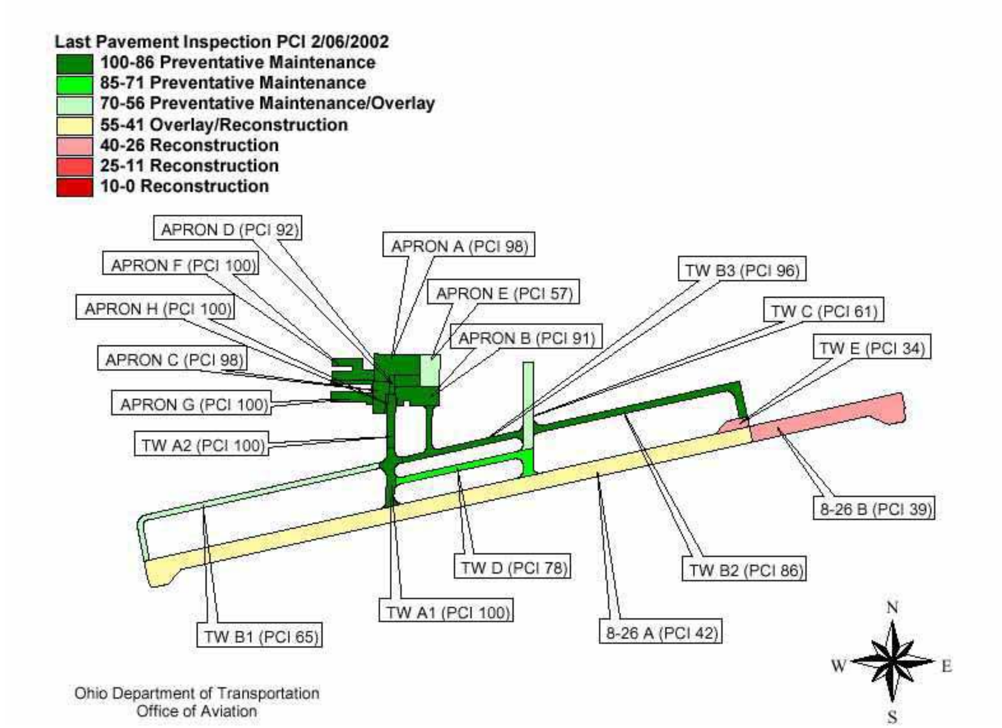
The selection criterion for ODOT is based on the PCI and priority ranking of pavements. ODOT considers the following when selecting eligible projects to be funded (in order of decreasing priority):

- Priority 1: Runways with a PCI less than 55
- Priority 2: Runways with a PCI between 55 and 65
- Priority 3: Taxiways and aprons with a PCI less than 55

State Grants:
Ohio pays 80% of the total project cost with the local match of 20% (limited to $175k)

FAA Grants:
FAA pays 90% of the project with the local match of 10%.

With the use of GIS, ODOT is able to supply our airports with a tool that shows current pavement M&R needs, Figure 7a. This information is located on ODOT, Office of Aviation website at www.dot.state.oh.us/aviation. The majority of the airport operators are not educated on pavement construction and M&R needs. For this reason they can use the information on the website to help secure grant funding. Also included on the website is a pavement history, an inspection letter suggesting preventative maintenance, and what pavement section to submit when applying for the next grant at each airport. An example of the GIS map and an excerpt from the inspection letter is included in Figures 7a and 7b.



(a)

[Pavement maintenance suggestions: Crack seal all pavements as needed. Runway A and B are in need of rehabilitation. This can be in the form of partial or full depth reconstruction, or a combination of both. Please contact me for further details. Taxiway B1 and C require a leveling course and thin overlay to correct surface deformities. Taxiway E (the turnaround button on the east end of the older runway) needs complete reconstruction, or removal of portions not used, and the balance reconstructed. Please call if you have questions.

Due to the decreasing funding available to the Ohio Airport Grant Program, and the ever-increasing cost of construction, we are requesting all airport sponsors to perform regular maintenance on all airport pavement surfaces. Our records indicate that when performed on a regular basis, a pavement life can be extended by as much as 50% by performing just the basic maintenance, i.e. crack filling. We find ourselves in a position of making grant funding choices based on whether sponsors perform regular pavement maintenance. Please use the suggestions in this letter as a basic guide. For more in-depth maintenance suggestions, please call.]

(b)

Figure 7: a) Example color-coded GIS map and b) corresponding inspection letter.

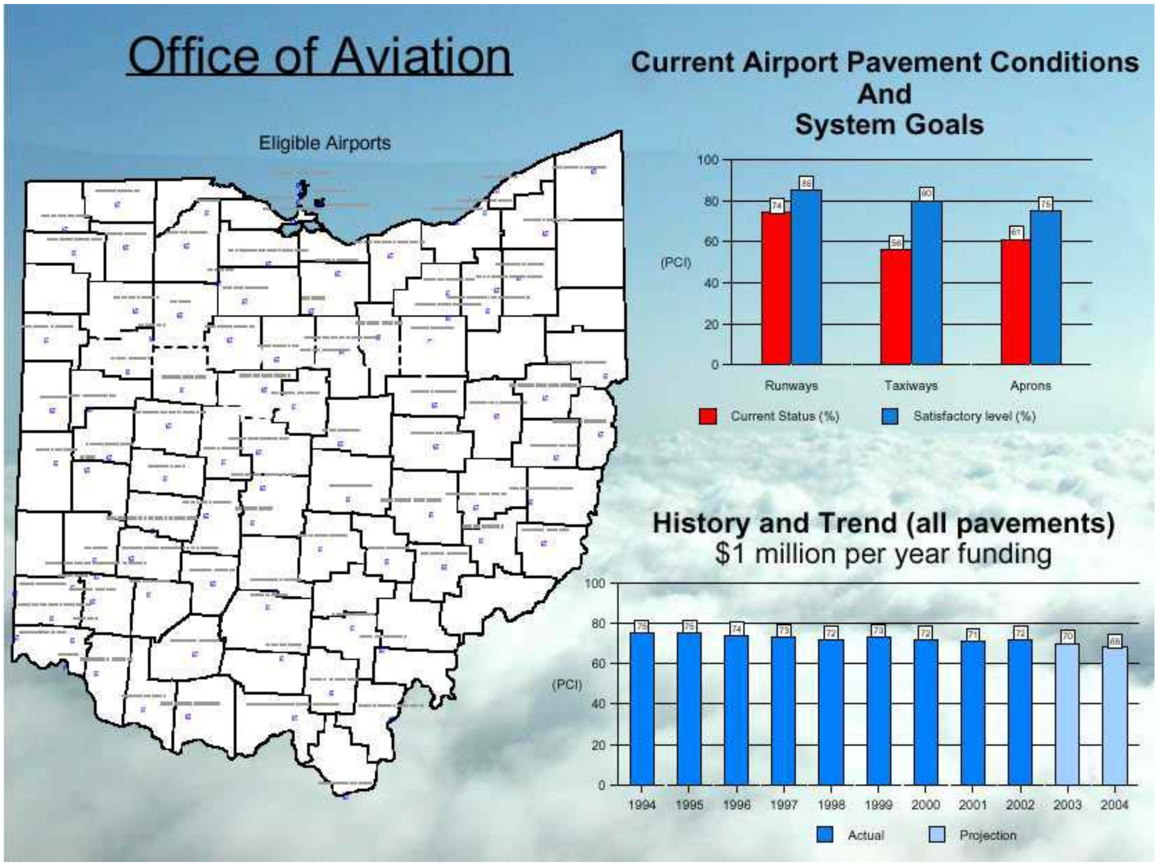


Figure 8: Sample output excerpt from the Ohio state of the airport system report.

Each year the ODOT Office of Aviation submits the state of the airport system to the Ohio legislators for budget determination.

With the PMS, the airport system report can be completed in hours as compared to four or five days. Using GIS, the information is more user-friendly to airport sponsors. The report includes current and future pavement conditions and future conditions and pavement trends system, Figure 8. In addition, ODOT also produces a detailed summary that shows the cost to maintain the airport system, and the funding needed to bring airport pavements to ODOT's system goals. PMS and GIS capabilities supply management and elected officials with consistent data in the most cost efficient process.

With the current trend of government funding, the ODOT, Office of Aviation needs to continue to be smarter with our grant funds and use of state assets. The need to maintain the Ohio Airport System is vital to state and local economies. Using an efficient Pavement Management System will insure that our airport pavements are maintained in operational and safe condition.

4. PMS IN NORWAY (AVINOR)

Avinor (known earlier as the Civil Aviation Administration in Norway) is a state enterprise, which owns and operates 44 passenger-traffic airfields in Norway. The area of airside pavements at these airports is about 7.5 million square meters. The majority of the pavements are asphalt, covering over 90 % of the total area.

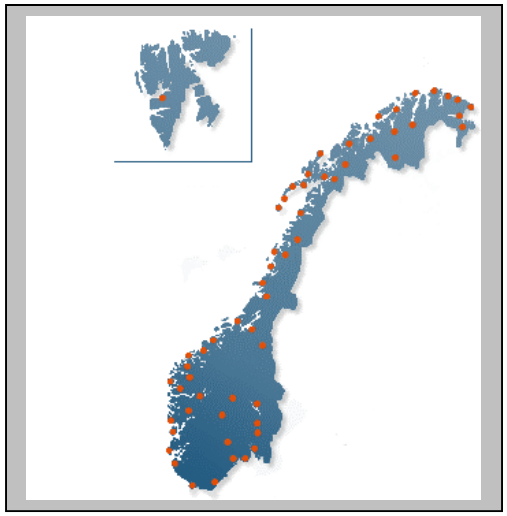


Figure 9: Airports managed by Avinor in Norway.

Major reconstruction and resurfacing, as well as major maintenance, for example slurry or fog seals, are handled by Avinor headquarters. Airport/region engineers handle minor maintenance.

In the late 1980's, Avinor collected comments from each airport (18 at the time) regarding pavement condition and required reconstruction or resurfacing for runways and taxiways. The feedback was enormous, but the problem was that 70 % of the runways required resurfacing the following year. To assist in maintenance prioritization, three engineers from Avinor headquarters conducted a pavement survey the same autumn with the aim of collecting enough information to create a prioritized budget for the next 5 years. A similar survey was conducted in 1995.

In 1997, the Norwegian government decided that 26 municipal airports with employees should be incorporated in Avinor. This incorporation created an additional 1.5 million square meters of pavement—most of which was in poor condition.

With 44 airports in different climates and with very different traffic (from 8 to 500 daily movements), a rating system was needed prioritize the projects and budgets between these airports. It was determined to use ASTM D5340, Airport Pavement Condition Index Survey, to obtain the condition of Avinor runways.

In 1998, five people, one in each of Avinor's regions, were educated in the PCI method and all of the airports were surveyed.

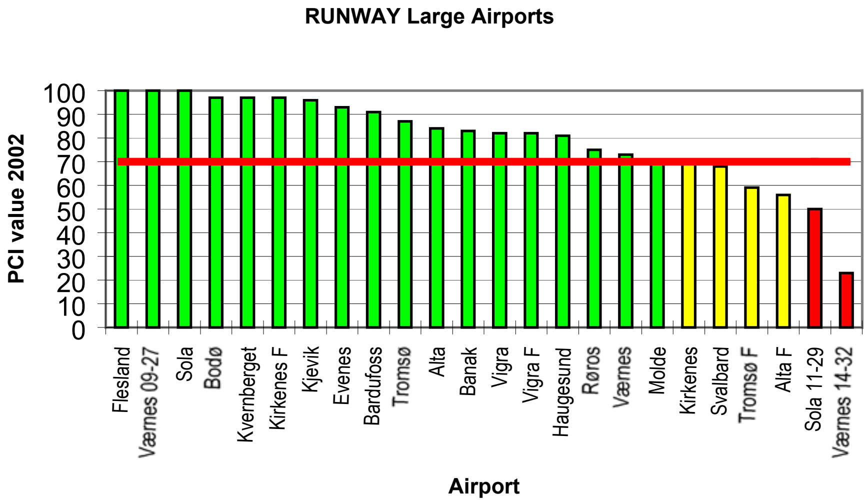


Figure 10: PCI condition for all runways at large airports.

Figures 10 and 11 show the conditions for all runways in 2002. Similar graphs are produced for taxiways and aprons but are not included here.

As shown in the figures, the acceptable condition limit for large airports (70) is higher than that for small airports (55) because small airports are only used by Dash 6, Dash 8, and Dornier 228 aircrafts.

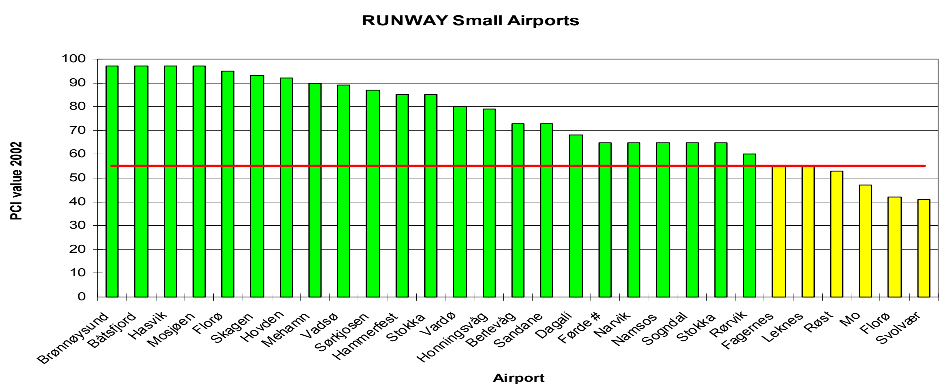


Figure 11: PCI condition for all runways at small airports.

The next step for Avinor is to do a condition analysis of the pavements. Additionally, a PMS has been implemented and each region and its engineer will conduct the PCI survey and add the results to the database. Major projects will, however, be prioritised by Avinor headquarters based on these survey results, and the complete and updated database will be handled by the headquarters.

5. SWEDISH CIVIL AVIATION ADMINISTRATION

5.1. Background

All nineteen airports in Sweden owned by the Swedish Civil Aviation Administration (SCAA) are a part of the Pavement Management System (PMS). There are also some other municipal and private airports included. Inspections are performed every three years. The inspection results constitute input to the Micro PAVER program. On the whole, Swedish airports have runways and taxiways of asphalt pavement. Concrete pavements exist at some apron stands and occur rarely on runways and taxiways.

5.2. Airfield inspections

There are four qualities that may be satisfied at airfield inspections: bearing capacity, friction, surface condition and pavement regularity. The Pavement Condition Index (PCI) is used for surface condition. At the inspections performed every three years, different distress types are evaluated including about 15 distresses each for asphalt and concrete.

About 10 % of the whole airport area with runways, taxiways and aprons compose input to the PCI value. Beyond these areas, some additional areas can be inspected, especially on runways and taxiways if particular distresses are represented.

Runways are divided into three longitudinal sections, three transversal sections, and shoulder sections (see Figure 12). The transversal sections consist of the two touchdown zones and the middle section between. Taxiways are divided up in taxiway sections and shoulder sections.

Notes and photos are an important part of the input to the evaluation report done after every inspection.

Wet friction tests are performed one time in a three-year period at the SCAA airports. A Saab friction tester is used with a measuring speed of 95 km/h. There are three friction values measured, one for each runway section. Falling weight deflectometer measurements are performed about every ten years.

5.3. Evaluation Report

The inspection results impose an input to the evaluation report done for the airports in PMS every three years. The Micro PAVER program is an essential part of the evaluation report. Maps indicating PCI are among the most important output results. The maps most frequently used are a PCI value map showing the present condition and a predicted condition map of the PCI value at an airport. Annual condition plots with area-weighted condition averages are also used as a forecast tool.

Maintenance for the airports can then be produced based on the PCI values. The minimum PCI value level is 70-85 before maintenance is performed. The report helps the airport identify areas that are in need of maintenance to improve the pavement quality. This maintenance plan helps airports guarantee high flight safety and create economical optimization of pavement maintenance. It also facilitates an environmentally friendly system when long-term planning can be used.

5.4. Pavement measurements

The most common examples of frequent damages on asphalt pavements are weathering and ravelling effects, mechanical influence, longitudinal and transverse cracking, slippage cracking and damages related to bearing capacity. The evaluation report suggests maintenance performance related to a timetable for the works.

To increase the useful life of the pavements bituminous seal and slurry seal are used together with crack repairing. This maintenance work increases the time between major maintenance work such as milling with addition of new wearing courses and remixing/recycling maintenance.

Frequent damages on concrete pavements are different types of cracking, joint damage and mechanical damage. The maintenance work consists of joint repairing, full deep repairing and new construction of pavement.

5.5. PMS as a planning tool

The PMS constitutes an important part of the planning tools for pavement maintenance on the airports owned by the SCAA. There are many economical benefits with the system. A long-term planning of the budget work leads to economical optimizing, and it is easier to plan and coordinate purchasing for several airports regarding pavement maintenance. It also facilitates pavement management to avoid acute measurements that often result in higher costs.

Further use of the PMS gives a good overview of the pavement standards at the SCAA airports. This helps the airports justify money for maintenance work and also help them give priority to the right maintenance measures.

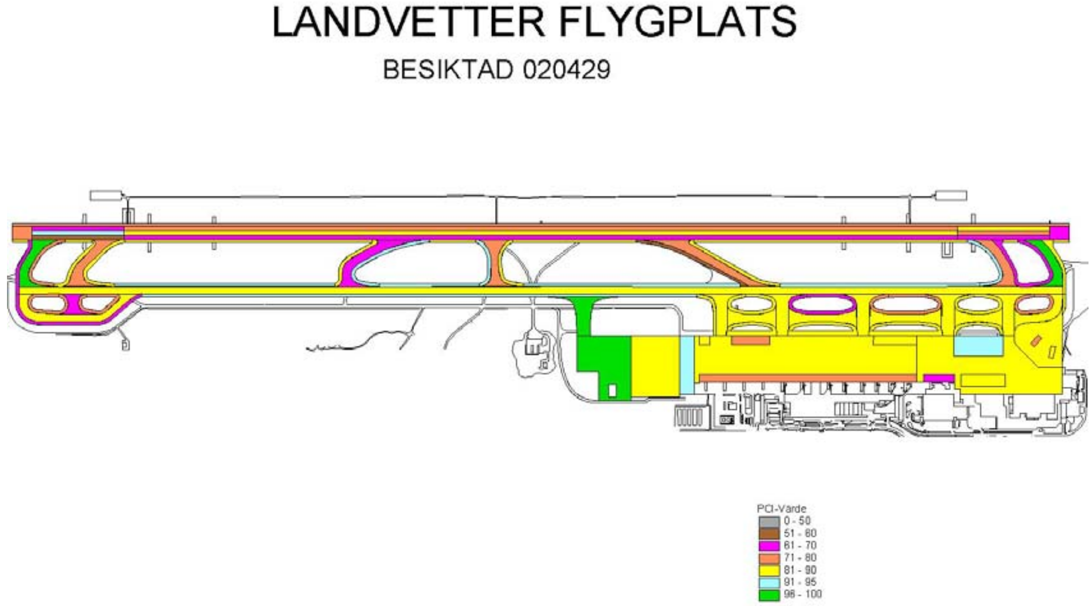


Figure 12: PCI value map from Gothenbug-Landvetter Airport showing the PCI values from the inspection done in April, 2002.

6. CIVIL AVIATION ADMINISTRATION, FINLAND

The condition of pavement surfaces is an important part of airport safety. Presently, it is vital for the pavement sector to have a tool for objective optimizing of the allocation of scarce resources.

The Finnish Civil Aviation Administration (CAA), which is responsible for the maintenance of 25 state-owned airports, has developed a new Pavement Management System for airfields. Experts from the Finnish CAA/Airports Department in cooperation with the University of Oulu, Finland carried out the work.

The PMS for Airfields has been completely used in Finland since 1993. Every airfield owned by CAA has been measured and the results have been fed into the program. Pavement condition analysis and maintenance management are executed by the assistance of PMS-Airfields. Thus far, the Finnish CAA has also measured some airfields in Sweden, Norway, and Estonia.

6.1. Pavement condition inventory

Condition data consist of functional data in terms of roughness and distress information. Structural data (bearing capacity), binder hardening, and skid resistance data can also be incorporated. All site-specific condition data can be gathered by automated equipment. The measuring device (mounted in any car, van, or truck) consists of a measuring detector, a pulse detector (connected to the odometer of the vehicle), and a central unit. The central unit has a keyboard and units for the collection and storage of data. Measurements can be taken by just one or two persons depending on the tasks involved. All site-specific data (IRI = International Roughness Index, cracks, depressions and swells) of one runway can be measured in a single 8-hour day.

6.2. Automatic data input

Stored data are transferred directly to a PC as basic data for the PMS software. Immediately after measuring, the PMS can be used for calculations with output in the form of critical points, condition indices, maintenance policy proposals, etc. Quick reports may be printed out on site.

6.3. Management and budgeting

The PMS software includes damage models for estimation and prognosis. Each measurement updates the prognosis curve, thus providing a better estimate of the future condition of the pavement.

6.4. Working principle of the Finnish PMS-Airfields

The workability and reliability of the Finnish PMS-Airfields system is based on the following:

- Damage to be mapped and measured can be clearly and unambiguously defined and the incidence of damage represents the overall condition of the pavement with sufficient accuracy
- Damage is mapped using a simple, standardized method of sufficient reliability and of low enough cost in relation to the total cost
- Damage data is easily and automatically transmitted from the measuring device to the PC
- Analysis of data is based on researched damage models specific to the prevailing conditions
- The system outputs reports containing prognoses of future development and proposals for alternative repairs of detected damage including cost estimates

6.5. Operation of the Finnish PMS-Airfields

6.5.1. Resident information

The pavement register contains register type data about pavements, contractors, aggregate, proportions, binder and other such information pertaining to construction and the paving materials of the airfield.

Runways and other areas contain data on structures, ages and types of pavement.

The maintenance register contains data on repairs, unit costs, and maintenance limits as a basis for the repair proposals and proposed annual estimates.

6.5.2. Damage inventory

ROADMASTER measuring equipment mounted in a measuring vehicle is used to map damage, not including skid resistance, bearing capacity and binder hardening which are subject to laboratory analysis. The operation of the measuring equipment is based on acceleration and slope detectors mounted on the rear axle of the vehicle, an electronic odometer pulse detector, and a central unit for data storage. Registered data deal with evenness and slope, depressions and swells calculated from vertical acceleration, and pavement damage subject to inventory (joint, longitudinal, transverse and alligator cracks).

6.5.3. Damage information analysis

The software calculates a Condition Index (CI) representing the pavement condition of the runway or part of the runway under study. The index is expressed in values from 0 to 100 (CI = 100 for a new and flawless pavement). The software compiles the Condition Index from the mapped damage and the damage models of sporadic damage, and the corresponding weights of the damage.

The forecast evaluates the development of the Condition Index on the basis of a life expectancy curve, which is updated with each measurement. A repaving year for the runway is calculated based on the forecast development of the condition.

Maintenance proposals contain proposals for the repair of sporadic damage as well as the total repair costs and the repair time. In the budget mode, the maintenance, cost, and timing proposals can be adjusted and edited to provide comprehensive maintenance programs.

6.5.4. Evenness and slope reports

The PMS-Airfields can be used to produce reports outside the system proper for the supervision and final inspection of pavement work. The evenness and transverse slope of the pavement surface can be monitored during construction, thus benefiting the quality of work in progress. The evenness of the new pavement can be measured immediately upon completion. An added function of the PMS-Airfields system is calculation and output of value alteration and distribution reports for acceptance inspection. The value alteration report reports on the compliance with the evenness requirements of the contract and the value alterations, if any, expressed in currency units. The distribution report gives the compliance with the overall evenness requirements and the distribution by sector in a number of evenness categories.

6.6. Summary of Finnish PMS-Airfields

The aim has been to develop the whole continuous inspection chain: inventory - calculation - analysis - management.
The PMS-Airfields is based on the following factors:

- Damage is surveyed using a simple, rapid, and sufficiently reliable standardized method, which is sufficiently low-cost, compared with the total.
- The transfer of damage data from the measuring device to the application running in a PC is easy and automatic.
- The analysis of the collected data (damage, roughness, depressions, swells) is based on thoroughly researched and condition-specific damage models.

7. SUMMARY AND CONCLUSIONS

This paper presented the essential components of a PMS for airfields and uses cases by four agencies from the United States, Norway, Sweden, and Finland. All the use cases clearly demonstrated the importance of implementing a PMS for airports. Stated benefits by the different agencies include:

- Provide necessary data to legislators and managers for budget determination.
- Creation of a prioritised 5-year budget.

- Establish minimum condition requirements.
- Identify areas in need of maintenance.
- Justification of M&R projects.
- Criterion for distribution of available budget among various airports in the agency.