APPENDIX B

CASE STUDIES

Case studies are an opportunity to explore additional details that help to illustrate successful practices and lessons learned in the collection, analysis, and use of pavement condition data. In this ACRP study, the project team identified candidate case study airports and agencies based on responses to the project survey, the experience of the project team, and input from the ACRP project panel. Agencies ultimately selected to participate as case studies had the shared characteristics of interesting and innovative practices, availability of additional information beyond their survey responses, and a willingness to participate in telephone interviews and subsequent reviews of completed reports.

Case studies were developed for the following seven airports and aviation systems:

- Houston Airport System (Houston, Texas)
- Salt Lake City Department of Airports (Salt Lake City, Utah)
- Dublin International (Dublin, Ireland)
- Columbus Regional Airport Authority (Columbus, Ohio)
- Gerald R. Ford International Airport Authority (GFIAA) (Grand Rapids, Michigan)
- North Dakota (statewide)
- Missouri (statewide)

As shown in Exhibit B-1, these case study subjects represent a broad span of airport sizes and locations. While within the case studies there are many more distinctions identified, this table highlights differences in pavement distress data collection methodologies.

Exhibit B-1. Categorization of case study airports and agencies.

Airport Type	FAA Region	Distress Data Collection Methodologies
Multiple Airport System (primary airport size) Houston Airport System (large hub) Salt Lake City Department of Airports (large hub) Columbus Regional Airport Authority (medium hub) Large Hub Dublin International[a] Small Hub Gerald R. Ford International Airport Authority (GFIAA) State Airport Authority North Dakota (89 airports) Missouri (69 airports)	Southwest Houston Mountain Salt Lake City Great Lakes Columbus GFIAA North Dakota Central Missouri	Manual Columbus GFIAA[b] North Dakota Missouri Automated Salt Lake City[b] Dublin Combination Houston

[a]Hub classification is only defined for U.S. enplanements, but if it were in the U.S. Dublin would be classified as a large-hub airport.
[b]Pavement condition data are collected by airport personnel.

In addition to providing insights that are used in the development of this report, the case studies are a source of more detailed information on the practices of these different agencies. It is clear that many different approaches to collecting pavement data can be successful under varying circumstances. An airport or consultant interested in learning more about the practices of others are encouraged to examine these case studies and consider the similarities and differences between their practices and those reported here.

The presentation of each of the studies follows a similar outline:

- Agency Background
- Data Collection
- Data Use
- Data Management
- Innovation/Best Practices
- Concerns and Desired Future Improvements
- References

CASE STUDY: HOUSTON AIRPORT SYSTEM (HAS)

Agency Background

The Houston Airport System (HAS) is a department of the City of Houston, Texas that manages three city airports—George Bush Intercontinental Airport (IAH), William P. Hobby Airport (HOU), and Ellington Airport (EFD)/Houston Spaceport, serving almost 55 million passengers annually (see Figure B-1). The mission of HAS is to connect the people, businesses, cultures, and economies of the world to Houston. Their vision is to establish HAS as a five-star global air service gateway where the magic of flight is celebrated.

Figure B-1. HAS airports.

The airfields found at the three airport facilities are capable of accommodating virtually any type of aircraft on runways that extend up to 12,000 feet. While the airports represent a significant contribution to Houston and the surrounding communities' economies, the airport system functions as an enterprise fund and does not burden the local tax base to pay for operations, maintenance, or capital improvements. HAS accomplishes financial self-sufficiency by deriving income from fees, rentals, and other charges. Surpluses generated are reinvested into capital development and bond retirement. According to the most recent economic impact study, the three airports collectively contributed more than $27.5 billion to the local economy and were directly responsible for more than 230,000 jobs that generated $8.7 billion in employment earnings.

Data Collection

History of Data Collection Practices

HAS realizes the importance of pavement condition data collection in managing its pavements. The HAS pavement management system was implemented in 1996 and has been revised continuously since that time. The implementation efforts have included manual Pavement Condition Index (PCI) data collection, Heavy Weight Deflectometer (HWD) testing, Ground Penetrating Radar (GPR) to verify pavement thickness, and cores at select locations. Since implementation, manual PCI data collection and HWD testing has occurred throughout each airport as part of periodic updates as well as part of detailed inspections with specific goals.

Current Practices

HAS updated its airport pavement management system in 2014 and has been integrating new technology practices for pavement assessment and evaluation for the past several years to support a multitude of operations and personnel accessing the given data. This provides consistent and updated information for different divisions making necessary decisions and for specific operational and department project support across the airports. Since 2014, the inspections have been performed by Woolpert with Applied Pavement Technology, Inc., Landtech, Inc., and Aviles Engineering Corporation serving as subconsultants.

Currently, HAS collects data at its airports for pavement distress/condition, longitudinal profile, surface friction, surface texture, deflection, and pavement cross sections. Pavement assessments are performed annually, while pavement conditions are evaluated every 3 years at each of the airports. Data are collected and maintained by a combination of internal staff and consultants.

HAS hires consultants to complete inspections and pavement condition assessments at its airports to verify the pavement inventory and collect condition data to develop PCI values. The PCI inspections are completed based on AC 150/5380-6C, *Guidelines and Procedures for Maintenance of Airport Pavements* and ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys*.

In addition to the evaluation of pavement conditions every 3 years, HAS operations and maintenance staff do frequent visual inspections of existing infrastructure and consultants work together on detailed evaluations of specific pavements. The initial data collection methods on these projects are the same as the inspections covering the entire pavement network; however, additional data collection and analysis are also completed. Consultants are utilized for pavement condition assessments at HAS for the benefit of using advanced technology for more detailed and accurate evaluations.

Data Use

HAS has multiple divisions interested in infrastructure conditions. Each airport has a General Manager that sponsors the funding of work within the Operations, Maintenance, and capital projects groups, based on the priority and resources available. HAS utilizes the collected pavement data in a number of different ways, including to document compliance with FAA requirements for inspections. HAS's Infrastructure Division utilizes the data to manage the total life cycle of the pavement system assets and to carry out project-level evaluation and design. The issues, operational impacts, and compliance with federal requirements presented and used by senior airport management are very beneficial in identifying projects and formulating budgets for their Capital Improvement Plans.

Results from evaluations are incorporated into several indexes which help HAS prioritize its needs. The airport's PCI surveys are translated into an Actual Condition Index (ACI), which provides an asset's condition from a physical condition perspective, with every section of pavement rated on a standard 0-10 scale (see Figure B-2). Pavement sections that are lower on the scale represent higher priority requirements for evaluation of maintenance, repair, or replacement needs.

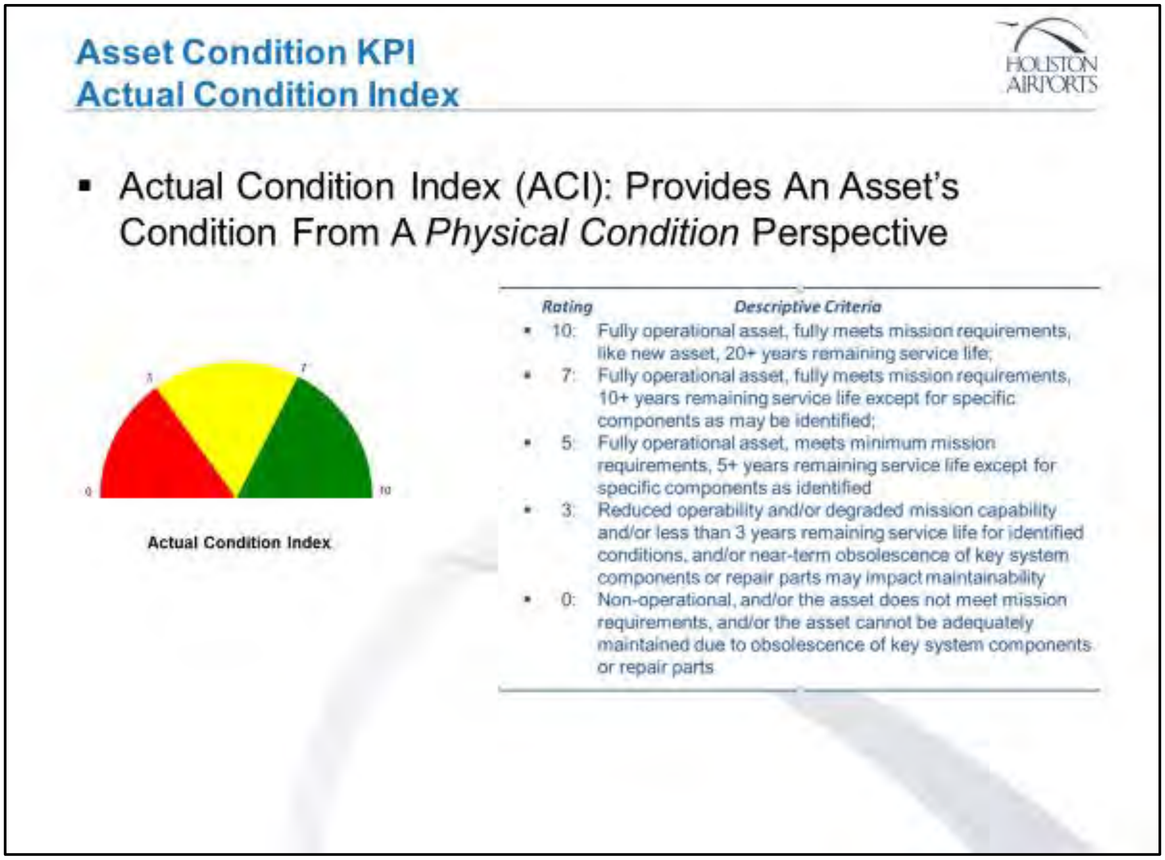

Figure B-2. Asset Condition KPIs, Actual Condition Index.

HAS also carries out a Financial Cost Index (FCI) investigation, which provides an asset's condition from a financial perspective and is essentially a life-cycle cost analysis for the recommended repairs (see Figure B-3). All aspects are considered in the analysis and a factor for rehabilitation versus full reconstruction is produced to determine the most cost-effective solution for the airport. The FCI is also applied to facilities owned by the airport and helps guide the decision-making process for all assets.

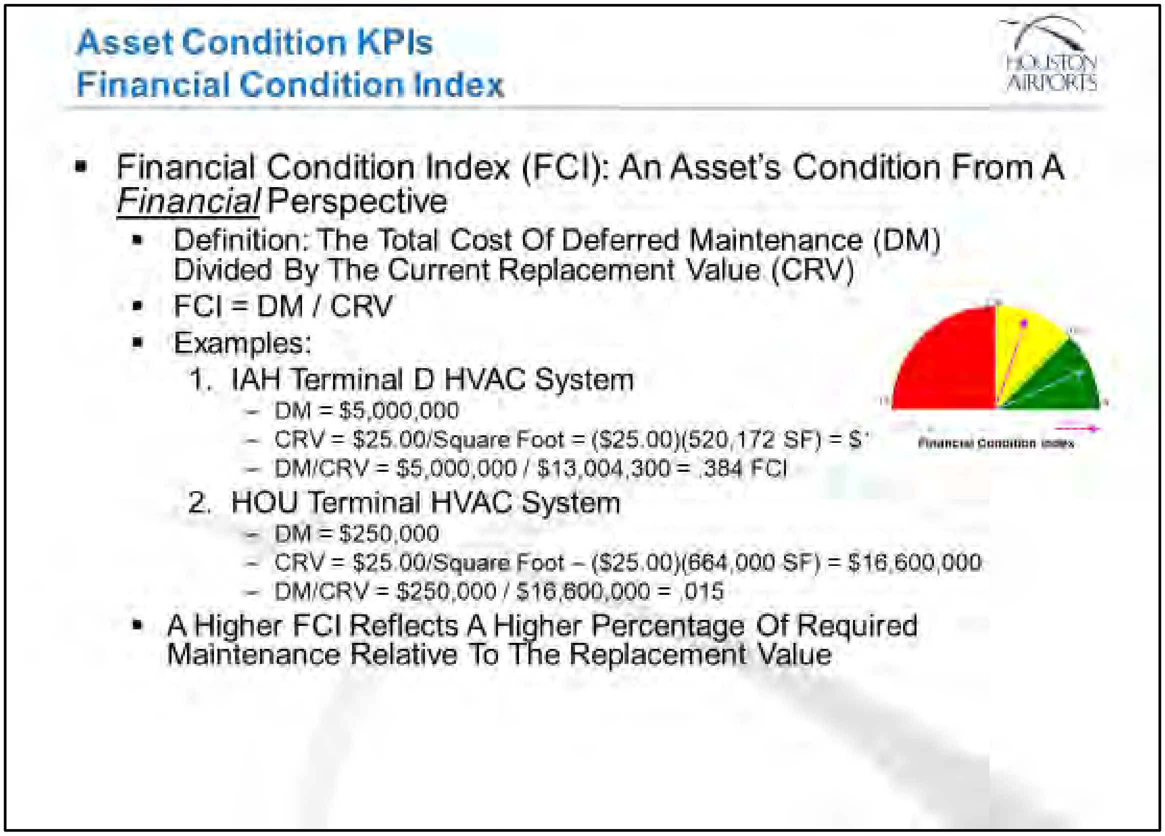

Figure B-3. Explanation of the Financial Condition Index.

Collected data are also used to communicate conditions to management and other governing bodies. With regards to specific recent projects, the use of a mobile mapping system with ground truth verifications has allowed HAS to create accurate estimates of its maintenance staffing needs. Airport personnel are given training to understand the information being produced from pavement condition assessments, which also aids maintenance efforts. With the breadth of data collected, each individual airport is able to bundle maintenance and repair work together at concentrated locations, saving HAS money and valuable operational time.

Data Management

HAS employs an Enterprise Asset Management System (EAMS), which is vital in facilitating timely and efficient maintenance across all facilities. The application helps manage preventive maintenance, inspections, and work orders for the Maintenance department without requiring extensive user modification. This helps employees to increase speed and efficiency in day-to-day maintenance tasks, and decision makers are better equipped to track assets, parts, and labor, while making informed decisions regarding repairs, purchases, and staffing levels. A running list is created of work requirements that are not addressed to identify projects and work orders still outstanding.

Pavement condition data are collected, maintained, and reported both internally and externally by HAS and its consultants. Various divisions frequently update the database, which helps to produce trending data and hot spot analysis, identifying locations where recurrent problems are observed. HAS relies on outside consultants to perform evaluations with the latest technology so that they can continuously monitor the varying degrees of change seen in their pavements. Consultants perform assessments every few years to update the condition of their pavements and provide a new reference point in the PAVER software, which is where the data resides.

The condition and location information also resides in the EAMS and GIS systems, which are updated by HAS Asset Management Systems Support Analysts. Both EAMS and GIS systems are integrated and structured to support data inputs form either platform and share the information among both, including shapefiles by panel and section as part of the deliverables. Although photos are integrated into PAVER and output is uploaded into GIS manually (spreadsheet) for each panel, the data unfortunately do not currently download directly into EAMS and GIS. HAS is exploring the possibilities for implementing this technology in the future.

Detailed Project Evaluation Examples

Two projects highlight HAS' pavement data collection, use, and management processes. These projects—the IAH Runway 15R Skidabrader Assessment and the IAH Taxiway NB Pavement Scanning, FWD Testing, and Condition Assessment—had specific goals outside of the routine pavement evaluation occurring every 3 years; however, they depict similar processes.

Both projects represented significant collaboration between HAS and hired consultants to evaluate conditions seen on airfield pavements using a multitude of pavement data collection processes, including next generation technologies that yielded valuable data for future evaluation. Although very different, the projects were intended to identify a solution to problems that had potentially costly impacts on maintenance, operations, and planning budgets.

IAH Taxiway NB Pavement Scanning, FWD Testing, and Condition Assessment

Based on previous investigations, there were indications of deleterious materials in the concrete mix used to construct Taxiway NB at IAH. Phase 1 was completed in 2014 and according to manual evaluation by HAS staff, more than 2,700 "popouts" (loss of surface aggregate potentially caused by defective aggregate) had been identified on the Taxiway NB pavement approximately 1 year after initial phases of the pavement reconstruction project were opened to traffic. The extent of the deleterious materials causing the popouts was not known and had not been identified, although steps taken to reduce the potential sources of deleterious materials after the completion of the first phase of paving had appeared to be effective (see Figure B-4).

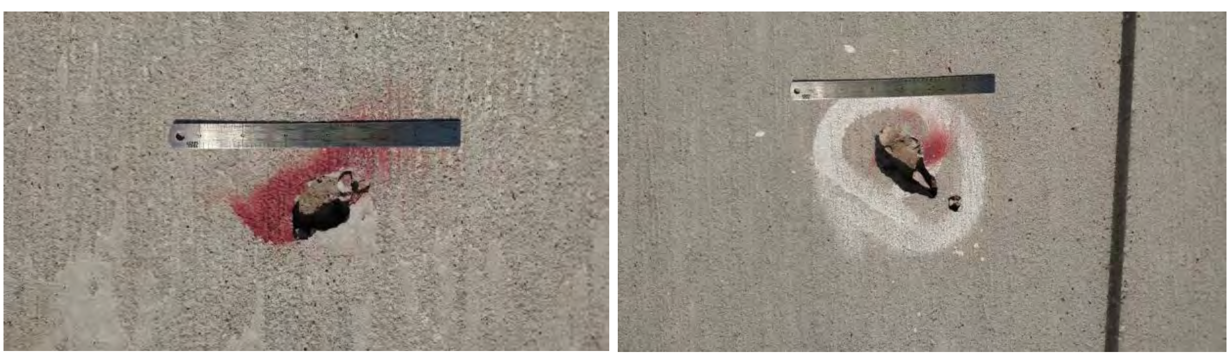

Figure B-4. Representative popout depictions and sizes (Woolpert 2015).

In August 2015, HAS investigated the condition of Taxiway NB using nondestructive testing, mobile mapping, high-resolution pavement scanning, visual field survey, geodetic data validation, materials evaluation, and materials testing. The purpose of such an extensive evaluation was to determine long-term impacts, anticipated future conditions and performance, maintenance requirements, and remaining pavement life.

Pavement Data Collection

HAS elected to use a Mobile Mapping System (MMS), which uses high-resolution digital imagery and Light Detection and Ranging (LiDAR) acquisition and processing at IAH in 2014 to gather data. Data collected with the MMS can be used to create pavement mapping features data (e.g., pavement distresses, edge of pavement, pavement markings, lights, etc.) and imagery for use in condition assessments and construction plans, as well as to support integration into GIS/Asset Management systems.

In addition to the MMS, data was collected using a high-resolution Pavemetrics scanner so that pavement deficiencies could be mapped in real-world 3D coordinates to provide high-resolution detail and an accurate, objective inventory of the existing conditions, while also functioning as a baseline for identifying future changes in surface condition and providing locations of pavement changes.

Distresses observed in this evaluation were digitally mapped by technicians using manual collection methods based on features observed in the high-resolution ortho imagery developed from nearly a half-million still images captured in the field. Combined with manual processes using workstations for mapping of pavement distresses, the MMS provided a high-resolution GIS dataset that could be used to compare distresses over time.

HAS categorized each individual panel of pavement as a separate asset in their system and provided section numbers from the PAVER software. Information rolled up from each individual panel to section to the given runway, taxiway or other pavement area was used for a bottom-to-top approach of understanding the condition of their pavements at all levels.

Surface deficiencies and panel joint pattern data were developed from the MMS scan data and utilized to perform a visual condition survey of the pavement surface. This survey showed the distresses in place and provided a good indication of the size and pattern of the identified defects. The results were used to develop ideas about potential repairs and to search for additional defective locations that had not yet been identified as popouts, all in order to create a distress map that could be used for effective progression comparison.

All collected data was analyzed for use in a project report provided to HAS explaining the observed conditions to address any additional concerns and further suggest avenues of exploration. After the collection of the raw dataset, trained geospatial technicians converted the imagery into a high-resolution ortho image, which was the basis for mapping pavement distresses using a combination of automated and manual feature detection methods.

Once collected, the mobile LiDAR data was processed for export from the system and converted to LAS files (the industry standard LiDAR file format). Upon review, the MMS data were transferred and subsequently post-processed by a consultant to produce the following:

- Extraction of POS (Positional) data.
- Extraction and review of LAS files for completeness.
- Seamless integration of point-cloud data.
- Translation of all data to the required coordinate system.
- Verification of point cloud to survey control.

The greatest benefit of using advanced technologies such as LiDAR and other laser-based surveys in high-speed vehicles with GPS capabilities providing distress surveys and mapping of pavements is the speed and efficiency by which the evaluation can be performed and integrated into a system for future use. However, hiring outside consultants and high-tech equipment and software comes at a cost. The hope is that the benefit and future use of the given information will help identify solutions that reduce the future cost of maintenance and funding requirements for capital planning. To date, it is difficult to quantify the benefits seen because the data are still raw.

A visual condition survey was performed in accordance with ASTM 5340 requirements to generate a PCI rating. For consistency with past and future surveys, all distresses developed through the MMS mapping were validated in the field on mobile data tablets. If the distresses did not fall into a category according to the ASTM definition, an alternate method was used to mark and digitally collect those non-ASTM standard defects.

HWD testing was also performed and with subsequent analysis provided several useful pieces of information, including the back-calculation of the pavement's strength, which was used to identify whether the overall load-carrying capability of the pavement had been compromised by the presence of the deleterious materials. The strength calculations could also be tracked over time to determine if there is a substantive change affecting the pavement's ability to carry loads, although this was not done for this study. How the actual strength of the pavement compares to the expected strength and whether that actual strength alters the pavement design life is another potentially useful analysis for future planning and necessary maintenance of the pavement structure.

The HWD testing results were also used as an input in the calculation of a Pavement Classification Number (PCN), which is a single number expressing the load-carrying capacity of a pavement for unrestricted operations based on variable conditions for aircraft use. The importance of calculating PCNs is to determine whether the pavement is able to carry the aircraft to which it is being subjected. Continued review and assessment of PCN will aid airport personnel in making critical decisions for use and repairs of the taxiway to meet and enhance the design life of the pavement.

Pavement core samples were collected in areas where other testing indicated it was appropriate. It was hypothesized that most of the clay in the PCC was vibrated to the surface of the pavement during construction and that the clay at the surface had been exposed and was in the process of being repaired by various methods. However, nondestructive attempts to determine if this assertion was correct, specifically GPR studies, were unsuccessful, since the GPR was unable to "see" below the steel reinforcement located 6 inches below the surface.

Twenty cores were taken to explore the possibility that there were clay balls in the lower section of the concrete. The strength of the existing material was also evaluated to determine if deleterious aggregates were present, and whether those aggregates adversely affected the load-carrying capability of the pavement. To complete this evaluation, splitting tensile strength tests were performed to provide flexural strengths of the concrete related to tests performed during construction. Given the design strength for the material and the construction results, the testing results showed material strengths representative of sound concrete.

Portions of five cores were sent for petrographic analysis, or petrography, which is an essential tool for evaluating many kinds of concrete issues, such as durability, low strength, freeze-thaw, surface distress, cracking, alkali-aggregate reactions [ASR and alkali-carbonate reaction (ACR)], and so on. The petrographic investigation concluded that no particles of clay, mudstone, or other soft particles were observed in the coarse or fine aggregate in any of the cores. None of the cores showed cracks or significant microcracking, and no significant secondary deposits were observed in the cores. As such, it was concluded that the concrete was consistent in terms of its material properties and that it was sound concrete.

Pavement Data Use and Conclusions

The PCI survey results were used to model the deterioration rate of the pavement and for comparison purposes against pavements without the popouts. How the calculated PCI compares to the expected PCI of similar pavements at IAH, which do not have these defective materials would be very useful in determining the remaining life of the pavement and what additional maintenance might be needed to enable it to function in a safe and effective manner.

The rate at which a pavement deteriorates can be determined from the PCI analysis. As part of the 2014 airport pavement management system update, performance models were developed for each pavement type and use (i.e., taxiways, runways, etc.). The taxiway performance model for the PCC associated with almost all taxiways (minus one which had an unusually high amount of deterioration after construction) showed a decline in the PCI of 0.69 points/year. In comparison, Taxiway NB sections had deteriorated between 1 and 2 PCI points over the course of the first year. This initial deterioration rate may not be representative over the life of the Taxiway NB pavements, but it does indicate the deterioration rate is similar to or slightly higher than other PCC taxiways at IAH. This deterioration rate can be reevaluated at regular intervals to determine if this pavement is behaving differently from other similar PCC taxiway pavements at IAH.

The evaluation and review of available records, visual field condition survey, and assessments of strength through nondestructive testing indicated that the pavement is in acceptable condition. In fact, other than the well-documented abundance of popouts, all testing results showed a pavement in overall excellent condition. The PCI numbers were representative of a new pavement, and it was found to have more than adequate strength.

More surface defects than expected or desired in new concrete were found. HAS determined that the repairs themselves were not likely to perform as well as the existing sound pavement, which would have created maintenance and operational problems for years to come. The specification under which the PCC was provided in accordance with FAA P-501 Portland Cement Concrete Pavement addresses the defects in several different capacities. For example, it states that the aggregate shall meet the requirements for deleterious substances contained in ASTM C33. That standard has been discussed by American Concrete Pavement Association (ACPA) and shows a generous allowance for materials such as clay balls.

Based on the analyses of others, it was found to be highly unlikely that the threshold for deleterious materials in ASTM C33 was exceeded. In section 501-4.5, the Special Provision states that “stockpiles shall be constructed in such a manner that prevents segregation and intermixing of deleterious materials. Aggregates that have become segregated or mixed with earth or foreign material shall not be used.” It is clear that this was not accomplished during construction of Taxiway NB.

The enforcement of proper oversight might have improved the quality of the contaminated PCC. For example, a Quality Control Program and Testing Plan requiring a program that addresses stockpile management is vital to ensure the quality of the material going into the mix for placement. The results produced did not support the application of sound principles of stockpile management.

Going forward, the lack of oversight on key components of construction helped HAS recognize the importance of such oversight and led to the development of methods for ensuring their construction management and resident engineering consultants were properly vetting material use and handling on the airfield. An increased need for pavement maintenance was also identified as a concern for future planning purposes.

IAH Runway 15R Skidabrader Assessment

An evaluation of the existing condition of the Runway 15R/33L surface was performed in 2016 to compare a test section of pavement that had been treated by a Skidabrader (a device which uses steel particles to scarify the pavement surface and increase surface friction) with the existing, non-treated pavement surface. The analysis was performed to determine if there was damage to the pavement surface and grooving caused by the Skidabrader treatment, as well as the degree of groove impact, the effect on braking action and regulatory compliance, and potential long-term effects on the remaining life of the pavement using this abrasion method (see Figure B-5).

Figure B-5. Pavement outside (left) and inside (right) Skidabrader treatment area (Woolpert 2016).

HAS used a consultant to perform the testing and provide a recommendation for future surface operations. Field and document investigations and research on the existing pavement conditions and construction of Runway 15R were performed. The review of "As-Built" drawings, existing GIS/Asset Management data, PAVER data, and interviews with appropriate engineering and maintenance staff aided in the evaluation process. Based on the results from analysis, while the Runway 15R/33L pavement surface appears to have remained mostly intact after the Skidabrader treatment, the chamfering effect on the grooving was of concern. Since the chamfering leaves a surface that does not meet FAA standard requirements, the Skidabrader method of treatment was not recommended on the pavement in question. Instead, it was recommended that HAS consider other alternate processes, such as ultra-high pressure water blasting, to increase surface friction values.

Several takeaways from the project included recommendations regarding feasibility of the testing and pros/cons of other potential alternatives to the Skidabrader method that consider the impacts to the pavements; the efficiency of the processes, including impacts to airport operations; and the short and long-term cost implications. All of the resulting analyses served to aid HAS on future projects and planning considerations when determining the proper maintenance of its pavements.

Innovation/Best Practices

HAS has demonstrated a desire to be on the forefront of implementing new technology that provides streamlined access and accurate information to pavement condition data to all users in its system. Whether the evaluation methods are aimed at providing a benefit to Maintenance, Operations, Planning, Engineering, stakeholders, consultants or others, HAS understands the value of various pavement condition data collection methods for different uses on its airfields and integration of collected data into a system that affords personnel the necessary information for making informed and accurate decisions.

Having a detailed GIS-feature distress dataset has allowed HAS to conduct ongoing analysis of their pavement conditions from one year to the next, or from one inspection to the next. For long-term monitoring, the high-resolution scanning will permit the identification of defects recorded in the future to be positively identified as either existing defects that are stable, new defects that did not exist at the time of the last scan, or defects that are deteriorating.

The main advantage of using advanced technology, including high-resolution pavement scanning, is that with subsequent pavement scans over time, it will be possible to accurately determine the extent of the deterioration through automated collection and classification. In addition, questions can be answered such as how rapidly deterioration is occurring and if there is a geographic relationship with new or deteriorating defects. It will also be possible to determine how many existing issues appear to be appropriate for conditional repair versus how many require additional monitoring or further consideration.

The development of information input into the HAS database after each project performed has vastly improved the production time and operational value for all divisions. The expedited retrieval of appropriate information has reduced search efforts and more frequent inputs have made records more accurate so that improvement recommendations represent sound judgement. Including the proper people within each division of HAS to understand the tools available is vital to the success for best implementing the given information.

Future Development and Concerns

HAS realizes that it can make vast improvements in the processes by which data are collected and disseminated. Such an effort requires a significant investment of both money and time. The ultimate goal for HAS is the incorporation and use of pavement condition data that is georeferenced, shares a consistent reporting scheme, and lends itself to a universal standard that enables all users and departments easy access and appropriate sharing capability for enhanced updates to all databases.

One of the difficulties in implementing a fully integrated system for pavement data collection is that it still relies on end users properly using the information. As technology advances, so does the need for appropriate management and evaluation of data collected to ensure pavements are being adequately addressed. The major factors and concerns with ongoing pavement data collection are the associated costs and ensuring that measures taken to assess the results are beneficial overall in guiding the decisions for the improvements being made. As additional evaluations are performed, the money spent on projects to update the data collection should help to improve the understanding of pavement issues and contribute to overall cost savings to HAS.

CASE STUDY: SALT LAKE CITY DEPARTMENT OF AIRPORTS

Agency Background

The Salt Lake City Department of Airports (DOA) is a part of the Salt Lake City Corporation and the Director of Airports reports to Salt Lake City's Mayor and the Mayor's Chief of Staff. There are eight divisions and over 500 employees within the Salt Lake City Department of Airports. The DOA is an enterprise fund. The funding for the DOA does not come from property taxes, general funds of local government, or special district taxes.

The DOA is responsible for Salt Lake City International Airport (SLC), South Valley Regional Airport (U42), and Tooele Valley Airport (TVY). Salt Lake City International Airport is a large-hub airport, while South Valley Regional Airport and Tooele Valley Airport are general aviation (GA) reliever airports that serve local communities.

Data Collection

History of Data Collection Practices

In the 1990s, the DOA competed the first pavement condition data collection efforts. DOA personnel performed manual visual inspections and each round of inspections used between five and ten employees. Distresses were recorded on paper forms which were later entered into pavement management software.

Beginning in the early 2000s, the DOA acquired a vehicle-mounted data collection system manufactured by Adhara Systems. This system includes a downward-facing progressive area scan camera mounted on a boom, a distance measuring instrument (DMI), and a computer to control data collection and store imagery. Since acquiring this system, the load-bearing airside and landside facilities at all three airports are inspected each year. The inspection process has not changed significantly since inception and is outlined in the following section.

Current Practices

Pavement Condition

GIS and Mapping personnel within the DOA's Engineering division perform pavement condition inspections every year with the vehicle data collection system. These inspections take place in the spring and early summer. In 2015, the data collection system software and hardware were upgraded to incorporate technological advancements. This system gathers images covering a 12-foot-wide swath of pavement in the direction of travel. These images have a resolution of 0.02 inches and the location of images is documented by the DMI.

All load-bearing airside and landside facilities are inspected each year, with the exception of pavements with committed rehabilitation projects. The inspection coverage varies between facilities. For parallel taxiways and runways, approximately 50 percent of the pavement will be captured, while the coverage for certain apron sections may be as low as 10 percent. Data for some sections are gathered manually if the data collection vehicle is not able to properly cover the section.

The DOA slightly altered the segmentation procedures for pavement condition inspections from those outlined in ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys*. Pavements with the same construction history are first grouped together within a branch. The result is that all pavements within a branch have the same construction history and only contain one section. The DOA will modify segmentation based on the observed conditions so that pavements performing dissimilarly are not evaluated together. An example of this segmentation is shown in Figure B-6. In this figure, A2-84 and A2-51 were constructed at different times with different materials. The data associated with each branch are kept separate even though they are both within Runway 16L-34R. Also shown in this figure is A2-114 which is composed of a deicing pad along with portions of Taxiways G and H.

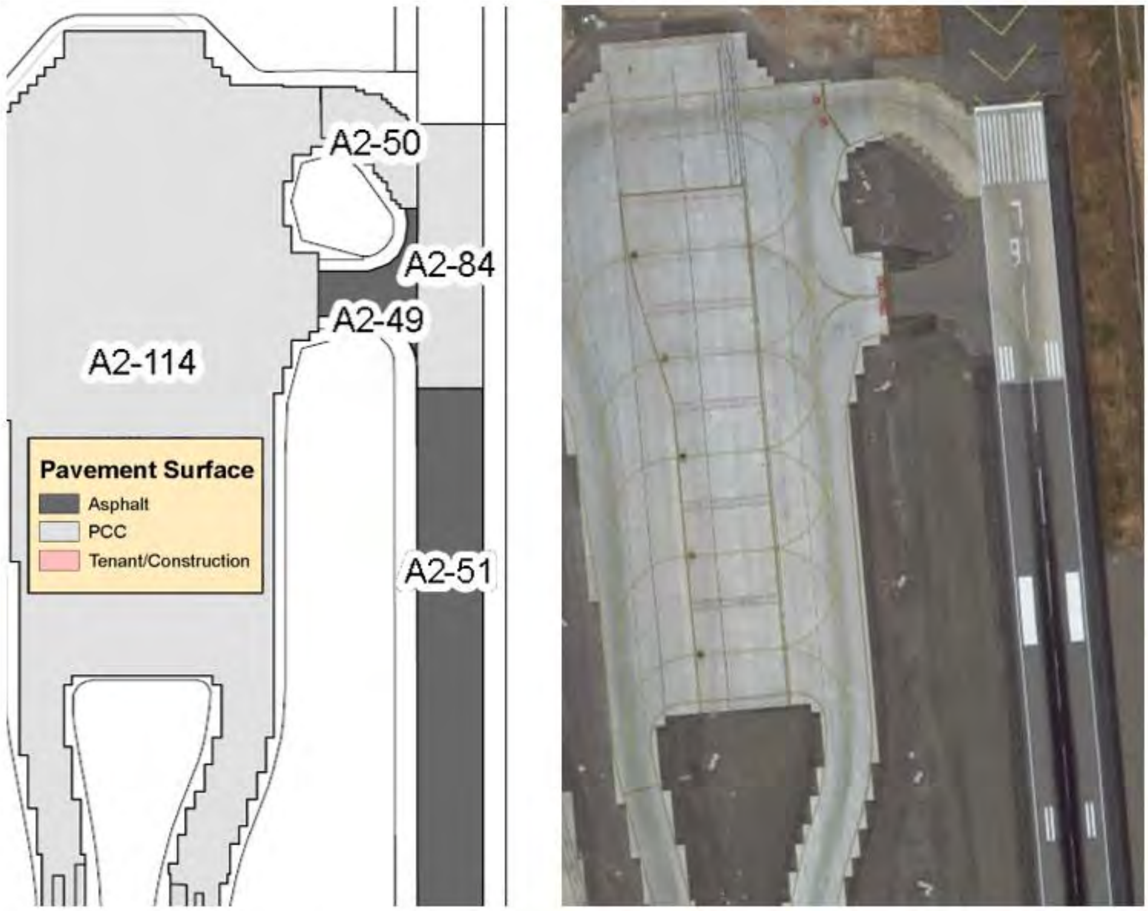

Figure B-6. Pavement segmentation example [SLC DOA 2017a (left)].

While this is not the typical ASTM segmentation process, this method has its benefits. Many of the Salt Lake City DOA pavements have been constructed as part of large projects. This segmentation process allows a construction project to be easily isolated within the database and it has reduced the number of sections and small sections within the pavement network, which can simplify reporting. However, with fewer sections, care must be taken to make sure that the reported PCI for a facility is representative of the pavement and that each section has consistent conditions. If significant changes in the condition are present, additional sections should be created. Pavement conditions are typically reported at a facility level, and since facilities (e.g., Runway 16L-34R) are not synonymous with branches, the reporting of conditions needs to be accomplished so that overall conditions are not misrepresented.

After the data collection is complete, all images are interpreted. The imagery is input into uniANALYZE, the equipment vendor's proprietary software, which processes the imagery for optimal viewing of distresses. Asphalt pavement surface conditions are processed by uniANALYZE, which has automated crack detection capabilities. While certain asphalt pavement distresses, such as weathering and raveling, are not captured by uniANALYZE crack detection, these distresses are not a primary concern for the Engineering division as they do not control the overall condition or usability of the pavement in most instances. Concrete pavements are manually interpreted within uniANALYZE by engineering personnel following ASTM D5340 distress standards.

The uniANALYZE software is able to export data into PAVER, the pavement management software that is used to calculate and store PCI data. The sample units within PAVER are created directly from the collected data. These sample units and areas of inspected pavement are distributed throughout each section. Between consecutive inspections the same areas within each section are intentionally not inspected to achieve random sampling.

Two DOA GIS and Mapping personnel are involved in the data collection and interpretation process. They work together closely to produce consistent results between inspections and pavement sections. These DOA employees have both been involved in this effort for the past 6 years. They are both intimately familiar with the processes, equipment, and pavement networks. During the data interpretation process, there are limited quality assurance (QA) procedures implemented. In order to conserve resources and because each pavement section is evaluated each year, extensive QA procedures are not required. The change in PCI of each section is examined yearly. By inspecting slightly different areas of pavement each year, over time the true condition of the pavement is captured; however, it may lead to slight variations in PCIs from year to year. For sections with either an increase or large decrease in conditions, the images are reviewed again to confirm the distresses are properly represented. If needed, Engineering personnel will manually verify the condition of a pavement section.

Pavement Structural Data

The DOA has had consultants collect structural data. The Pavement Classification Number (PCN) has been calculated for all runways and select taxiways at all three airports. For the PCN calculations, the consultant followed Federal Aviation Administration's (FAA) Advisory Circular (AC) 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN*, and ASTM D4694, *Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device*. Coring was completed to confirm the pavement structure and deflection data were also collected for all pavements with a falling weight deflectometer (FWD).

Friction Data

The Operations division conducts friction testing at Salt Lake City International Airport, but not at South Valley Regional Airport or Tooele Valley Airport because these airports do not receive commercial air traffic. The equipment manufacturer is Scandinavian Airport and Road Systems (SARSYS) and the system is mounted in a Saab. Friction testing follows AC 150/5320-12C, *Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces.* Before, during, and after winter storms, friction testing will occur anywhere from three to twenty times, depending on observed conditions. During periods without winter storms, each runway is tested once a month. This testing frequency ensures that the runways can be safely used at any time.

Data Use

The DOA uses the PCI data to demonstrate and document compliance with FAA requirements, including FAA Grant Assurance #11 and Public Law 103-305. The data are also primarily used to plan localized maintenance, identify projects for the CIP, determine budgets for the CIP, and communicate conditions within the DOA and to the FAA.

Localized Maintenance

The DOA attempts to preserve and lengthen the life of its airports' pavements by implementing a well-defined, localized maintenance program. This program involves the Maintenance and Engineering divisions, and includes extensive repair projects in the CIP, contracted repairs, and typical in-house repairs depending on the resources required.

With the exception of emergency repairs, all pavement maintenance plans are based on PCI data. When yearly PCI data are reported, they serve as a guide to examine which areas need repairs. If extensive and costly repairs are required, these activities will be grouped into a CIP project and oversight will be provided from the Engineering division. The Maintenance division references the PCI data to identify potential problem areas that may require frequent repairs. Less extensive, non-CIP repairs will be addressed either with in-house or as contracted repairs. In-house repairs are performed within the yearly Maintenance division operational budget. There is also a set yearly budget for contracted repairs. The overall approach to developing localized maintenance does not vary between the three airports; although, they do have different levels of priority and funding. The established process is not static and the DOA is always open to refining their processes to yield better results.

CIP Development

Following on the annual collection and reporting of pavement condition data, the CIP is developed on a yearly basis. However, while the CIP is specifically for 1 year, the Engineering division is aware of the age and condition of facilities allowing it to anticipate when rehabilitation will be necessary in future years. The CIP is developed in the fall after the conditions from that year's inspection have been reported.

The DOA has generally been using a "worst first" approach to select pavements for rehabilitation. The "worst first" methodology has been effective as the funding available for pavement rehabilitation has not been limited to the point where substantial portions of the airfields are in need of rehabilitation each year. The pavements have remained overall in GOOD condition without significant decreases over time. PCI maps are examined to identify sections in the worst condition and in need of rehabilitation. After these are identified, the condition is visually confirmed. The rehabilitation type and estimated budget are determined based on engineering experience.

The initial plan to rehabilitate these sections is discussed with Operations, Maintenance, and Planning & Environmental personnel. The Operations and Maintenance teams regularly work at the airports repairing distresses and observing current conditions, which give them insight into the state of the airports. The Planning & Environmental Program understand the DOA property as a whole, the long-term goals, and the environmental impact of projects. If rehabilitation is required, Engineering will populate a Project Nomination form, which includes a project description, justification, engineer's estimate, and project location. The Project Nomination forms are then reviewed by the Director of the DOA and the Director's staff. Projects with the appropriate justification are then approved for design and added to the CIP for the upcoming fiscal year. Some projects are delayed based on the funding available from other sources, such as the Airport Improvement Program (AIP) and Passenger Facility Charge (PFC). Once projects for the fiscal year are determined, they are reviewed by the Airport Board's Financial Committee and included in the budget, which is sent to the City Council and Mayor's office for review and approval.

All capital projects, ranging from mill/overlays and slab replacements to reconstruction, go through a design process, in which input is sought from on-call consultants. This allows the Engineering division to be flexible in the number of design projects occurring at a single time. The Engineering division also performs design reviews. The design process includes updating the estimate of the construction cost shortly before the project is posted for bidding.

Condition Reporting

DOA's reported pavement condition information is close to a real-time representation of the data. Printed maps and a summary of the conditions are sent to other divisions (Maintenance, Operations, and Planning & Environmental Program) within a few months of completion and electronic copies of the distributed information are stored on the network. An example of a summary condition map is shown in Figure B-7. GIS shapefiles are also made available to those DOA departments with GIS capabilities. The maps are also distributed to the FAA District Manager.

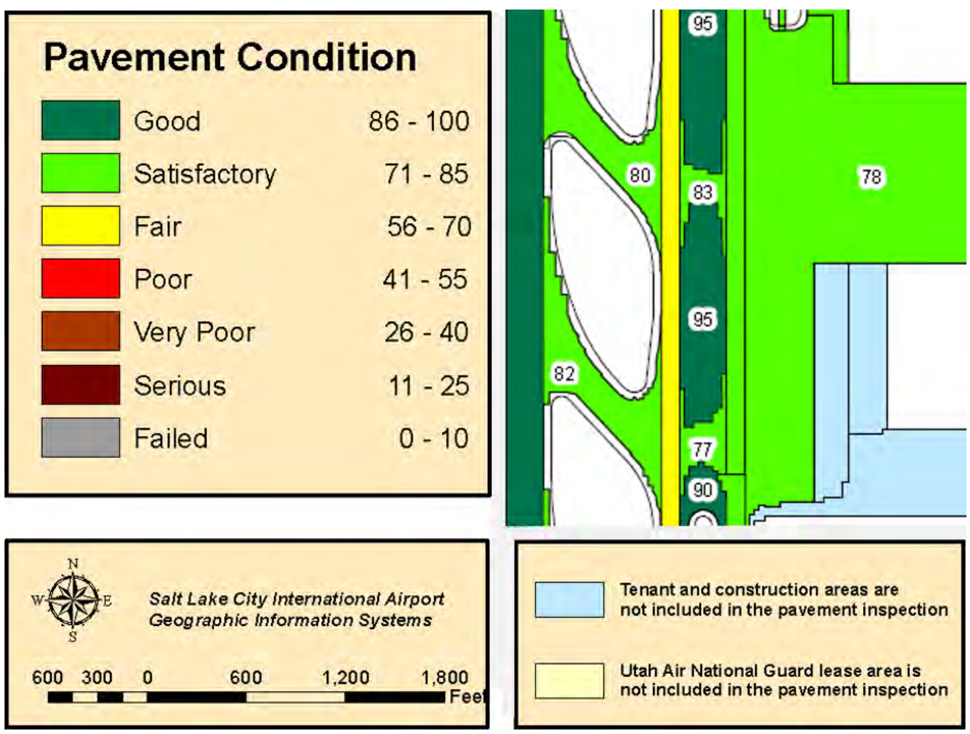

Figure B-7. Condition summary map example (SLC DOA 2017b).

PCNs are distributed to the Planning & Environmental Program, Operations, and other divisions as required. These numbers are also reported to the FAA on Form 5010. The friction data are stored on a local computer and reported internally within the DOA. These data are not stored in the same database as the pavement condition or pavement structural data.

Data Management

The pavement management database is updated by the Engineering division every year so that the database closely reflects current pavement conditions. Specifically, GIS and Mapping personnel retain ownership of pavement condition data at all times. The program uniANALYZE is used for pavement data interpretation, while PAVER is used to calculate and store PCI data. The condition data are also migrated to ESRI's GIS platform for data storage and visualization. By keeping the data management internal, it is less likely that information will be lost or misrepresented in communications between multiple parties. The Engineering division has access to all necessary files to populate the PAVER database and they have equipment to inspect the pavement. The results are presented to senior airport management every year in the form of PCI map and a summary of results. Since the PAVER database is actively maintained, the Engineering division can extract current pavement condition information as needed.

Innovation/Best Practices

The DOA pavement data practices are unique and they excel in certain areas. Most agencies do not collect pavement condition yearly. By collecting pavement condition data yearly, the DOA always has a near real-time representation of the pavement and does not use projections of pavement condition. This aids in the yearly development of the CIP. In addition, by collecting random samples each year to generate pavement condition data, a true representation of each section over time is captured.

Only two employees are involved in the collection and evaluation of pavement condition data. Each has been collecting pavement condition for the past 6 years. This continuity and experience yields consistent evaluation of the pavement and handling of data. These employees are very familiar with the pavement network.

The DOA uses input from multiple stakeholders when planning localized maintenance and CIP projects. Maintenance and Engineering divisions work together to develop a yearly localized maintenance program. Engineering, Operations, Maintenance, and Planning & Environmental review CIP projects to ensure each is appropriate and serves the needs of the DOA. The Engineering division believes including other divisions in planning is vital to maintaining airport pavement.

Concerns and Desired Future Improvements

The DOA has some concerns about their pavement management program related to collection and use. The primary concern is whether the collected data allows the DOA to make the correct decisions on how to manage their airports. Two practices directly affect the decisions made. The collection of pavement data every year makes a robust program; however, it is labor intensive. It may be possible to reduce the frequency of inspections while not harming the pavement management program. Similarly, it is necessary to ensure the coverage of the pavement inspections is appropriate. If the coverage is too low, an improper decision may be made. Conversely, inspecting a high proportion of the network can use more resources than necessary (or available).

In addition, the DOA is in a unique position in that they own pavement data collection equipment and software. The current equipment is 3 years old and is functioning well. When the useful life of this equipment is reached, a decision will need to be made whether to reinvest in new technology or change the data collection method. This question becomes challenging to answer as technology continues to advance. It may not be cost effective to invest in new technology to inspect DOA pavements in the future.

CASE STUDY: DUBLIN AIRPORT

Background

Agency Background

Aer Rianta, an Irish state company, was founded in 1937 to serve as a holding company for the national airline and to generally promote aviation in Ireland. Many years later, the national airline was separated from Aer Rianta, and Aer Rianta became the airport authority for the state's international airports.

In 1966, separate boards were established to manage Dublin, Shannon, and Cork airports, all under the oversight of Aer Rianta. In October 2004, as a result of the State Airports Act, Aer Rianta was renamed Dublin Airport Authority plc, and all assets and liabilities previously owned by Aer Rianta were transferred to Dublin Airport Authority. In 2014, the Dublin Airport Authority was officially renamed "DAA plc" by the Irish government. Today DAA is wholly owned by the government of Ireland, and has a commercial, for-profit remit. It currently owns and manages both Dublin Airport and Cork Airport.

Airport Background

Dublin Airport is an international airport serving Dublin, the capital of Ireland. The airport is located 6 miles north of Dublin City center. Work first began on the development of the airport in 1937, and by the end of 1939 a grass airfield surface, internal roads, car parks, and electrical power and lighting were established. The end of World War II heralded a major expansion in services at the airport. Aer Lingus resumed its London service in November 1945 and in 1947, KLM started the first European flights to Dublin with service from Amsterdam. Three new concrete runways were completed in 1948. Throughout the 1950s, Dublin Airport expanded with virtually uninterrupted traffic growth. Runway extensions and terminal enhancements were carried out to deal with the influx of traffic and passengers. A new terminal building designed to cater to an expected 6 million passengers per year opened in 1972.

Throughout the 1980s, major demand, especially on the Dublin-London routes, resulted in continuously increasing passenger numbers. In 1989, a new main runway and associated parallel and high-speed exit taxiways were opened, as well as a state-of-the-art air traffic control center.

Dublin Airport continued to expand rapidly in the 1990s. Pier A, which had been the first extension to the old terminal building, was significantly extended. A new Pier C, complete with air bridges, was built and as soon as this was completed, work began to double its capacity. Pier D, completed in October 2007, is a dedicated low-fares boarding area and provides 14 quick turn-around stands and departure gates. In November 2010, Dublin Airport's Terminal 2 and its connected boarding gate pier were opened. The new terminal was designed to comfortably handle more than 30 million passengers per year.

In 2017, over 29.5 million passengers passed through the airport, making it the 14th busiest in Europe. This passenger volume represents a 6 percent increase in passenger numbers, which was the seventh consecutive year of growth. Dublin Airport currently has more than 600 aircraft movements every day and two active runways: the main Runway 10/28, and a secondary Runway 16/34, which is operationally critical to the airport as a secondary cross-wind runway and backup to the main runway. A new 10,203-foot long runway is scheduled to be constructed parallel to the existing main runway in 2018/2019. In the meantime, DAA has invested heavily in extending aprons and creating rapid exit taxiways to derive maximum efficiency from the existing main runway.

Airport Governance

The Commission for Aviation Regulation (CAR) regulates certain aspects of the aviation and travel trade sectors in Ireland. CAR is an independent public body under the Department of Transport. The principal function of CAR is to set the maximum level of airport charges at Dublin Airport for 5-year periods. From a pavement perspective, there are two major cost categories allowed in the determination of airport charges at Dublin Airport: maintenance and capital improvement. In its 2014 Determination, which covers the 5-year period from 2015 to 2019, CAR provided Dublin Airport with total capital investment allowances to support growth in passenger volumes from 21.7 million (2014) to a forecast level of 24.8 million passengers per annum (mppa) in 2019. However, since the publication of the 2014 Determination, both the global and local macroeconomic climates have dramatically improved across a broad range of key indicators, which has fueled a surge in passenger demand to and from Dublin Airport to 27.9 mppa in 2016 and 29.5 mppa in 2017. These volumes significantly exceed the consensus forecasts developed in 2014.

This significant increase in annual activity (both in passenger and aircraft volumes) has placed an elevated strain on existing airport infrastructure, with certain facilities nearing or already operating at maximum capacity throughout 2017. Dublin Airport undertakes a comprehensive assessment of capacity across the key processing facilities on an annual basis. This 2017 capacity assessment highlighted that immediate capacity enhancements are required with respect to the aircraft parking stands and taxiways.

Data Collection

Overview of Current Pavement Collection Practices

The range of pavement data collection carried out at Dublin Airport is comparable to most international airports in Europe. Data collection specifications are typically based on International Civil Aviation Organization (ICAO) standards rather than FAA standards, but as identified in the following, the devices used for data collection do not differ substantially.

Current Friction Data Collection

Skid resistance of the pavements is carried out directly by DAA operations personnel using a Griptester Mark 2 device. The Griptester is used primarily to check for adequacy of skid resistance on the runways in frost/ice/snow conditions, and is also used to check for wet skid resistance of runway surfacing and areas with significant areas of pavement markings and rubber deposits.

Current Structural Data Collection

Because the Airport is operating near capacity, it has been increasingly difficult to access pavements at Dublin Airport in daylight hours. All of the structural evaluations take place at night, typically between 11 pm and 5 am, and even within this window there are some restrictions on operations. Structural assessment is carried out for Pavement Classification Number (PCN) reporting as per ICAO requirements, typically on a 5-year cycle, and also on a project-specific basis to determine structural capabilities and strengthening/reconstruction requirements as the airport capacity plans evolve. Structural assessment is carried out using a Heavy Weight Deflectometer (HWD) supplemented by a Ground Penetrating Radar (GPR) survey and limited pavement coring to calibrate the GPR survey results and provide a visual core log of the pavement layer thickness, composition, and condition.

Pavement Condition Visual Assessment

In Ireland, pavement distress data has traditionally been collected using manual surveys, and more recently, using visual assessment from high definition digital video. The pavement condition has been assessed using a high definition digital video camera system to record the forward and pavement-oriented view of the pavement surface since 2007.

The camera is mounted on the dash of the survey vehicle and the digital video is recorded by an onboard computer. The digital video is recorded as individual, georeferenced JPEG images taken every 16 feet. A very accurate DMI is attached to the vehicle and connected to the hardware interface. The video camera outputs a high definition digital video stream to the hardware interface and the frames are compressed using state-of-the-art compression algorithms to retain maximum definition at minimum storage space. The video data collection can be carried out at normal driving speeds, and the video is recorded using both stationing and GPS-referenced coordinate systems. The digital video can be subsequently post-processed in the office to carry out a visual condition survey and record pavement distress data.

The distress data are identified from the digital video using a desktop computer and a specially designed software program. The software program presents the forward view video as a windshield survey on the left of the screen, and a list of the defect types and severities on the right side of the screen that allows the observer to record the distress data as in a live survey. The distress data are recorded for each 328-foot length of pavement and are used to produce a Video PCI (VPCI) on each 328-foot long sample unit.

Manual and visual assessments from high definition digital video are based on human observation, which can produce subjective results and can be labor intensive, time consuming, and involve safety risks. Because of these risks, other means of pavement data collection have been evaluated.

Evolution of Current Pavement Condition Data Collection

Time constraints make access to Dublin’s pavements to perform manual inspections according to ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys*, very challenging. This led to the examination of alternative methods for visually assessing pavement conditions that could be carried out in short periods between flights. The option that was ultimately evaluated in detail is the use of three-dimensional (3D) laser imaging of pavements using the Laser Crack Measurement System (LCMS), which has been in use in Ireland since 2012, and has been used to provide automated data collection on the entire National Road network annually since 2013.

The LCMS is a 3D, laser-based, high-speed and high-resolution transverse profiling system. The LCMS consists of two downward-facing high-speed line scan cameras and high-power laser line projectors to acquire both 2D images and high-resolution 3D profiles of the pavement surface. Lasers are projected on to the pavement surface to be inspected and its image is captured by the cameras. The LCMS acquires 3D data by measuring the distance from the sensor to the surface for every sampled point on the pavement. The sensors simultaneously acquire both 3D “Range” (height of each pixel) and “Intensity” (the intensity of the reflected light for each pixel) images of the scanned surface and can be operated in full daylight or in nighttime conditions. The LCMS can be driven at speeds of up to 75 mph, but in Ireland is typically operated at 45 to 50 mph. The LCMS is mounted on the rear of a Road Surface Profiler (RSP) survey vehicle. The data are station-referenced using a highly accurate DMI, and georeferenced using a high-specification GPS device and Inertial Navigation System (INS).

The LCMS range and intensity data are processed using automated image/data algorithms that analyze each data profile to determine the extent and severity of distress data in the pavement surface, including cracking, patching, raveling, and rutting. Following the LCMS processing, the data are then analyzed to classify and output the type, severity, and quantity of pavement distress data for input into the PAVER database. Figure B-8 shows an image created from the raw LCMS data and the same image with the distress type overlay.

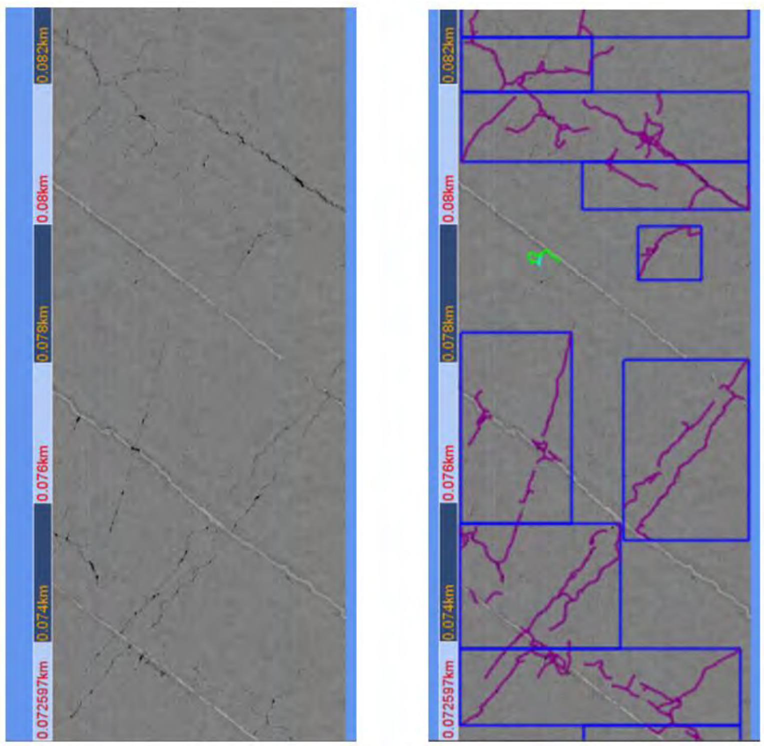

Figure B-8. Example of LCMS data and LCMS date with distress overlay.

Evaluation of Pavement Condition Assessment Alternative

Because of severely constrained access to airside pavements, a consultant undertook a study to evaluate the suitability of using automated data collection and interpretation instead of manual surveys for airport pavement management purposes. In the study, a LCMS was used to establish pavement conditions on Runway 16/34 at Dublin Airport and Runway 17/35 at Cork Airport. The automated distress data were compared to visual distress data identified from manual walking surveys (at Cork Airport) and forward view digital video (at both Dublin and Cork Airports). As previously noted, DAA operates both Dublin and Cork International Airports. For consistency with surveys done prior to 2012, the manual and video distress surveys were conducted using the PCI methodology as described in the 2003 edition of the ASTM Standard D5340. The manual survey is based on a sampling procedure and detailed measurement is carried out only on the selected sample units. For asphalt-surfaced airfield pavements, 16 possible distress types are defined in the 2003 edition of ASTM D5340 and a detailed survey manual is used by the survey team. In the 2012 edition of the D5340, there are 17 distress types listed, as weathering and raveling are treated as separate defects. In this study, weathering and raveling were evaluated as a single distress type using the 2003 standard. The pavement distress data were assessed manually by detailed measurement and recording of distress quantities on each sample unit using a hand odometer, a tape, a straightedge, and a scale. The sample unit PCI results are extrapolated to represent the pavement section as a whole.

The asphalt-surfaced runways were divided into sample units approximately 10 feet wide and 328 feet long to accommodate a single pass of the LCMS equipment. The pavement condition data were collected on both runways during daylight hours between flights. To establish a reference value to compare with the automated LCMS pavement distress measurement and video distress data, a manual walking survey was carried out to establish ground truth at Cork Airport. The manual PCI distress survey was carried out by personnel with years of experience performing condition surveys using the PCI methodology (ASTM Standard D5340).

As the manual survey is a time-consuming task and the runway was in live operation, a sampling procedure was adopted. In total, 42 sample units (13 percent coverage) were manually surveyed, consisting of seven sample units randomly selected in six different lanes or passes. The pavement distress was also recorded using visual assessment from the forward view video to determine the Video PCI for the same 42 sample units. The sample unit and section PCI values from the LCMS, video, and manual surveys were compared in the analysis.

At Dublin Airport, Runway 16/34 was divided into twenty passes across the runway, identified by letters A to T starting from the east edge to the west. Each pass had 19 sample units, with a total of 380 sample units over the whole runway. The high-speed LCMS survey and forward view video in each of the twenty passes was carried out on Runway 16/34 in June 2013. The data collection included 100 percent coverage over the full length of the runway. Due to traffic restrictions, however, it was not possible to obtain sufficient daylight access to carry out a manual survey on this runway.

The LCMS data was processed for all twenty passes to determine the LCMS-PCI. The Video PCI survey was carried out for each 328-foot sample unit on the full length of passes D, H, I, J, K, L, M, P and S (180 sample units in total). The PCI values from the LCMS and video were compared in the analysis.

The distress data from the manual, video, and LCMS surveys were processed and evaluated using PAVER to determine the PCI results for the three survey methods. There was very good agreement between the overall average PCI from the manual, video, and LCMS methods. For Runway 17/35 at Cork Airport, the Manual PCI was 89, Video PCI was 90, and LCMS-PCI was 94. For Runway 16/34 at Dublin Airport, the Video PCI was 69 and LCMS-PCI was 74.

The results generally showed good consistency between the type, quantity, and severity of distress data identified from the manual, video, and LCMS methods. The most common defects observed were longitudinal and transverse cracking, weathering and raveling, and alligator cracking. During the analysis, in general, there was little need to intervene with the automated distress data outputs from the LCMS. Where intervention was required, this involved some manual verification and adjustment for short lengths of hairline longitudinal and transverse cracking. The runway at Dublin Airport had transverse tining throughout, while in Cork Airport the runway had transverse tining throughout along with combined transverse and diagonal (multi-directional) tining over a 2,300-foot stretch of the runway from chainage 1,000 to 3,300. As part of the processing, the LCMS automated image/data algorithms were modified to prevent the transverse tining being diagnosed as linear cracking. In the areas with multi-directional tining, the automated algorithms had a tendency to misdiagnose these areas as raveling, requiring some manual adjustment. The algorithms were also improved to help in the identification of short lengths of low severity sealed cracks. See Figure B-9.

Figure B-9. LCMS data collection at Dublin Airport.

The sample unit PCI values ranged from 68 to 100. Generally, there is very good agreement between the three surveys across all the sample units, with the automated LCMS being slightly higher. Based on the sample unit PCIs, the average absolute difference between the manual and LCMS was 5 PCI points, manual and video was 2 PCI points, and video and LCMS was 4 PCI points. Table B-1 shows the average PCI values for each pass and indicate that the three survey techniques give very similar section PCI values.

Table B-1. Average PCI values for manual, video, and LCMS.

17/35 Test Pass	Manual PCI	Video PCI	LCMS PCI
Test Pass B	96	96	99
Test Pass D	93	92	97
Test Pass F	88	88	91
Test Pass I	83	86	87
Test Pass K	92	92	96
Test Pass M	85	86	92
Average	**89**	**90**	**94**

A comparison of the video and LCMS sample unit PCI data for passes D, H, I, J, K, L, M, P, and S on Runway 16/34 at Dublin airport are shown in Table B-2. The average PCI values for each pass shown below indicate the two survey techniques result in similar values.

Table B-2. Video and LCMS sample unit PCI data comparison.

16/34 Test Pass	Video - PCI	LCMS - PCI
Test Pass D	75	82
Test Pass H	71	77
Test Pass I	66	65
Test Pass J	67	69
Test Pass K	69	74
Test Pass L	60	69
Test Pass M	69	67
Test Pass P	68	77
Test Pass S	81	86
Average	**69**	**74**

Use of Structural Data

The collected structural data are primarily used to determine the strength of existing pavement. This is an important and difficult task, as Dublin Airport is an "old" airport, with some concrete pavements dating to the late 1940s. Many of the original pavements and airport layouts have been repurposed numerous times. Some of the original aprons have been strengthened over the years as pier and terminal developments evolved. In undertaking pavement evaluations, it is common to encounter a variety of "non-standard" pavement structures, with multiple layers of overlying concrete slabs dating from different eras, "sandwich" layers of old bituminous surfaces between concrete slabs, and multiple layers of bituminous surfaces dating from different eras overlying concrete slabs, lean-mix bases, or granular bases.

A variety of different methodologies and pavement evaluation guides are used to perform structural investigation of these complex pavements. These include:

- Defence Estates Guide – UK – A Guide to Airfield Design and Evaluation – DMG_27, and in particular Appendix I of DMG 27, Structural Investigation of Airfield Pavements.
- ICAO Aerodrome Design Manual Part 3 – Pavements and ICAO Annex 14.
- FAA 150/5370-11B Use of Non-Destructive Testing in the Evaluation of Airfield Pavements.
- FAA 150/5335-5 Standardized Method of Reporting Airport Pavement Strength PCN.
- FAA 150/5320/6F – Airport Pavement Design and Evaluation.

However, determination of a representative PCN on these non-standard pavement structures is not straightforward and requires significant pavement engineering expertise and judgement.

Use of Pavement Condition Data

The collected pavement condition data are used for a variety of purposes. The data are transformed into a format that allows the pavement and pavement conditions to be visualized. The detailed crack mapping is used by the operations staff to monitor distresses, to identify the need for more detailed inspections, and to schedule maintenance operations.

The forward view, range, and intensity images were output as JPEG images from the LCMS survey to use in the graphical reporting of the data. The imagery, distress data, and PCI from the automated LCMS survey were graphically reported using color-coded thematics in ArcGIS and Google Earth GIS formats, and the detailed distress data were also mapped in AutoCAD layers. The ArcGIS was reported using a .shp (shapefile) format, the Google Earth output was reported using a .KMZ file, and the AutoCAD data were reported in layers using a .dwg file format. The data were reported for each 328-foot x 10-foot sample unit on both runways. The color-coded designations in ArcGIS and Google Earth reported the area and linear distresses in separate layers using a three-color scale (red, amber, green) depending on severity. By clicking on individual sample units, the PCI data, detailed distress data, and the forward view and LCMS imagery are displayed using pop-up links. Figure B-10 shows a sample of the graphical output in Google Earth.

Operations staff use the .KMZ file to monitor distresses. This platform provides DAA with the exact location of distresses and the characteristics of each distress. For pavement areas of concern, the .KMZ file can be referenced against additional manual inspections and reports from airfield users. By reviewing the .KMZ file, maintenance treatment options can also be identified and shared with those performing the repairs.

Overlay: © 2018 Dublin Airport Authority

Figure B-10. Example of Google Earth distress output.

Data Management

Consultants collect all pavement-related data except for runway friction data. The raw data are provided to DAA and are also retained by the Airport's consultants. Processed data are provided in a range of formats, depending on the specific final use by DAA. PAVER data are stored and retained by DAA. Processed data in .KMZ format are provided directly to DAA for internal distribution to a number of departments within the organization. Data were required to be processed into an AutoCAD-compatible format, as this was the default package within DAA for commonality of data exchange and data display.

Innovation/Best Practices

DAA and the consultants match the data collection methods with airport access restrictions. With the aircraft traffic present at Dublin, automated pavement distress data collection is the most practical method. This allows the pavement distresses to be captured quickly without significantly affecting aircraft operations.

Identifying problems and potential problems when collecting pavement data is important. During the evaluation of condition assessment alternatives, the consultant was able to identify and address a significant issue. The most challenging part of the automated LCMS survey was detecting and classifying pavement distresses, with a difficulty in some instances in correctly identifying some defect types and severity levels. In this study, the automated software had some difficulty with the identification of short lengths of hairline longitudinal and transverse cracking, short lengths of low severity sealed cracks, and with the initial misdiagnosis of transverse and diagonal tining as linear cracking. The automated data algorithms were successfully improved during the study to prevent misdiagnosis due to tining and to better identify short lengths of low severity sealed cracks.

Using a .KMZ file to share the information within DAA provides an effective data visualization platform, and this platform has changed the manner in which data are viewed and shared. Prior to the deployment of .KMZ files, it was not possible to view the distress conditions. With DAA having easy access to the collected pavement data, they are better able to determine their needs and ensure issues are addressed.

CASE STUDY: COLUMBUS REGIONAL AIRPORT AUTHORITY

Agency Background

The Columbus Regional Airport Authority (CRAA) was formed in 2003 by a merger of the Columbus Airport Authority and the Rickenbacker Port Authority. The Rickenbacker Port Authority was established in 1979 to redevelop land the U.S. Air Force released with the closure of Rickenbacker Air Force Base. The Rickenbacker Port Authority took over operation of Rickenbacker Airport in 1990. In 1991 the operations of the Port Columbus International Airport, now John Glenn International Airport (CMH), and Bolton Field Airport (TZR), were transferred to the City of Columbus creating the Columbus Airport Authority.

CRAA oversees the maintenance and operations at John Glenn International Airport, Rickenbacker International Airport (LCK), and Bolton Field, a general aviation (GA) reliever airport. CRAA's mission is to "develop and operate their aviation system assets in a manner that provides passengers, businesses, and the community the highest level of service, safety, satisfaction, and economic benefit" (CRAA 2018) .

Data Collection

History of Data Collection Practices

The Columbus Airport Authority began collecting pavement condition data for the John Glenn International Airport in 1997 during the initial implementation of their airport pavement management system (APMS), which included both the landside and airside pavements at John Glenn International Airport. The APMS was subsequently updated in 2001 with the addition of the landside pavements at Bolton Field. Data for the airside pavements at Bolton Field have been collected by the Ohio Department of Transportation (ODOT) Office of Aviation since 1987.

Because of the inspection frequency and the resources needed, CRAA decided to use consultants to evaluate the pavement networks. For the 2003 APMS update, CRAA hired consultants to complete the updates for the airside pavement at John Glenn International Airport and for the landside pavements at all three airports. The 2003 airside pavement condition surveys for Rickenbacker International Airport and Bolton Field were completed as part of a statewide general aviation survey commissioned by ODOT. The data collected by ODOT were then incorporated into the APMS update completed by the consultant for CRAA. Beginning in 2006, APMS updates completed by consultants have included the pavement condition surveys at both airside and landside pavements at John Glenn and Rickenbacker International Airports, along with landside pavements at Bolton Field. Airside pavement condition data at Bolton Field continues to be collected by ODOT. This arrangement continued with APMS updates completed for the system in 2009, 2012, and 2015. The 2012 APMS update included the collection and analysis of structural data for the runways at John Glenn International Airport and Rickenbacker International Airport.

Current Practices

CRAA hires a consultant to update the APMS and collect data on the pavement distresses and conditions for airside and landside pavements at John Glenn International Airport and Rickenbacker International Airport, and for the landside pavement at Bolton Field. The last inspections at those three airports were conducted by RDM International, Inc. The airside pavement data at Bolton Field is collected as part of the ODOT Office of Aviation's statewide survey. The work history in the pavement database is continually updated by CRAA as projects are completed between inspections.

The PCI inspections are completed in accordance with the Federal Aviation Administration's (FAA) Advisory Circular (AC) 150/5380-6B, *Guidelines and Procedures for Maintenance of Airport Pavements* and ASTM D5340-12, *Standard Test Method for Airport Pavement Condition Index Surveys*. The PCI procedure is based on a visual inspection of the pavement surface. Typical equipment used for this inspection include a measuring wheel, a digital camera for documenting pavement appearance, maps depicting the airport layout, and a tablet capable of running APMS software–in CRAA's case, PAVER–for data entry during the inspection. Once the evaluations are completed, CRAA relies on the consultant to perform quality control of their data. Figure B-11 shows the pavement condition inventory and Figure B-12 shows an excerpt of the PCI map for John Glenn International Airport.

Facility	Area (SF)	% Area	Sections	% Sections	Area-Wt. Avg. Age	Area-Wt. Avg. Condition	Condition Rating
CMH Airfield Pavement Condition by Branch Use							
Runway	2,687,022	14.9	12	3.7	1	93	Good
Taxiway	6,698,390	37.2	125	38.8	5	85	Satisfactory
Apron	5,975,857	33.2	74	23.0	15	74	Satisfactory
Shoulder	2,483,266	13.8	107	33.2	5	89	Good
Blast Pad	160,008	0.9	4	1.2	1	94	Good
CMH Airfield Pavement Condition by Surface Type							
AAC	4,240,152	23.6	59	18.3	6	81	Satisfactory
AC	9,438,942	52.4	203	63.0	5	86	Good
APC	1,282,460	7.1	27	8.4	10	77	Satisfactory
PCC	3,042,990	16.9	33	10.2	19	81	Satisfactory
Overall	**18,004,544**	**100**	**322**	**100**	**8**	**83**	**Satisfactory**

Figure B-11. Pavement condition inventory at John Glenn International Airport (CRAA 2016).

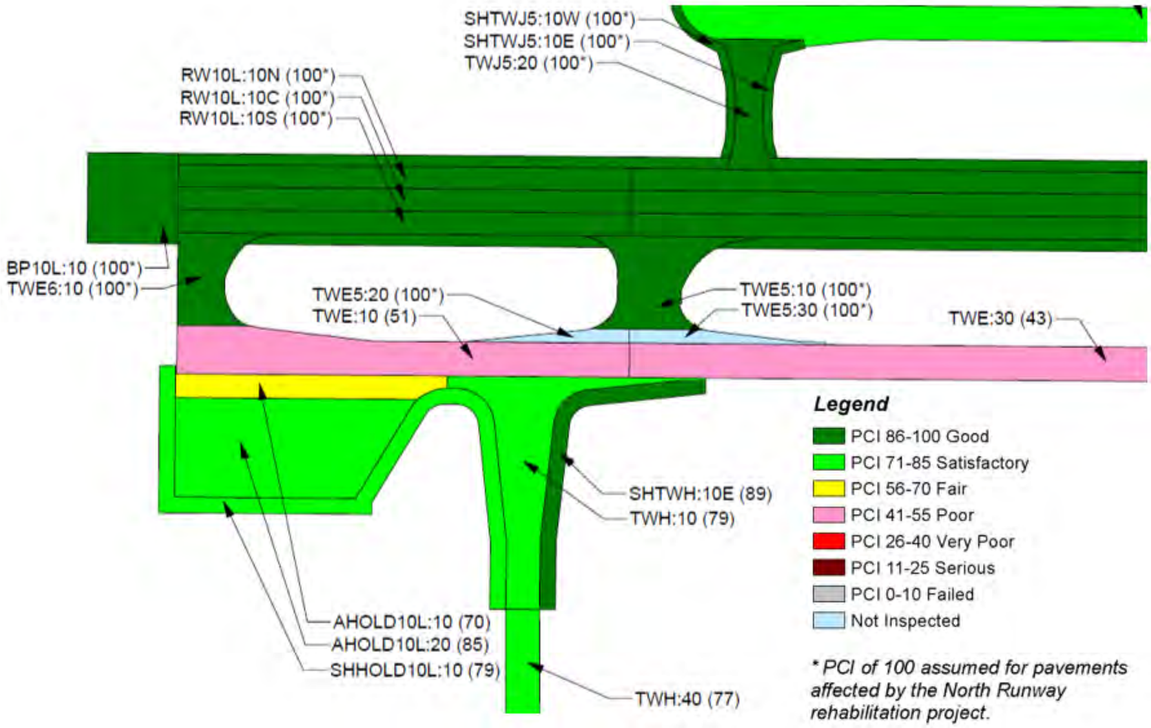

Figure B-12. PCI map example from John Glenn International Airport (CRAA 2016).

The 2012 APMS update included analyses of runway pavement strength at all three airports to meet FAA requirements. CRAA plans to include the structural evaluation of selected taxiway pavements in the next update. For the PCN calculations, CRAA follows AC 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN*, and ASTM D4694, *Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device*. FWD data collection and analysis were only performed where subgrade strength was not available. The PCN for pavements with known geotechnical characteristics were calculated without FWD testing.

Data Use

CRAA uses the PCI data to demonstrate and document compliance with FAA requirements, including FAA Grant Assurance #11 and Public Law 103-305. CRAA also uses the data to create network-level pavement management plans, identify maintenance requirements, create projects for the CIP, and determine the budget for the CIP. The PCI data helps to communicate conditions to other departments in CRAA, such as Asset Management, the Steering Committee, and the Finance Oversight Committee to the FAA, as well as to local community members.

The analysis provided to CRAA by the consultant begins by using PAVER to create an unlimited budget analysis plan. These initial results identify maintenance and rehabilitation needs, cost estimates, and a timeframe for the recommended work. These recommendations are used as the foundation of the 5-year CIP. The cost estimates are based on detailed unit costs that are developed by the consultant, which account for varying pavement structures, mobilization, construction engineering, supervision, design, and contingency costs. Figure B-13 breaks down the funding for recommended work presented in the last APMS update between the three airfields.

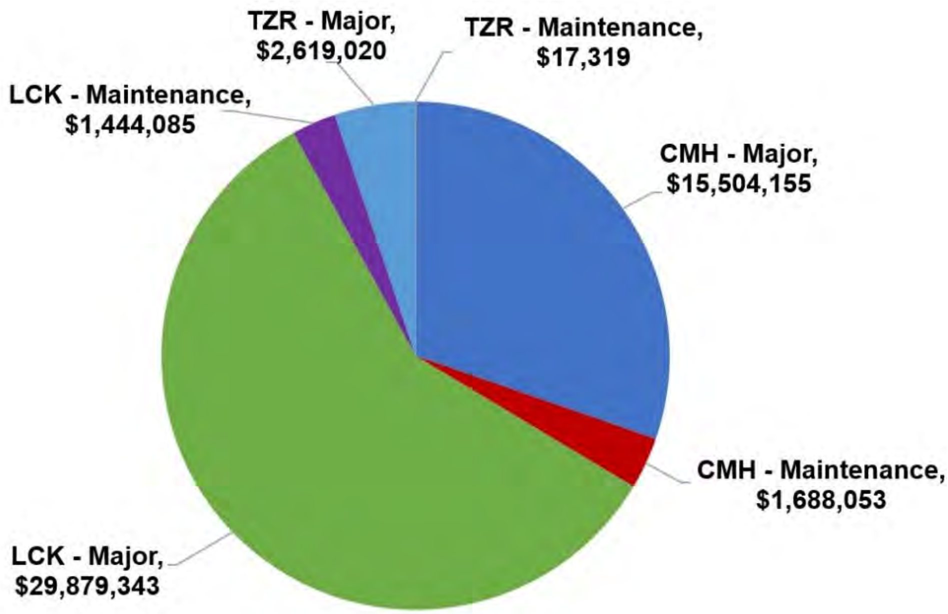

Figure B-13. Funding breakdown of recommended work for CRAA (CMH is John Glenn, LCK is Rickenbacker, and TZR is Bolton Field) (CRAA 2016 redrawn).

As the reports and recommendations from the consultant are delivered, the Planning and Engineering department meets with Airfield Maintenance to discuss the results, develop a maintenance plan, and to turn the recommended rehabilitation needs into the CIP. Planning and Engineering and Airfield Maintenance are both in CRAA's Asset Management department. Distress data and pavement condition results are used to first identify maintenance activities that could extend the life of pavement. Any pavement areas that could benefit from maintenance to postpone rehabilitation are not included in the CIP. Planning and Engineering and Airfield Maintenance then identify any high-priority repair work that needs to be addressed quickly. Next, pavements in need of rehabilitation are evaluated and prioritized.

CIP priorities are based on the current condition of pavements as well as predicted traffic and usage of the pavements. Once a CIP project is identified, CRAA performs a ground truth verification to ensure the condition reported is correct and the recommended work is appropriate. CRAA also verifies the initial cost estimate provided by the consultant by either creating an in-house estimate or by outsourcing a detailed estimate to a consultant. A charter is then drafted by the Planning and Engineering department, which contains all necessary work and condition information for the project.

The charters are first submitted to the Steering Committee. Once a charter has been approved by the Steering Committee, it is then submitted to the Finance Oversight Committee. The Finance Oversight Committee evaluates the budget for each project and available funding for the airport. Projects for Bolton Field receive funding through FAA entitlement funds, Capital Reserves, or State funding for GA public-use airports. Projects for Rickenbacker International Airport receive funding through FAA entitlement funds or Capital Reserves. Projects for John Glenn International Airport receive funding through the Passenger Facility Charge (PFC), FAA entitlement funds, Capital Reserves, and Rental Customer Facility Charges (RCFC). After projects are approved by both committees and the funding division is determined, they are added to the CIP. The CIP is posted on the CRAA website where each project is described with a justification for the project and the priority level is presented. CRAA's CIP covers 5 years and is reevaluated every year to account for both projects that receive funding and for strategic planning changes. In years between surveys, the Planning and Engineering department meets with Airfield Maintenance to discuss the current projects. The meeting is also used to identify any unexpected problem areas that need to be addressed.

Data Management

The pavement management database is updated by a consultant during APMS updates as needed. The PAVER database for CRAA is treated as a dynamic resource. Between APMS updates, CRAA personnel routinely update the PAVER database with work history as projects are completed. This is possible because the Planning and Engineering department has access to all necessary files to populate the PAVER database after each project is completed. This practice ensures that the PAVER database closely represents the current pavement conditions and that pavement history is properly captured. This process also reduces the changes to the database that the consultant needs to make every 3 years. The PAVER database is referenced between inspections when making any changes or additions to the CIP. The results from the APMS are presented to senior CRAA management every 3 years in the form of an Executive Summary. Since the PAVER database is actively maintained, the Planning and Engineering department can extract current information when requested by CRAA management.

Innovation/Best Practices

CRAA excels at using inputs from multiple stakeholders. During both maintenance activities and CIP projects, the Planning and Engineering department holds meetings with members of Airfield Maintenance. These teams regularly work on the airfield repairing distresses and observing current conditions, which can give them insight on the state of the airfield. The Planning and Engineering department believes the Airfield Maintenance's experience and opinions are vital to selecting and prioritizing projects.

CRAA's management of the PAVER database is effective. It is an active process in which a consultant takes ownership of the database during the APMS project while the Planning and Engineering department maintains the database between APMS projects. By keeping the PAVER database current, pavement history is more likely to be properly accounted for in the pavement management database. Keeping the work history current also allows extraction of accurate data at any time between APMS updates.

Concerns and Desired Future Improvements

One of CRAA's challenges is using the collected pavement condition data to make decisions on work types and then justifying its recommendations. CRAA would like a decision tree or matrix that could consider such factors as the age of the pavement, structural capacity, overall conditions, and presence of specific distresses in order to generate viable work types for maintenance or rehabilitation. Such a decision tool would simplify the project planning stage and provide useful information when presenting projects to committees.

CRAA also would like their pavement data to be better integrated with the Airport's GIS system. PAVER allows the linking of a GIS map within the software, but is currently only used for reference. As distresses are entered they are not associated with specific locations on the GIS map. CRAA would find it useful to include distress locations and condition information within their GIS system. This would enable Airfield Maintenance to know the exact locations of distresses that need repairs. CRAA would also find the GIS mapping beneficial when doing ground truth inspections for verification of conditions. Having the data in a GIS map would also allow CRAA to more easily retrieve the data and integrate those data with other programs used at CRAA. The GIS mapping could also be used when presenting recommended projects to committees to better illustrate current conditions. CRAA's GIS division, along with Airfield Maintenance, is a part of Asset Management and intends to be involved with data after the next pavement inspection.

Similarly, CRAA would like to see the pavement data be more accessible to all stakeholders, such as Planning and Engineering, Asset Management, and other committees. Currently CRAA uses the PAVER database to update work history between inspections but does not find the PAVER interface user-friendly when trying to retrieve historical data.

The airport pavement management field is currently witnessing several new emerging technologies such as image capturing through the use of unmanned aerial vehicles (UAVs), advances in algorithms for detecting distresses in 3-D images, vehicles mounted with instruments to measure roughness, capture images; laser technology to measure cracking; and GPS to identify exact locations. CRAA hopes to utilize these technologies in the future to keep the cost of maintaining an APMS down and improve retrieval of data.

CASE STUDY: GERALD R. FORD INTERNATIONAL AIRPORT AUTHORITY (GFIAA)

Agency Background

The Gerald R. Ford International Airport (GRR) was opened in 1963 as Kent County Airport. The airport was renamed Kent County International Airport in 1977 with the opening of a U.S. Customs Office, and it was again renamed in 1999 after the 38th President of the United States who spent much of his childhood in Grand Rapids and who was also a Congressional Representative for the Michigan District containing Grand Rapids for 25 years.

The airport was owned by Kent County and managed by the Kent County Department of Aviation (KCDA), although it never received funding through the County. In 2015, it was unanimously decided by officials that Kent County would divest itself of the Airport and a separate entity would assume responsibility for the Airport. While the employees and stakeholders largely remained the same, the KCDA was replaced by the Gerald R. Ford International Airport Authority (GFIAA) on July 1st, 2016. This autonomy has streamlined management processes at GRR and improved efficiency.

Data Collection

History of Data Collection Practices

The Michigan Department of Transportation (MDOT) first performed visual inspections to generate PCI data at GRR in 1988. In 2006 GFIAA hired a consultant to update PCIs for all airside pavements, as well as to inspect and calculate PCIs for landside pavements, and to perform nondestructive testing on areas with significant load-related distresses. The FWD test results were used to calculate the PCN for the areas with load-related distresses. The consultant used this data to create a 20-year Pavement Maintenance Management Program (PMMP) for GRR, which was incorporated into the master plan. Figure B-14 shows the condition distribution of the airside pavement at GRR in 2006.

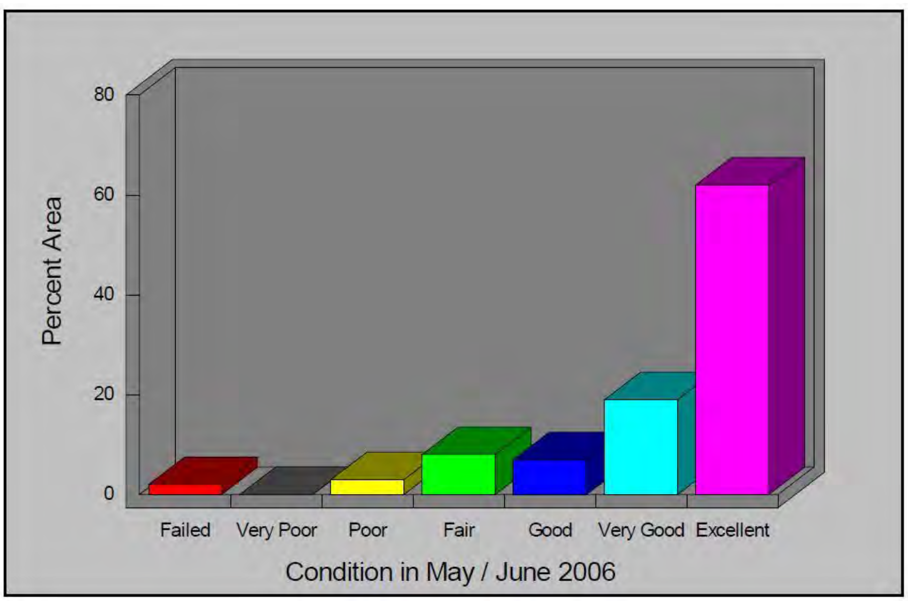

Figure B-14. Airside pavement condition distribution at GRR in May/June 2006 (GFIAA 2007).

Current Practices

GFIAA has not hired a consultant to complete a network-level PCI survey at GRR since 2006. Instead, GFIAA has elected to have Facilities Division staff inspect the pavement each year and update the PMMP for a 5-year period. The GFIAA Facilities staff complete visual surveys of approximately one-third of the airport's pavement annually and assign condition ratings of EXCELLENT, VERY GOOD, GOOD, FAIR, POOR, VERY POOR, or FAILED. The condition ratings are associated with a range of PCIs and the results are summarized in the PMMP Report. This report is updated each year and presents pavement conditions, common distresses, maintenance or rehabilitation activities performed throughout the year, planned maintenance and major rehabilitation work, and any collected project-level condition information.

The Operations staff also conducts daily inspections of all airside pavements to identify distresses such as cracking, spalling, holes/blow-ups, joint and crack seal damage or failures, patch failures, or other FOD-producing distresses. Field Maintenance staff then complete localized maintenance to address these distresses.

GFIAA has hired consultants to calculate PCNs for the airports runways based on known cross sections and geotechnical data. For any major rehabilitation projects completed, PCNs are calculated during the design phase.

GFIAA also hires consultants to update PCIs and PCNs for pavements on a project-level basis. Project-level investigations and designs have been performed on several areas of the airport and are incorporated into the PMMP and master plan. Once GFIAA identifies a problem area that requires rehabilitation, a consultant is hired to investigate the problem area and create a rehabilitation plan based on the findings. The consultant typically begins by collecting condition data and PCIs. On some projects, the consultant will also create a detailed map of all distresses within the project limits.

After distresses are identified, an investigation into the causes of the distresses is completed. Typical testing completed for the investigation process includes nondestructive testing to identify structural deficiencies or coring and additional testing if warranted. Cores are used to confirm pavement cross sections, measure the depth of distresses, and for performing petrographic analyses on PCC pavements. An image of a core from Runway 8R – 26L under a petrographic microscope is presented in Figure B-15, showing microcracks filled with alkali-silica reactivity (ASR) gel that were identified during the petrographic analysis. Figure B-16 is a portion of the map of distresses created during the project-level investigation and identifies the locations where cores were taken. The consultant then creates the rehabilitation plan including pavement designs, specifications, and possibly an estimated budget based on the analysis performed.

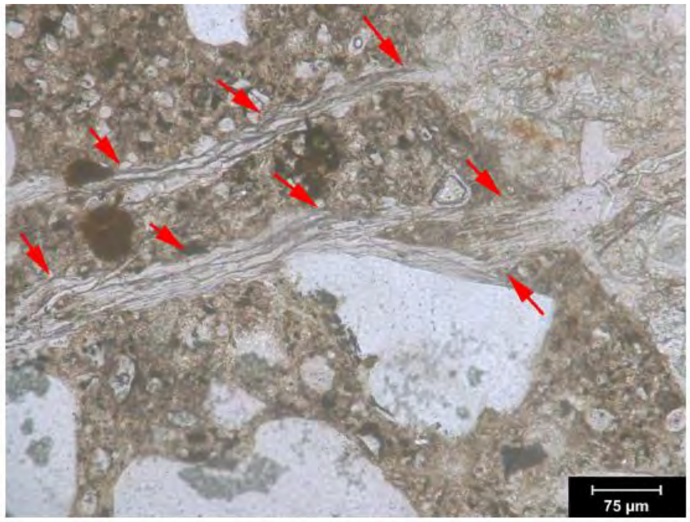

Figure B-15. An image of a core from Runway 8R – 26L taken with a petrographic microscope identifying ASR (GFIAA 2016a).

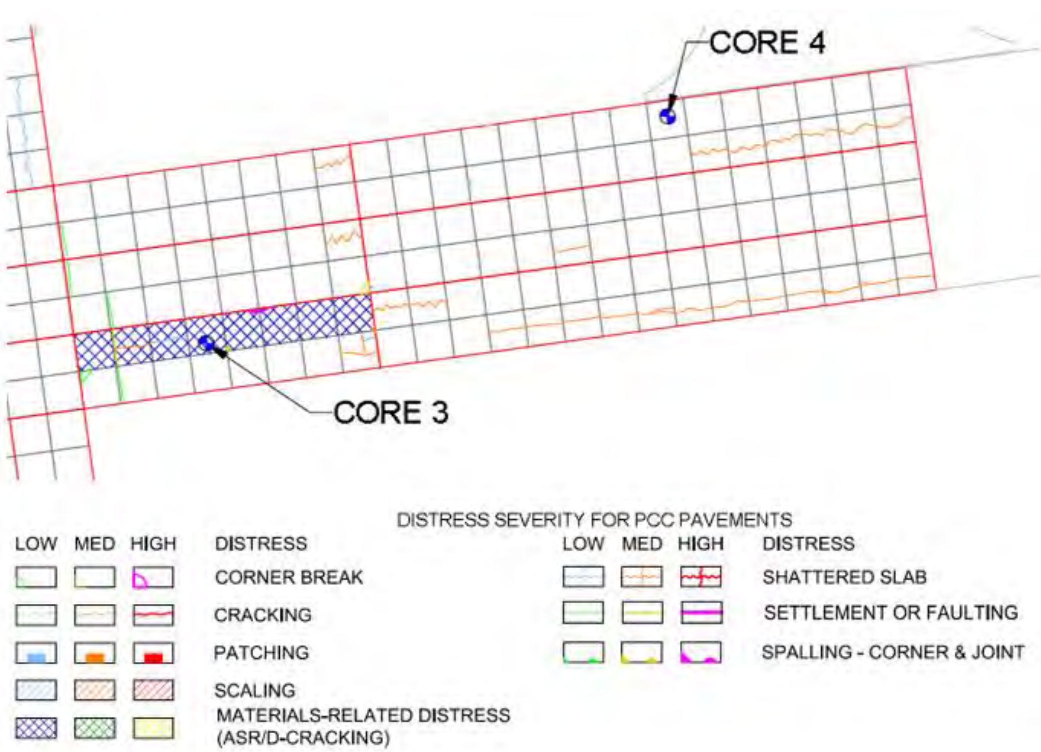

Figure B-16. A portion of the distress map for Runway 8R – 26L (GFIAA 2016a).

The project-level PCI inspections are completed in accordance with the FAA AC 150/5380-6B, *Guidelines and Procedures for Maintenance of Airport Pavements* and ASTM D5340-12, *Standard Test Method for Airport Pavement Condition Index Surveys*. The PCI procedure is based on a visual inspection of the pavement surface. Typical equipment used for this inspection include a measuring wheel, a digital camera for documenting pavement appearance, maps depicting the airport layout, and a tablet capable of running APMS software for data entry during the inspection.

For the PCN calculations GFIAA follows AC 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN*, and ASTM D4694, *Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device*. The PCN for pavements with known cross sections and geotechnical characteristics were calculated by consultants during the 2006 inspection, while pavements without this information were tested with a FWD. For pavements that have been reconstructed since that time, PCNs were calculated during the design process.

The cores are obtained using a core drill and following ASTM C42M-16, *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*. If necessary, a consultant will complete petrographic analysis of the cores following ASTM C856, *Standard Practice for Petrographic Examination of Hardened Concrete*.

Data Use

GFIAA uses the PMMP Report to demonstrate and document compliance with FAA requirements, including FAA Grant Assurance #11 and Public Law 103-305. GFIAA uses the network-level condition data to create pavement management plans, identify maintenance requirements, create projects for the CIP, and determine the budget for the CIP. The PCI data are used by the Facilities, Operations, and Field Maintenance Divisions. The data are also helpful when presenting the pavement needs to the Airport Authority Board, the Airport Administration, the FAA, and other stakeholders.

GFIAA hires a consultant to consolidate the distress information collected during project-level work and the Operations Division's daily inspections and to create a localized maintenance plan. Figure B-17 presents the localized maintenance plan developed by GFIAA and a consultant based on the distresses identified during the investigation. GFIAA and the consultant separated the localized maintenance items into different projects and prioritized those projects based on types of distresses, severities, and locations. The consultant then estimated the costs for each project. The projects presented in Figure B-17 had a prioritization rank of 2, 4, and 5 out of 17 based on the prioritization criteria described.

Figure B-17. The localized maintenance plan for Runway 8R – 26L (GFIAA 2016b).

GFIAA creates a CIP for a 5-year period each year with the previous CIP used as a starting point. After GFIAA has collected the visual pavement condition data, this information, along with any project-level data, are combined with the previous CIP to identify the projects for the current CIP. The project-level data are also used in determining the budget for the CIP. GFIAA staff or on-call consultants develop the budgets for rehabilitation or localized maintenance projects. The Facilities Division first prioritizes major and localized work projects based on the pavement rank, use, and condition. The Facilities Division then meets with the Operations and Field Maintenance Divisions to ensure all parties agree on the prioritized list. Most members of the Facilities Division work closely with the Operations and Field Maintenance Divisions and therefore have a good understanding of their perspective prior to the meeting.

Following the agreement of the three divisions, the CIP is then submitted to the Airport Authority Board. The CIP covers all areas of pavement that require attention, even though the Facilities Division understands some of these projects will not be funded due to budget limitations. The Facilities Division feels that providing a full list of projects conveys the true state of pavements to the Airport Authority Board and Airport Administration. The Airport Authority Board has full confidence in the expertise and recommendations from the Facilities, Operations, and Field Maintenance Divisions and typically approves the recommended CIP as is. Any changes made to GFIAA's CIP are often due to FAA feedback or budget constraints.

Once the CIP is finalized and approved by the Airport Authority Board, the Facilities Division creates the PMMP. GFIAA's PMMP is an abbreviated version of the CIP. Major rehabilitation and localized maintenance projects are described in the report, without specified details or budgets. The CIP and PMMP Report are then submitted to the FAA. While the PMMP Report meets the FAA's requirements for Grant Assurance #11 and Public Law 103-305, more justification is often required when requesting funding. The data collected at the project level are used to justify the projects to the FAA.

Data Management

The data used in creating the PMMP are updated routinely by GFIAA staff. Throughout the year the Operations Division monitors and identifies distresses and requests maintenance on a shared Google Doc. The Field Maintenance Division has access to this document and is immediately able to see requests. Once the Field Maintenance Division completes an activity, the document is updated. This system allows GFIAA employees in several different divisions to monitor distresses and work requests instantly. It also provides a simple way to summarize localized maintenance performed throughout the year. Facilities Division staff also collect and update the pavement condition data each year for the PMMP. These data are entered into an Excel worksheet that is kept on an internal network drive accessible to all Facilities Division staff. The PAVER database, PCIs, and PCNs are only updated when a consultant performs either network-level or project-level projects.

Innovation/Best Practices

One of GFIAA's best practices is the effort put into the project-level rehabilitation projects. GFIAA takes the time to investigate what types of distresses are present and what mechanisms are causing these distresses. With this information GFIAA can make appropriate choices on rehabilitation methods. Spending time and effort to investigate pavement problems before rehabilitation allows GFIAA to learn from previous problems and construct pavements that will have a longer service life.

Another practice that helps GFIAA excel is the open communication and trust between departments. Since employees in the Facilities, Operations, and Field Maintenance Divisions often work together, each is likely to be aware of the viewpoint of other departments. This allows for open and honest discussions when identifying and prioritizing projects for the CIP. There is also a large amount of trust between the divisions and the Airport Authority Board. The CIP recommended by the Facilities Division is often accepted by the Airport Authority Board with little to no additional changes, unless dictated by budget constraints, because of the trust in the Facilities Division's expertise.

An additional practice that has proved beneficial to GFIAA is the inclusion of maintenance activities in their PMMP. Throughout the year the Operations Division notes any areas in need of localized maintenance in a Google Doc, which is shared with the Field Maintenance Division. If any work is completed, such as patching or crack sealing, it is noted in the Google Doc by the Field Maintenance Division and included in the PMMP. Having maintenance needs, completed work, and the current pavement conditions in one centralized location allows GFIAA to quickly identify issues. The PMMP also reports any remaining localized needs to be completed in the following year.

Concerns and Desired Future Improvements

GFIAA has concerns related to the current process for collecting data. The first concern is related to the frequency and density of inspection. GFIAA is unsure of what frequency and density of condition data are needed to effectively manage their assets. While the FAA has standards for the frequency of inspections, GFIAA is unsure of the most appropriate density and what frequency is best for GRR.

GFIAA is also concerned with the value of the data collected, and specifically how the collected data translates to the decision-making process. GFIAA is concerned that some of the data collected is not needed to develop the CIP and other types of data that are not collected could be more useful. GFIAA is also concerned that the data currently collected are not easily understood by those without a background in pavements. While the Facilities, Operations, and Field Maintenance Divisions find the data easy to understand, members of the Airport Authority Board or the Airport Administration without applicable experience may not understand the data as well.

In the future, GFIAA hopes that the pavement data can be better integrated with the Airport's GIS system. PAVER allows linking of a GIS map within the software, but it is only available as a reference. Entered distresses are not associated with specific locations on the GIS map. GFIAA found it useful to have distress locations and condition information from the distress maps created on several of their project-level projects. This allowed the Field Maintenance Division to know the exact locations of distresses that required repairs. GFIAA hopes that similar distress maps can be incorporated into their GIS map in the future.

CASE STUDY: NORTH DAKOTA AERONAUTICS COMMISSION

Agency Background

The North Dakota Aeronautics Commission (NDAC) was established in 1947 by the North Dakota State Legislature. NDAC's mission is "to serve the public by providing economic and technical assistance for the aviation community while ensuring the safe and cost-effective advancement of aviation in North Dakota" (NDAC 2018). NDAC currently serves 89 public-use airports, including 8 commercial service airports and 53 in the National Plan of Integrated Airport Systems (NPIAS). By communicating with state and local organizations, the FAA, legislative and government offices, local airports, and national aviation groups, NDAC supports aviation activities throughout the State. Funding for NDAC comes from aviation fuel taxes, aircraft excise taxes, and aircraft registrations. Figure B-18 presents the public-use airports included in the State's 2015 airport pavement management system (APMS) update.

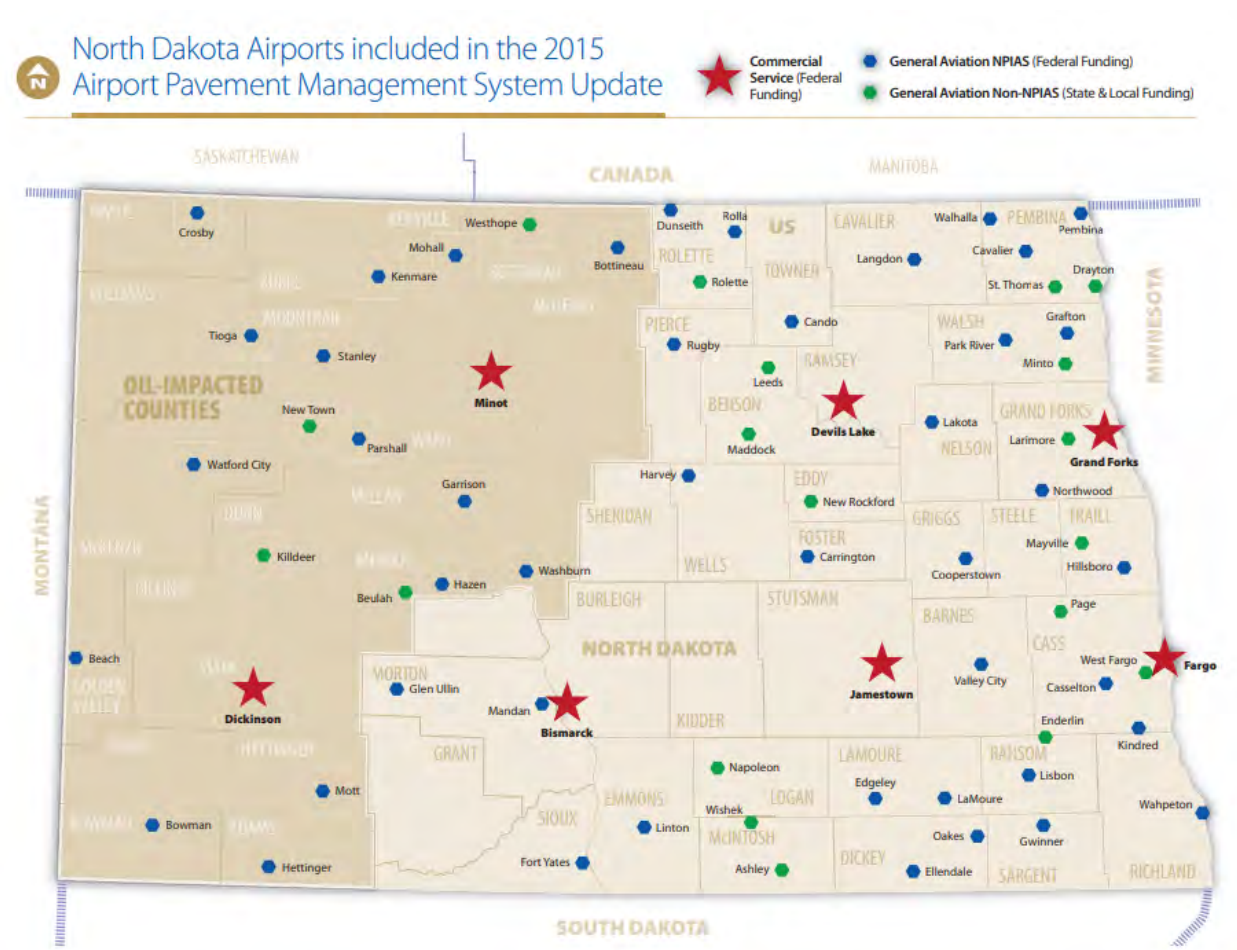

Figure B-18. Airports included in the 2015 pavement condition survey (NDAC 2016a).

Data Collection

History of Data Collection Practices

In NDAC's early years there were no standard practices or required methods for evaluating and prioritizing pavement repair and rehabilitation needs within their system. Airports would submit requests for funding and NDAC would distribute the available funding based on the priority of the airports, which was based on the airports' traffic. Some information collected during the FAA 5010 airport inspections would be used to help verify the funding requests and prioritize funding. In 1988, NDAC implemented their first APMS using the PCI procedure to visually assess pavement conditions. Since then, condition data and updates to the NDAC APMS have been completed by outside consultants. This decision was made to focus their limited staff on other responsibilities.

In 2006, the Upper Great Plains Transportation Institute (UGPTI), a part of North Dakota State University in Fargo, collected condition data for NDAC at select airports using a van equipped with instrumentation to measure ride quality and record imagery of the pavement. The collected images were subsequently evaluated on computer monitors to identify distresses. The imagery technology available at that time made the accuracy of the condition inspections uncertain and ultimately NDAC decided to use traditional on-foot visual condition inspections for all airports. Based on the results, NDAC also did not see a benefit to measuring pavement ride quality.

From 1992 until 2012, NDAC's condition data and pavement management reports were analyzed using AIRPAV, a proprietary pavement management program developed by the consultants completing the APMS updates. In 2012, NDAC switched from AIRPAV to PAVER, a pavement management program developed by the U.S. Army Corps of Engineers. Inspection information from the 2009 survey was transferred to PAVER, while all earlier results were not migrated. Any information needed from historical inspections can be accessed in hard copies of previous reports.

In 2011, with AC 150/5335-5B, the FAA mandated the determination of a PCN for runways at commercial service airports by 2014, and with the subsequent release of AC 150/5335-5C, the deadline for reporting PCNs was extended to 2015. To comply with this mandate, NDAC included the structural evaluation and analysis of commercial service runway pavements as part of their 2012 APMS update. Since 2012 the PCN has been determined and reported for any pavement that is constructed using federal funding.

Current Practices

Currently NDAC collects data for pavement maintenance and construction annually, while pavement conditions are evaluated every 3 years at all public-use airports; the most recent inspection was performed in 2015 by Mead & Hunt with Applied Pavement Technology, Inc., serving as a subconsultant. PCNs were calculated for the runways at North Dakota's eight commercial service airports in 2012. In addition, PCNs are calculated for newly constructed pavements that are federally funded.

Pavement maintenance and construction history is collected internally before consultants perform PCI inspections and calculate PCNs. During the 2012 APMS update, NDAC recognized the difficulty in requesting pavement maintenance and construction history information from airports or design firms during the pavement condition updates. To update construction history for APMS projects, airports and design firms had to locate records up to 3 years old; many either had difficulty recovering this information or did not have the time to do so.

With input from several consultants and airports throughout the state, NDAC developed a work history form which is now completed by the airport or its consultant once a maintenance or rehabilitation project is finished and must be submitted with any applicable AutoCAD as-built drawings. At the end of each construction season NDAC checks with all airports to ensure that all work history forms and applicable as-built drawings have been submitted. This annual request helps to ensure that needed information is readily accessible. Since adopting the use of the form, the process of collecting pavement repair and construction records has been streamlined. It provides a benefit to NDAC, the airports, and their consultants who no longer must spend time to collect the information long after the completion of a construction project. All collected records are submitted to the consultant to update maps and the database at the beginning of each APMS update. The electronic work history form is presented in Figure B-19.

AIRPORT PAVEMENT HISTORY UPDATE
NORTH DAKOTA AERONAUTICS COMMISSION
SFN 60268 (12-2012)

Number

INSTRUCTIONS: Please complete and submit this document for all completed pavement maintenance and construction projects that occurred at a North Dakota public airport.

Airport Name	Engineering Firm

Contact Person	Telephone Number

Complete this section for History of Pavement Maintenance

Provide the following information for all new pavement maintenance:

Project Name	Date Construction Completed

Briefly Describe the Maintenance Performed

Location (check all that apply)
☐ Runway ☐ Taxiway ☐ Apron

Pavement Type
☐ Asphalt ☐ Portland Cement Concrete

Type of Maintenance
☐ Crack/Joint Repair ☐ Patching ☐ Mill and Overlay ☐ Surface Treatment

Complete this section for History of New Pavement Construction

Provide the following information for any new pavement construction, removals, extensions, overlays, or reconstruction:

Project Name	Date Construction Completed

Briefly Describe Changes in Pavement Structures

Drainage System Installed
☐ No ☐ Yes - Specify which system: ☐ Edge Drain ☐ Under Drain System

Provide AutoCAD drawing files of the following (See attached pages for CAD Drawing examples):

For new pavements:

☐	Centerline of each runway must be shown and labeled on the CAD File
☐	Pavement layout(s)
☐	Pavement section detail(s) with each layer thickness identified
☐	Joint Layout Information on all PCC Pavements
☐	Any other pertinent details for new pavements

For pavement maintenance:

☐	Areas maintained with description of what type of maintenance was performed
☐	Details of work performed
☐	Patching

Signature of Airport Authorized Representative or Airport's Designated Engineer	Date

Figure B-19. North Dakota Aeronautics Commission Work History Form (NDAC 2012).

Every 3 years consultants complete inspections at all paved public airports to verify the pavement inventory and collect condition data to develop PCI values and update the APMS. The PCI inspections are completed based on AC 150/5380-6B, *Guidelines and Procedures for Maintenance of Airport Pavements* and ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys* using visual inspection of the pavement surface. The inspection rate is slightly reduced from the coverage recommended in ASTM D5340. Typical equipment used for this inspection includes a measuring wheel, a digital camera for documenting pavement appearance, maps depicting the airport layout, and a tablet capable of running PAVER software for data entry during the inspection. Once the evaluations are completed, the consultant performs quality control of their data. On an as-needed basis, NDAC will also verify results from the most recent FAA Form 5010.

FAA 5010 inspections are completed periodically in accordance with AC 150/5300-19, *Airport Data and Information Program*. Inspections for commercial service airports are periodically completed by an Airport Certification Safety Inspector, while general aviation airport inspections are conducted by any authorized regional airport, state, or contractor personnel either annually or triennially. Inspectors use the airport's latest Form 5010 and GIS to validate or identify any discrepancies in the infrastructure, services, or general information about the airport. These inspections include a cursory rating of the airport's runway pavements: the runways are rated EXCELLENT, GOOD, FAIR, POOR, or FAILED, based on typical distresses such as cracking, condition of joints, spalling, and surface condition. The runway ratings can be used to identify any discrepancies from the surveys conducted in the APMS update. Once inspections are completed, the inspector will enter inspection findings into the AirportIQ 5010 database.

As noted previously, in 2012 PCNs were calculated for the runways at North Dakota's eight commercial service airports in accordance with AC 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN*. For four of the eight commercial service airports, subgrade strength data were not available. These data were collected and determined in accordance with ASTM D4694, *Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device*, using an FWD. Since the 2012 APMS update, PCNs are determined by individual airport consultants as part of each design and construction project. The PCN data are reported to NDAC at the completion of each construction project.

Data Use

NDAC uses the PCI data to demonstrate and document compliance with FAA requirements, including FAA Grant Assurance #11 and Public Law 103-305. NDAC also uses the data to create network-level pavement management plans, identify projects for the State's CIP, determine budgets for the CIP, and communicate conditions to various stakeholders, including airports, consultants, local and state agencies, and the FAA.

The analysis performed by NDAC and consultants to develop the CIP begins by using PAVER to create an unlimited funding budget scenario for all pavements for a 5-year period, while because of their importance runway pavements are evaluated for a 10-year period. These initial results identify maintenance and rehabilitation needs, provide approximate cost estimates, and include a timeframe for the recommended work. When NDAC began their APMS program the unlimited funding budget scenario was used as the foundation of the CIP. As they gained experience in the CIP development process, NDAC used the results of an M&R needs analysis to compare and adjust the existing CIP, which they update annually between APMS projects, using forecasted condition data. When an APMS update project is completed, each airport or governing body is expected to review the information and develop their own CIP based on the presented current conditions and the recommended work. Each fall, NDAC meets with as many airports as possible to discuss the airport's recently completed work, planned work, and their CIP. Then NDAC reviews the airport's latest conditions to determine if the airport's recommended CIP projects are necessary and realistic. NDAC also uses the collected distress data to identify any pavements whose life could be extended with localized maintenance alone.

NDAC planners, consultants, and other decision makers discuss the individual airport projects in the airports' proposed CIPs and evaluate several factors. First, NDAC identifies the projects that will be high priority and may receive FAA discretionary funding. The priority of projects is based on the airport's traffic and current conditions of the pavements. NDAC then identifies any projects that could be funded by NPIAS entitlement funding. NDAC identifies any additional contributions that may be required for the projects that can be funded through discretionary or NPIAS entitlement funding. Once the funding for federal projects has been budgeted, NDAC identifies the remaining rehabilitation and maintenance projects and selects those which will not receive federal funding but are deemed critical. NDAC's State funding is distributed biennially, so the CIP and initial budget are also created to span 2 years.

Once the anticipated CIP is finalized and agreed upon by NDAC and the airports, NDAC helps the airports to identify what types of funding are available for each project and assists with obtaining the funding. Airports with localized maintenance or low-cost projects are encouraged to apply for local and/or state funding only and not request federal funding. By not using federal money for these smaller projects, the airports are able to complete these smaller projects for less because they do not require the additional administration, engineering, and other costs associated with the use of federal funding.

In 2012, NDAC started to use a web-based platform to communicate pavement condition information from the most recent inspection, as well as past conditions and estimated future conditions. This website provides statewide summaries, specific airport details, maintenance guidelines, and pavement inspection guidelines. The site also includes an Airport Details section where the following information is available: airport maps, pavement conditions, forecast pavement conditions, pavement distresses, recommended M&R for each airport, PCNs for commercial service runways, as well as links to individual airport and statewide executive summaries developed as part of current and past APMS updates. Figure B-20 shows an example of some of the information available on the web-based platform (NDAC 2016b) which was developed as a collaboration between NDAC and consultants. It is hosted by NDAC; however, the data are updated every 3 years by the consultant.

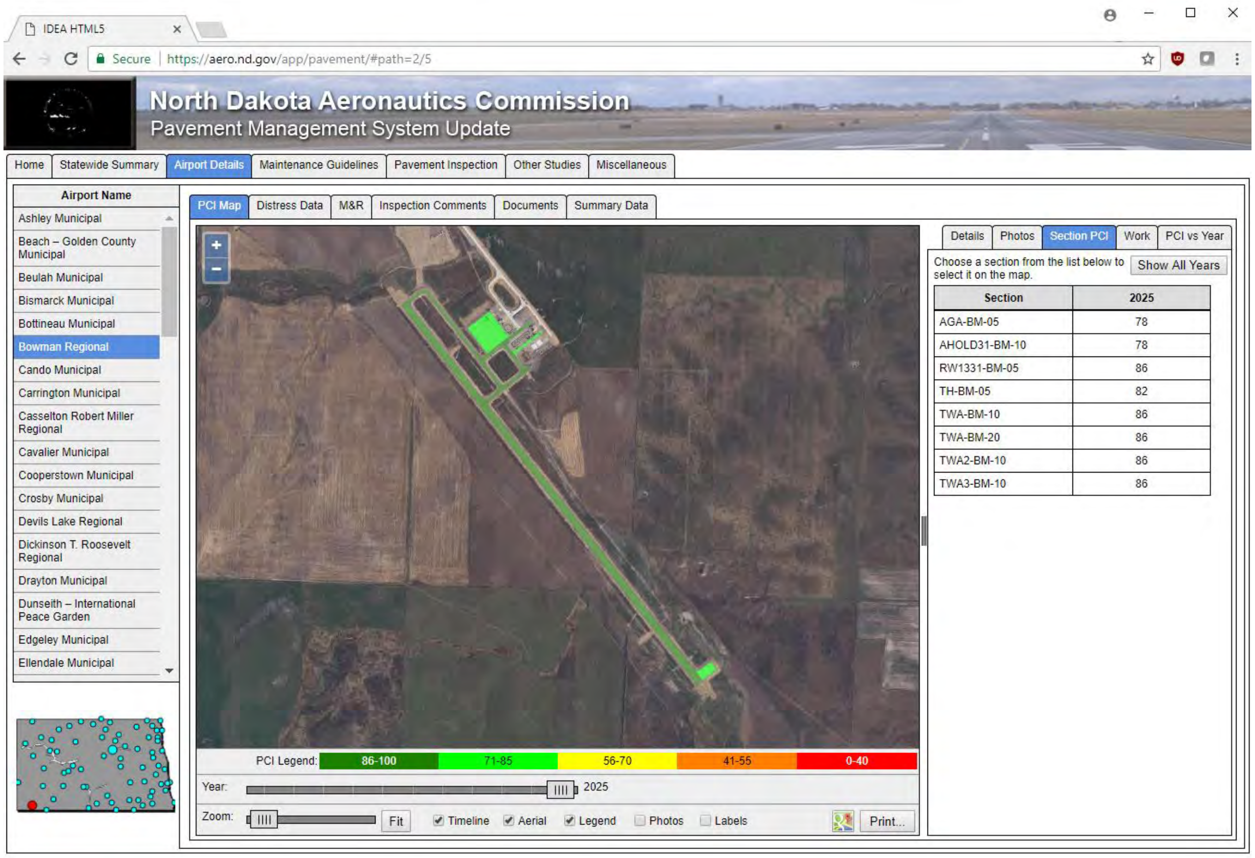

Figure B-20. North Dakota Aeronautics Commission web-based platform (NDAC 2016b).

In developing this website, NDAC set up focus groups of airport managers and other agency staff, and participants were asked what they would like to see on the website, what information would be most helpful for them in their decision-making process, and what information would help to present funding needs to a governing body. Once the first draft of the website was created it was showcased to the focus group to get a second round of comments and suggestions for the site. When the final site was released, NDAC staff traveled across the state to meet airport managers and agencies to demonstrate how to use the website to its full potential. NDAC now expects all airports to access the website when creating CIPs and when presenting funding needs to governing bodies.

NDAC also uses the web access when presenting data to their governing bodies, such as the North Dakota State Legislature. The funding for NDAC is distributed biennially and the interactive website allows them to easily communicate the condition of the airport pavement infrastructure, as well as to highlight any areas that will require special funding.

Data Management

The web-based platform contains all APMS data and results and is available to the general public. However, the typical users of the web-based information are state aeronautics staff, airport management, airport consultants, local governing bodies, and the FAA. Before the information could be accessed over the internet, NDAC used a GIS-based tool to share the information within NDAC and hard copies of the reports were delivered to each airport. While hard copies of executive summaries are still distributed to airport managers or agencies, the web-based platform is always available and allows the information to be accessed and used by a larger audience.

NDAC retains a copy of the PAVER database, but the database is only updated by a consultant when an APMS update is completed every 3 years.

Innovation/Best Practices

A practice that has changed NDAC's pavement management system is the development and use of the work history form. The system has eliminated the need for NDAC to contact airports and consultants to attempt to retrieve records for projects that were completed up to 3 years earlier. The form is expected to be submitted when a construction project is completed and has led to more accurate construction history records and less time searching for those records every 3 years prior to a pavement inspection. More accurate construction records mean that the pavement database is more accurate, so that project recommendations can also be more accurate.

Another innovation is NDAC's use of the web-based platform to share their network information. Prior to the deployment of the web platform, the use of pavement condition data was sparse and disconnected. Airports only received hard copies of the reports and relied on NDAC to make M&R plan decisions. Only airports that had staff with backgrounds in interpreting pavement management data were truly able to understand the data and use it to make their own M&R plans. That process also required more effort to convey the general ideas of the APMS to stakeholders. Decisions on M&R plans and the state's CIP were often being made without using the actual pavement condition data.

Airport managers and agencies are now expected to review the APMS project findings. Airport managers and agencies can review their results and recommended work plans to develop their own list of projects based on those findings. This allows the airports to create their own M&R plans and CIP that they can present to NDAC. This shift in the process allows the airports to be more involved in the M&R decisions while relieving NDAC of some of its responsibilities. This is unusual for statewide airport systems, where usually the decision-making is centralized. The web-based platform can also be used by airports when seeking local funding for M&R projects through the easily understandable interface to present summaries on current conditions and future condition predictions.

The key practice that has made both these tools successful for NDAC is the time spent learning what users wanted. The focus group discussions held when developing the tools allowed NDAC to identify the needs of those outside NDAC. The inclusion of various types of users of these tools during their development also fostered a sense of ownership and acceptance of the tools and information. Another important aspect to making the web-based platform successful was the time spent by NDAC instructing the airport managers and agencies on how to best use the new platform. NDAC traveled throughout the state to meet with the managers and agencies to provide instructions on how to use the platform and all the resources and information available on the platform.

Another practice that has driven NDAC's success is their regular meetings with the airport managers and agencies. Each fall NDAC travels throughout the state to meet with airport managers and agencies to discuss the airports' needs, including those not related to their pavement infrastructure. During these meetings NDAC and the airports can also decide on the most appropriate funding sources for their projects.

Concerns and Desired Future Improvements

NDAC has two primary concerns with the current process for collecting data. The first is related to the cost. While the FAA covers the majority of the cost of conducting the surveys every 3 years, NDAC still must fund surveys for any non-NPIAS airports. Once the condition surveys are completed, NDAC must be able to fund any projects not qualifying for FAA funding. In recent years the state's oil boom has generated more funding than in the past, but the state still has major shortfalls between the funding requested and the funding available. Figure B-21 presents the requested funding from all of the airports' CIPs from FY 2015-2016; the funding requests total nearly $360 million, with over 57 percent requested for pavement needs. The anticipated funding from all sources for that year was approximately $150 million, leaving a $210 million shortfall. Even though pavement inspections do not require significant funding compared to large construction projects, NDAC must be efficient in using the funding that is available.

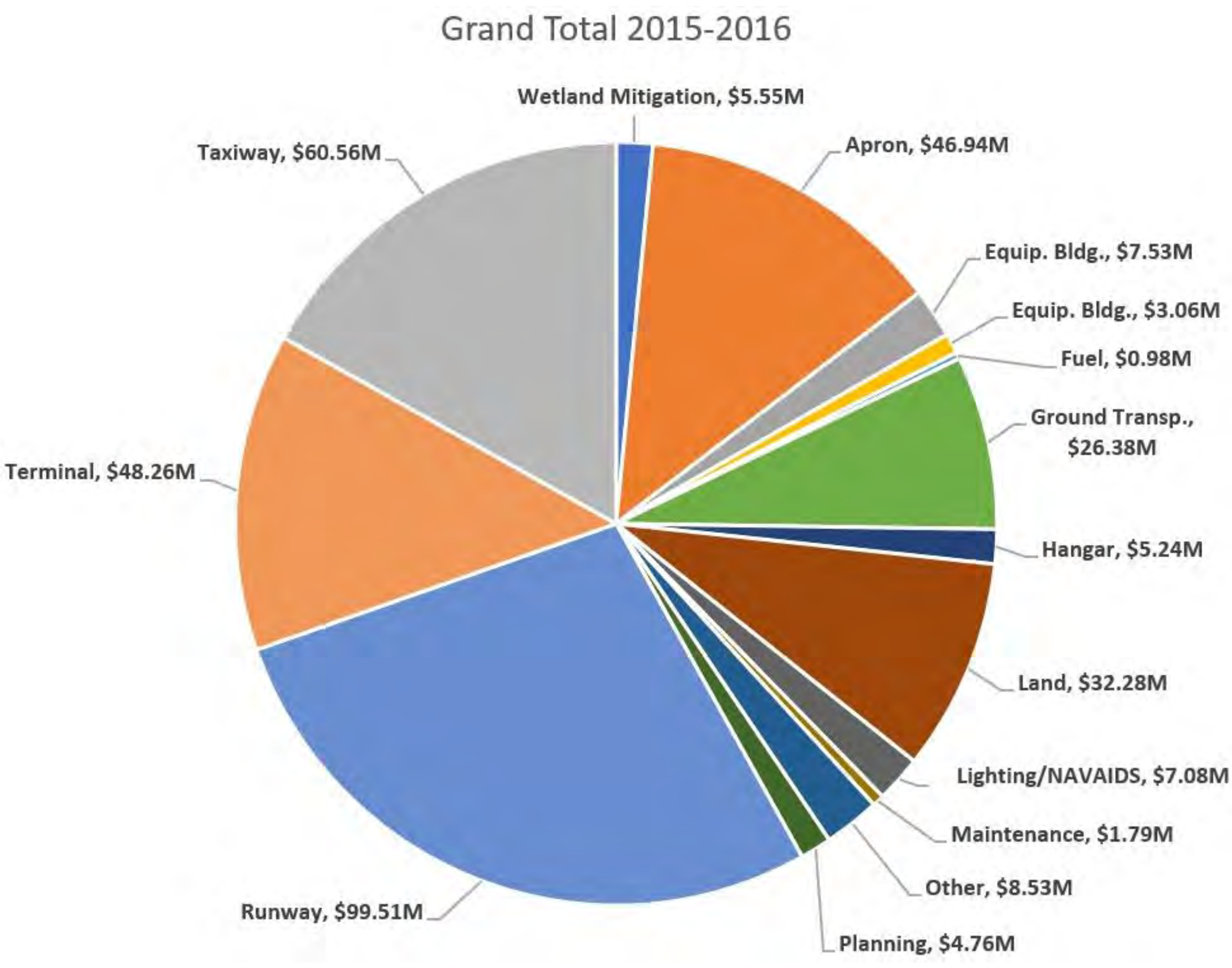

Figure B-21. Total requested funding for airports in 2015-2016 (NDAC 2014 redrawn).

The second primary concern for NDAC is the lag between the collection of new pavement condition data and when the results are delivered. On recent data collection efforts, the final deliverables are provided about 9 months after the notice to proceed is issued. It is important for NDAC to receive results quickly after an inspection so that accurate information can be used for decision making and planning purposes. For example, if an inspection occurs in the fall and the results are not published until the spring, any areas of unexpected concern would not be included in the next construction season. Also, pavement is constantly deteriorating and being worked on, so if there is a large gap between the completion of the inspections and publishing of results, some of the information may not be relevant.

CASE STUDY: MISSOURI DEPARTMENT OF TRANSPORTATION (MODOT) AVIATION SECTION

Agency Background

The Missouri Department of Aeronautics was formed in 1937. Over the span of several years the Department acquired land around the state and developed numerous small airports as well as hangars. With the establishment of the State Resources and Development Commission in 1943, the responsibility to distribute funds for maintaining airports was moved to the Commission. In 1947 the Department of Business and Administration was created and the responsibilities for aviation-related functions for the state were moved to the Division of Commerce and Industrial Development. The Missouri Department of Transportation (MoDOT) was created in 1974 and aviation responsibilities were moved to the Division of Aviation within MoDOT, which was later renamed as the Aviation Section.

Prior to 1989, the Aviation Section operated using state general revenue funds and a very small, dedicated gas tax. In 1989, Missouri was one of the first three states selected to receive block grant funding from the FAA. The block grant made possible the distribution of federal funding to non-primary, NPIAS airports within Missouri. The Aviation Section became responsible for distributing federal funding [non-primary entitlement (NPE)], state apportionment, and discretionary funding) to eligible airports under the Airport Improvement Program (AIP).

Data Collection

History of Data Collection Practices

The Aviation Section began collecting PCI data in 2002. A pilot Pavement Management Program (PMP) included five airports, with the PCI surveys and subsequent needs analysis completed by a consultant. Due to the success of the pilot, the PMP was expanded to include PCI inspections by a consultant at the majority of the paved, publicly owned, public-use airports in Missouri. This work was completed between 2004 and 2006 and included 61 airports. In 2011, the Aviation Section hired a consultant to complete PCI surveys and update the PMP at forty NPIAS airports. The PMP was also expanded at that time to include deflection testing with an FWD and pavement coring to calculate the PCN for the runways at thirteen airports chosen by MoDOT.

In 2014, the Aviation Section hired a consultant to complete PCI surveys and update the PMP for thirty NPIAS airports, and to calculate PCNs for the runways at nine airports chosen by MoDOT. Selection of the airports to receive FWD testing and coring during the 2011 and 2014 PMP updates was based on several factors, such as if the airport had commercial service and PCNs were therefore required by the FAA, if the airport had sufficient subgrade and cross section information to calculate the PCNs, if the airport was Part 139 certified, or if funding was available to the airport. During the 2014 PMP update, a web-based platform to access pavement condition data was implemented so that all stakeholders, including the public, would be able to view the collected data. Additionally, a separate project to complete PCI surveys and update to the Aviation Section's PMP for the 27 non-NPIAS airports was completed by a consultant for research purposes.

Current Practices

In 2015, the Aviation Section began a multi-year contract with a consultant to complete PCI surveys and update the PMP for 69 non-primary NPIAS airports throughout Missouri with a single consultant team. This PMP update was conducted by Applied Pavement Technology, Inc. with Jviation, Inc., and Engineering Design Source, Inc., serving as subconsultants. These surveys were completed over a 3-year period, with approximately a third of the airports inspected each year. Figure B-22 shows the airports included in this PMP update. In the first year of this project, runways and select supporting taxiways or aprons at five airports had deflection testing to calculate PCNs. The airports and test locations were chosen based on similar criteria used in the 2011 and 2014 PMP updates. In addition, a questionnaire was sent to the inspected airports to investigate their current process for identifying maintenance needs, the sources of their maintenance funding, and any concerns they have regarding their maintenance funding.

Figure B-22. NPIAS airports included in the Aviation Section's current PMP update (MoDOT 2018).

PCI procedures are based on a visual inspection of the pavement surface. The PCI for all inspections are completed based on FAA Advisory Circular (AC) 150/5380-6C, *Guidelines and Procedures for Maintenance of Airport Pavements* and the ASTM D-5340-12 procedure, *Standard Test Method for Airport Pavement Condition Index Surveys*. Typical equipment used for this inspection include a measuring wheel, a digital camera for documenting pavement appearance, maps depicting the airport layout, and a tablet capable of running the APMS software—PAVER is used for the Aviation Section—for data entry during the inspection. Once the evaluations are completed, the Aviation Section relies on the consultant to perform most of the quality control or quality assurance of the data. The Aviation Section will also verify results from the airport's latest FAA 5010 inspection to identify discrepancies.

FAA 5010 inspections are completed periodically in accordance with the FAA AC 150/5300-19, *Airport Data and Information Program*. Inspections are completed by an Aviation Section employee. Inspectors use the airport's latest 5010 form and GIS to validate or identify any discrepancies in the infrastructure, services, or general information about the airport. Required in these inspections is a cursory rating of the airport's runway pavements, although the Aviation Section also opts to inspect the taxiway and apron pavements as well. The pavements are rated EXCELLENT, GOOD, FAIR, POOR, or FAILED based on typical distresses observed, such as cracking, the condition of the joints, spalling, and surface condition. The inspector will reference the most recent PCI information during the 5010 inspections. If the inspector identifies any discrepancies, the inspector will call the manager of the airport to discuss the differences. Once inspections are completed, the inspector enters the findings into the AirportIQ 5010 database.

For the PCN calculations, the Aviation Section's consultants follow FAA AC 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN*, FAA AC 150/5370-11B, *Use of Non-Destructive Testing in the Evaluation of Airport Pavements*, and ASTM D4694, *Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device*. The pavement strength evaluation is carried out with a FWD. The cores are obtained using a core drill and following ASTM C42M-16, *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*.

Data Use

The consultant and the Aviation Section work together to develop a statewide CIP. The consultants first analyze the collected data with PAVER to determine the recommended M&R needs of the entire pavement system using an unlimited budget scenario. Cost estimates for the recommended work are generated based on average bid tab cost data gathered from pavement work completed throughout the state. Four sets of unit costs are developed for each of the Aviation Section's airport classifications (Commercial, Regional, Business, and Community). This budget scenario shows which pavements are currently in need of M&R or are projected to fall below a set target condition within the next 5 years. After this budget scenario is developed, the consultant reviews the results to create a recommended project plan with a more realistic budget. The consultant determines which projects can be addressed with NPE funding, and which projects qualify for the state's apportionment or discretionary funding. The consultant also identifies which projects have already been awarded or planned for the current year's funding. Finally, the consultant prioritizes the recommended projects by the airport's classification and facility use. This list of projects is then submitted to the Aviation Section for review.

Each NPIAS airport is required to submit their own CIP to the Aviation Section. The non-NPIAS airports are also encouraged, but not required, to submit a CIP. Formal guidance from the Aviation Section is not provided to the airports in creating their CIP, but they have the information from the most recent PMP and can contact the Aviation Section if any questions arise.

The Aviation Section reviews the submitted CIPs, along with the PCI data, to ensure that the requested projects are necessary and that the rehabilitation type is appropriate. The Aviation Section's CIP is primarily based on the individual airports' CIPs because the Aviation Section wants to ensure both that the airport agrees with the prioritization of projects and that the airport is ready to handle the needs of the projects. With limited funding available, the Aviation Section tries to prioritize runway projects first, followed by taxiways, and then aprons. The FAA requires the current PCI data to be submitted with the CIP, along with additional information such as the forecasted PCI for when the work is requested if the current PCI does not necessarily support the requested work. In the state's CIP, the costs for projects are based on the costs presented in the individual airport's CIP, because each airport is familiar with local site conditions and can provide accurate estimates. The cost estimates developed by the consultant are used as a check against the individual airport's cost estimate.

The Aviation Section maintains an open dialogue with the FAA when creating the state's CIP to identify projects likely to receive funding. After the Aviation Section submits the state's CIP along with the most recent PCI data, the FAA reviews the information and ultimately determines what projects will be funded. The data captured by the consultant is also utilized to insure compliance with Public Law 103-305 and Grant Assurance #11.

In recent years the Aviation Section has used an interactive web-based platform that provides widespread access to information collected as part of the PMP project. The Airport Details section of this platform provides airport maps, current pavement conditions, photographs of pavement distresses, historical and forecasted pavement conditions, and the recommended M&R plan for each airport. In addition to the airport details for each airport, this platform also provides statewide summaries, maintenance guidelines, and information on the pavement inspection procedure. The platform allows any airport manager, stakeholder, government official, or the public to view the information collected as part of the PMP update. The platform is frequently used by the FAA, airport consultants, and individual airports and it permits the Aviation Section to easily communicate conditions of airports. Figure B-23 provides an example of an airport map and the pavement condition information that can be viewed on the platform.

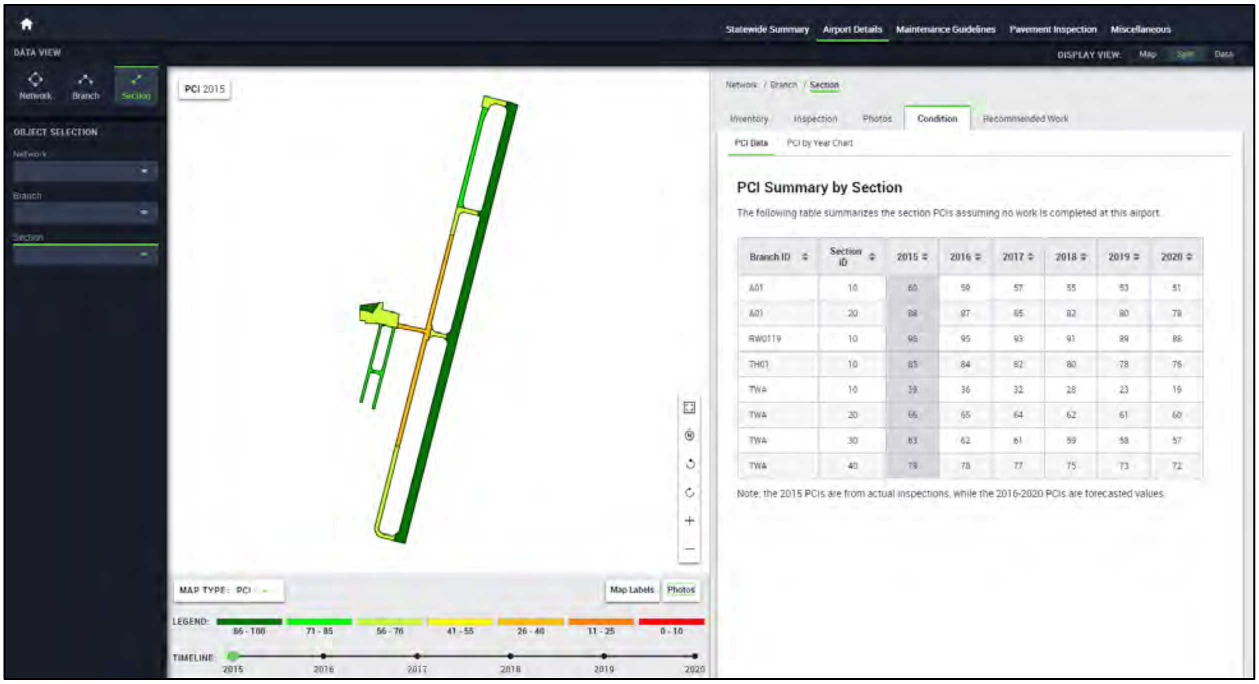

Figure B-23. An example airport map and pavement condition on the web-based platform (MoDOT 2017).

Data Management

A web-based platform is used for internal and external access to the data to a broad cross section of users. The typical users of the platform are the Aviation Section, airport sponsors and their consultants, and the FAA. Prior to the web-based platform, hard copies of the individual airport pavement management reports were provided to each airport. Now the airports can access the electronic copy of their report through the platform. While the PAVER database and platform is updated by a consultant only when an update to the PMP is completed, the Aviation Section works with each airport to update their CIP annually and references projected PCIs.

Innovation/Best Practices

The Aviation Section's web-based platform that is used to share the information from the PMP is the largest innovation for the group. Prior to the development of this platform, airports had to rely on hard copy reports or pdf files of those reports posted on its website, along with the Aviation Section, to make major decisions. The platform has changed the manner in which data are viewed and shared. With airports and their consultants having regular access to the information collected in the latest PMP update, they are better able to determine their needs and ensure they correlate with the recommended projects. The data are also easily accessible for the FAA while reviewing the State's CIP. Figure B-24 shows an example of the recommended work to be completed at an airport in 2019 based on the unlimited budget scenario.

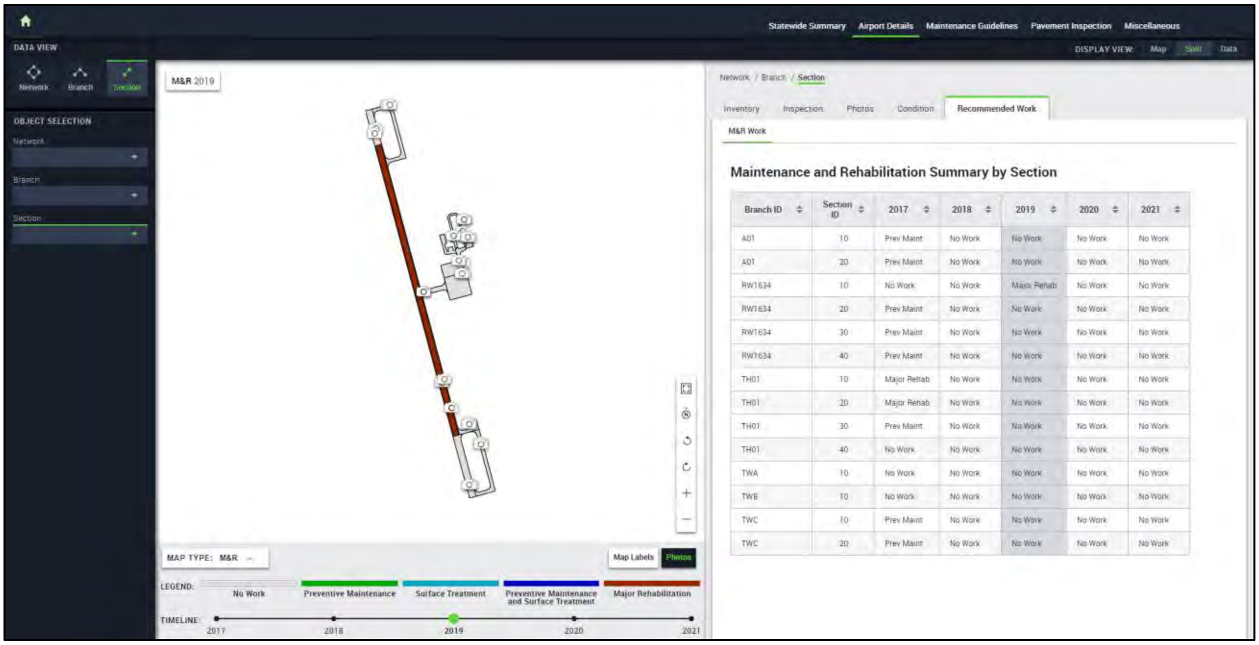

Figure B-24. Recommended work to be completed at an airport in 2019 displayed on the web-based platform (MoDOT 2017).

A key practice that has ensured the success of the Aviation Section is their open channels of communication between airports and the FAA. The questionnaire sent out in 2015 helped the Aviation Section to develop a better understanding of airports' individual practices for identifying and funding maintenance. This knowledge helps the Aviation Section each year when they work with the airports to update their CIPs. Throughout the year they are available to help airports identify the best maintenance types, identify options for funding, and answer the airports' questions. The Aviation Section also communicates with the FAA to have a good understanding of what types of projects are a priority given the limited funding. Having open communications with both the airports and the FAA helps the Aviation Section create more realistic and accurate CIPs.

Concerns and Desired Future Improvements

In the future, an improvement that the Aviation Section hopes to see is the incorporation of PCN data into the web-based platform. The Aviation Section believes that presenting the PCN data would be beneficial to the Aviation Section, the airports, and the FAA. In addition, being able to export customizable data from the web-based platform, similar to how this is done from the PAVER database, would be helpful to the Aviation Section. Because the Aviation Section uses the web-based platform more regularly than the PAVER database, having a tool to export distress data or conditions at individual airports from the platform would allow the Aviation Section to access the data more seamlessly. The same tool would also allow the FAA and individual airports, who do not have access to the PAVER database, to export customizable data sets for review.

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