

An investigation of the airport pavement management system (APMS)

Mohammad Sami A. Qabaja^{1*}, Ahmed Labeedi²

^{1*}Ph.D. candidate, Department of Civil Engineering, Cyprus International University, Mersin 10, Turkey

² Master student, Department of Civil Engineering, Cyprus International University, Mersin 10, Turkey

mohammad.kabaja@hotmail.com, ahmed.labedi@gmail.com

ABSTRACT. The research aims to discuss and investigate the process of airport pavement management system (APMS). The methodology of the research is based on previous studies that describe the major elements of the APMS to gain more solutions from the previous different case studies. The investigate includes various subjects such as components and cost approach of the APMS. The methodology used in the research is a descriptive method based on previous studies and from different books by using pavement management system (PMS). The study describes the typical distress types of the asphalt-surfaced pavements and the Portland cement concrete pavements of airports. Additionally, the research clarifies the test methods of the airport pavement, such as the ASTM D5340 and ASTM D6433. Research investigates that the software used in the APMS like PAVER and Road-SIT, Airport PMS that are used by the airport agencies to collect information about the situation of the runway pavement. The APMS still needs more research and new studies due to a lack of information and studies in different airports around the world. The airports shall use the service life estimation (SLT) for the pavement in the runways and parking. In recent studies, the method is not used, whereas including a quantitative methodology which demonstrates results to facilitate the clarity of the results to illustrate the advantage of the SLT.

KEYWORDS: APMS, maintenance, rehabilitation, distress, pavement condition, software

1. INTRODUCTION

The airport pavement management system APMS is widely used for many tasks that are important for the long-live service of the airport. It is used with a full system that includes setting schedules, specify resources and maintenance of the pavements with prepare required recommendations for the cost of rehabilitation (Bennett, 2010). The implementation of the APMS is following the aim and methodology of the PMS and applying the system of the APMS requires enormous time and resources (Tighe & Covalt, 2008). APMS help to upgrade the level of decision-making and improve the level of traffic (Pigozzi, 2015). Table 1 below shows the main components of the airport pavement management system in seven main steps (Hajek, 2011). The majority of airport overseeing groups make decisions on pavement maintenance and rehabilitation propped by current needs or experience rather than repair underpinned via quick requirement

alternately experience, as opposed long-term organising or instituted documented information. This approach did not permit them to assess the spending and influence of others stand by reform maintenance strategies leading to inactive use of existing resources (Pittenger, 2011). Those choices taken in this may have a chance to be reflected in the pavement future condition, and the accessibility for resources needs to bring the required with creating execute supporting tools, similarly as the APMS. The network level is related to the cost in the two cases, the long and short need for the present and the future. The management of the network level helps to maintain and rehabilitation of the pavement or reconstruction it in many cases, and it depends on the inspection of the networks, the inspection depends on the optical test of the pavements (Tighe & Covalt, 2008).

Table 1. Main activates of the APMS (Hajek, 2011)

| Main Level | The Activates |
|---------------|---|
| Network Level | 1- Design the APMS, including the expected results. |
| | 2- Pavement evaluation. |
| | 3- The used technology for the preservation treatments of the pavement. |
| | 4- Defining the needs. |
| | 5- Planning and budgeting. |
| Project Level | 6- Project design and implementation. |
| | 7- Operation and enhancement. |

2. RESEARCH OBJECTIVES

The main objectives of the current research are as follow:

- Execute an overview of the airport pavement management system and the main components and benefits of the system.
- Describe the main components and the cost approach of the APMS, focusing on the cost-effects of the maintenance and rehabilitation of the pavement.
- Explain the airport pavement distress in the Asphalt-Surfaced Pavements and the Portland Cement

Concrete Pavements and the maintenance way of the different types of distress.

- Explain the ASTM test methods of airport pavement. The ASTM D5340 describes the airport pavement condition index surveys, and ASTM D6433 does determine the condition of roads and parking.
- Discuss the software programs used in airport pavement management system like PAVER and Road-SIT Airport PMS.
- Use previous studies that are related to airport pavement management systems

3. COMPONENTS OF APMS

To benefit the airport pavement management system, the information on the condition of the pavement shall be collected and updated the data continuously to keep the information updated. Effective alternative methods for rehabilitation shall be recognised to determine the procedures of the rehabilitation. The airport pavement management system requires some models for prediction and cost strategies and other things that take into account the entire life cycle of the pavement. To achieve those goals of the system shall include the following (Larkin & Hayhoe, 2009):

- A system to collect and store information related to the current pavement structure and situation of the pavement.
- A system for evaluating the pavement condition.
- A system to predict pavement conditions for the future.
- A system for the design performance of the pavement in different conditions.

4. BENEFITS OF APMS

Several advantages can be accomplished by utilising the APMS system. It may be employed to providing improvement in the inventory documentation data, which is available for the pavements in a specific system. Also, pavement-relevant data is stored in a single automated repository, where access becomes considerably more manageable. The main benefit of an APMS is that it provides a more effective approach to govern the condition of the system of pavement, as well as overview any Maintenance and Refurbishment plans. A more added benefit of the APMS system is that it can be utilized to inspect the depletion patterns in the system of different pavement parts into the system (Gendreau & Soriano, 1998).

This ability equates to the ability to prophesy future conditions of pavement. An APMS can help the agency and airports to make it a most cost-effective way to ensure the Maintenance and Refurbishment procedures and its

efficient duration, but at the same time, the understanding of the long-dated effects of the decisions will be made. The capacity will also lead to the amendment of the pavement system because of an additional effective way of assigning available funding.

5. COST APPROACH OF APMS

The costs involved with an APMS provide the cost of collecting item data, evaluating the condition of the pavements, establishing a database for pavement management and analysing the data collected. It is not a one-time cost because if it should stay remain current, the database shall be updated from time to time. For more than four decades, cost-benefit analyses have been used in road assessments, stimulated primarily by the data reported in the AASHO Red Book (Vadakpat & Dixon, 2000). Also, it is clear for the cost of delay of the APMS shall be divided into two types that are related to aircraft operation and passenger time.

The APMS input and output modules are shown in Table 2; the input modules represent the components of the APMS that includes the effect of the construction procedure on airport activities. The activities might include gate delays, management of slot and other costs such as extra work required to manage planes that arrived after the time located. The expressed of fees shall be in dollars depending on the 24-hour cycle, then we can apply the construction and rehabilitation cycle that are associated with construction activity (Winfrey, 1969). When building work is ongoing as well as the fees of the aircraft that are linked to the fuel shall be computed. From the aircraft delays, we can cucullate the delays of the passenger time.

The associated fee of the output modules is the noise of taxiing and the polluted air and the pollution of ownership around the airport. Also, another of the output modules seem to be a method of rehabilitation that are related to issues with minimising the total costs of it. The total cost shall include a full report with details about the noise, air quality, passenger costs, and other things. The full cost analysis extends the quality and length of service life for the pavement airport. To keep away from the cutting of landing and departure of the aircraft and to prevent any issues in the pavement before the rebuilding of the pavement is necessary (Moavenzadeh & Alexander, 1971).

6. TYPICAL DISTRESS TYPES IN AIRPORTS

The descriptions in Table 3 show the most frequently observed pavement distress that happens in airports, and it includes Asphalt-Surfaced Pavements and the Portland Cement Concrete Pavements and this kind of pavement is the majority of the airport's infrastructure.

Table 2. Full-cost analysis of APMS (Winfrey, 1969)

| Module Types | |
|----------------------|------------------|
| Input Module | Output Module |
| Airport operation | Rehab strategies |
| Parkways costs | Air delay |
| Runway costs | Passenger delay |
| Aircraft costs | Noise |
| Local external costs | Fuel |
| Area external costs | Air quality |

Table 3. Types of distress in the airport pavement and maintenance methods (Loprencipe & Di Masci, 2017)

| Type of distress | Distress causes | Maintenance methods |
|---|---|---|
| Alligator cracking | It happens when the asphalt concrete surface fatigue under frequent traffic load. | Depending on the type of crack, it is maintained by asphalt patch or it requires major rehabilitation. |
| Bleeding | Happen when the quantity of tar or asphalt cement is excessive in the mix and with a low level of air void content. | It can be solved by spread or sweep heated sand or by removing/ replacing the asphalt. |
| Block cracking | It happened in asphalt concrete due to shrinkage and the daily temperature. | Depending on the severity, if a low it is done by surface treatment and crack seal and if the severity is high, it is considered overlay. |
| Corrugation | This problem occurs when the action of the traffic is happening with the layer of unstable pavement. | By the mill or by removal /replacement. |
| Depression | Happens when the settlement of the foundation soil during construction. | By patching. |
| Jet blast | It happens when the binder of the bituminous burned or carbonised. | By patching. |
| Joint reflection cracking | Because of the move of the concrete slab under the asphalt, this crack happens because of the changes in the thermal and moisture. | The maintenance way for the low- and medium-risk are by the crack seal and for high-risk is by the overlay. |
| Longitudinal and transverse cracking | It happens for different reasons that are pavement joint constructed poorly or AC surface shrinkage because of the low temperatures and hardening the asphalt. Last reason for cracks due to cracks in the underlying slab. | For the low- and medium-risk are done by the crack seal and for the high-risk level of cracks is done by overlay options. |
| Oil spillage | The surface of the pavement have deterioration and softening due to oil and fuel spilling. | By patching. |
| Patching | - | if deteriorated by change or replace of the patch. |

| | | |
|-------------------------------------|---|--|
| Polished aggregate | It happens during repeated traffic. | The rehabilitation for this by mill or aggregate seal coat or overlay. |
| Raveling | It happens when the asphalt binder becomes hardened that leading to the dislodging of coarse aggregate parts. | The maintenance strategy patch for normal cases and for high levels is by rehabilitation. |
| Rutting | It happens when the material moves caused by traffic loads | To solve this issue by the patch for a high and medium level or by rehabilitation for an extensive case. |
| Shoving | When the PCC pavements verge the flexible pavements that push the asphalt pavement. | The maintenance way by patch and mill as necessary. |
| Slippage cracking | The weak bond between the surface and the layers of pavements or it happens due to low strength mix. | It can be fixed by using a patch. |
| Swelling: | It occurs when soil swelling or when the action of frost. | The maintenance way of this problem by a patch for normal cases and rehabilitation for extensive cases. |
| Weathering | It happens when the binder between the fine aggregate and asphalt becomes separate because of the ages or hardens. | By patch or by treatment of the surface. |
| Alkali-Silica Reaction (ASR) | It occurs when the silica minerals react with the alkalis in the Portland cement and use the chemical deicers of pavements can speed up the formation of ASR. | By slab replacement in the high cases, is the most useful way for maintenance. |
| Blow-up | It happens when the joints are in an incompressible situation. | By patch in normal cases and slab replacement in high cases. |
| Corner break | It occurs when the repetition of a load with a lack of support. | By seal cracks in normal cases and by patch in high cases. |
| Cracks | It is a group of frequent loads, stress and shrinkage. | By seal cracks, patch and slab replacement, dependent on the problem case. |
| Durability Cracking | It occurs when the lack of ability of concrete to resist the environmental factors like freeze-thaw cycles. | In normal cases, it solved by a patch and for higher levels solved by slab replacement. |
| Joint Seal Damage | It happens for different reasons like weed growth, oxidation, and failure of the bond to the edges of the slab. | By Substitute the joint seal. |
| Pop-outs | Occurs when the aggregate expansion with freezing in combination. | By monitor. |
| Settlement | Because of the consolidation and upheaval, it occurs. | For high levels will be by patch or grind. |

7. TEST METHODS OF AIRPORT PAVEMENTS CONDITION

The evaluation of the pavements is done by using the Pavement Condition Index PCI, and the procedure of evaluating is documented in the ASTM D5340 and ASTM D6433 (Arabali & Borowiec, 2017). There is a scale for PCI that is valued from zero to one hundred (0 to 100). The value of zero represents the pavement condition are failed, and one hundred represent the pavement condition is excellent. If the pavement PCI is more than 70 will not showing immense distress related to load like cracks and in this case, it just needs preventive maintenance actions. If the pavement condition index from 40 to 70, major rehabilitation may be required, such as overlay. The last case of PCI if it is less than 40, it needs reconstruction due to considerable damages in the pavement structure (Loprencipe & Di Masci, 2017).

7.1. Airport pavement condition index surveys ASTM D5340

It is used for airport pavement condition index surveys as mentioned before. Since 1970 until now, this method was developed many times depending on the new knowledge of pavements science. This test used for pavement management in the network level and rehabilitation and maintenance in a project level (Pierce & Zimmerman, 2013). Data collection of the distress will be collected in accordance with ASTM D5340 and PCI and depending on this data, it is used for determining the maintenance and rehabilitation. The methods used for data collecting are automated methodologies and sometimes on foot (Greene and Alexander, 2004).

7.2. Airport pavement condition index surveys ASTM D5340

This test method created by the American Society for Testing and Materials, is used for determining the condition of roads and parking depending on using the Pavement Condition Index (PCI) (ASTM, 2007). This test method describes 20 types of distress for pavement that showed in Table 2. In general, the manual provided each distress type by details. The data collecting way for the test done in two ways manually, a hand odometer wheel and a straightedge (Loprencipe & Pantuso, 2017)

8. SOFTWARE'S USED IN AIRPORT PAVEMENT MANAGEMENT SYSTEM

8.1. Geographic information system GIS integrated with APMS

One of the biggest challenges facing organisations today is the capacity to effectively and securely manage, share and update the available data. In recent years, the use of GIS at airports has increased and new aeronautical infrastructure the combination of Global Positioning System GPS with GIS technology in maintenance enabling better coordination and management of aeronautical the combination of GIS with APMS subsystems can supply an assortment of advantages, including activities:

- Graphical map display of the network of pavements and appraisal of pavement condition (for example, in terms of pavement condition index – PCI), for selected branches.
- Graphical map display of other major networks for pavement management such.
- As drainage networks, lighting, and signs, markings, among others, and its description.
- Graphical display and characterisation of externalities (pollution, noise).
- Generation of input files for APMS analysis modules, extracting relevant data from pavement evaluation.
- Graphical display of the results of the APMS analysis modules and graphical output that can be included in the APMS reports.

8.2. Paver

Initially, the Pavement Maintenance Management System was introduced at the beginning of the 1970s to assist the Department of Defence in managing M&R, To a comprehensive pavement inventory. It utilizes a pavement condition index PCITM and inspection data ranging from 0 (failed) to 100 (excellent) for characterising the pavement condition to predict the M&R requirements for several years into the future also report on past and future pavement performance (Shahin& Kohn,1982). The PAVER can organisations as a state-of-the-art concerning the technology of pavement management, and its development has benefited strongly from powerful support both through the DOD community and outside it. PAVER also offers numerous technological improvements inclusive like the following (Almuhanna & Alasadi, 2018):

- It allows users to choose to use databases such as Access or SQL.
- The capacity to provide tables for private or shared paving systems (such as cost tables for M&R, maintenance initiatives, etc.) This feature was tough to realise in all previous PAVER versions.
- A lot of improved capabilities for GIS / GPS.
- A new wizard that allows pavement sections to be split.

- Use an Excel spreadsheet to create or update Inventory and Work History.
- Report on the new part history.
- Performance optimised for large databases.

Prediction modelling, the PAVER prediction modelling purpose helps define and similarly constructed group pavements that are subject to comparable climate, traffic, and different factors affecting the performance of the pavement. Historical data on the pavement condition (PC) can be used to construct a model which is used in the prediction of the kind of the pavements and at the same time, it can predict the future performance with high accuracy (Shahin, 1991).

The storage and retrieval of the data, the PAVER database is a custom-designed data framework defined on the System 2000 computer database administrator that is commercially obtainable. (System 2000 is a known brand of the Intel. company) The data framework is made for up of 12 sets of data which are connected to shape a tree structure. The storage of data in this form helps the user to get information according to their connection to different data in the database Space is ready for storing particular items regarding that data group in every data group.

8.3. Road-SIT Airport PMS

The Road-SIT PMS application, totally inserted into the strong mapping system ESRI ArcGIS. SIT Airport Pavement management system is based on the arrangement of the GIS system's specific information layers, that represents all the PMS data: vehicle survey routes, scanning of Important points and zones analysed in the inspection of the load capacity, PCI, and data of the survey (Gandolfi & Burchi, 2008).

The main benefit of this software is the analysis of the distress by the images that have high-resolution properties and by the laser that can penetrate the ground. This module enables all functional pavement to be surveyed deficiencies registered in the system's relational database, and carries out monitoring activities, Use of "mobile" devices like PDA, tablets, etc. The index of the Pavement conditions is calculated accordingly to ASTM D 5340 standards, the output worth and the results of the inspections are updated based on the maintenance activities carried out (Gandolfi & Burchi, 2008).

The second benefits are the planned subdivision of the infrastructure and the pavement, as we know there are various types of paved surface and it is known as a pavement grid map, and depending on these types the decision-makers decide the suitable methods of maintenance for the pavement. The pavement surface divided into a suitable constant number of areas that around 300 to 400 m² depending on the PCI and other properties of pavement to investigate the distress.

Also, the other benefits of the software are scanner survey of the road of the paths, and that leads to a report

contain data of the pavement condition by choosing the suitable area to examine it. The chosen area is examined by special software that covers the runways and taxiways for each 4 to 5 meters. The scanning of the distressed surface depends on the specifications of the ASTM D6433 that help to assess the condition of severity. The scanning can be done by visual detection and laser scanner. The decision-makers decide about the status of the maintenance from the results of the survey that can be displayed on the map or from other numerical results. The results contain the PCI and the thickness of the layer and other properties of the pavement (Gandolfi & Burchi, 2008).

9. PREVIOUS STUDIES

9.1. Application of GIS/GPS in shanghai airport pavement management system (SHAPMS)

The study on the airport pavement management system was done by Chen et al. (2012) to improve a system for determining the most suitable way for maintenance and rehabilitation in the airport. The SHAPMS system is integrated with GPS and GIS technologies, and this system includes a large volume of information about the pavement conditions like distress condition and traffic data and other things. The data collecting of this information is done manually and by electronic equipment like using a GPS technology (Trimble Real-time sub-meter GPS receiver along with a field computer). GIS used for locations of slabs and locations of distress. The survey that includes the PCI of each section after divided it on the full width and it shows some sections that need for maintenance because it is not acceptable for the requirements of aircraft operations (Chen & Li, 2012).

The main results of this study are, technological tools reduced the time required to survey the pavement condition due to use a GIS and GPS and these technologies help in the management of pavement and help engineers to get the reliability of data (Chen & Li, 2012).

9.2. Some issues on surface distress of airport pavements in Japan

The research conducted by Hachiya et al. (2013) aims to use the APMS to evaluate and rehabilitation of Osaka Itami Airport pavement. The evaluation of the surface and the structure is done by using the Pavement Rehabilitation Index (PRI) to help to make decisions for rehabilitation or maintenance work, after that he compared the results with the other surveys that were done during 20 years (Hachiya & Kitauchi, 2013).

The evaluation of the surface condition is done every three years, depending on the condition of the surface and the PRI method decides if there any necessary rehabilitation. The evaluation of the structural will done by the PRI method and by the Falling Weight Deflectometer

(FWD). The asphalt pavement consists of 42 distressed sections and the concrete pavement consist of 25 distressed sections. The used formula for Pavement Rehabilitation Index (PRI) is given below (Hachiya & Kitaochi, 2013):

For asphalt pavements,

$$PRI = 10 - 0.450CR - 0.0511RD - 0.655SV \quad (1)$$

For concrete pavements,

$$PRI = 10 - 0.290CR - 0.296JC - 0.535SV \quad (2)$$

where:

CR: the ratio of the crack in percentage,

RD: the maximum section rut depth in millimetre,

SV: the standard deviation of the roughness in millimetre,

JC: the total of the length of failed joints / total length of joints in percentage,

SV: maximum faulting in a section in millimetre.

From the PRI results, the pavement condition divided into three types. The Rank A means the operation not necessary for the rehabilitation. Rank B means for the future rehabilitation operation is necessary, and Rank C means the immediate rehabilitation is necessary. For the surface distress, the crack ratio for the runway section is 70% and 50% for the taxiways. The average of the rut depth is 18.1 mm in the taxiways and 14.4 mm in runways. The average of the roughness is 2.03 mm in taxiways and 1.60 mm in the runways. The comparison of new results with the past results based on the PRI values, the results of B are increased more compared to the past results and C increase with a low rate with past results (Hachiya & Kitaochi, 2013).

The results indicate that the surface condition in the runway pavement is better than the condition of the taxiways from the survey that was done 20 years ago. Comparing the current PRI values, it can be identified that there is no needing for rehabilitation, and the pavements of the airport are maintained in a good way (Hachiya & Kitaochi, 2013).

10. CONCLUSION

The APMS methodology aims to make the pavements served to long-live and improve the level of service with taking into consideration the cost of the maintenance or reconstructed, depending on the current condition of the pavement. The components of the APMS shall contain updated data to create a system for evaluating, predict and performance of the pavement condition. There are many benefits of the APMS, such as providing efficient methods for control the maintenance and rehabilitation activities for achieving the cost-effective. The APMS cost modules

divided into two types, input modules and output modules. Each module contains different types of activities. Throughout the pavement, there are also more than 25 typical types of distress that occur in the pavement of the airport such as alligator cracking, joint seal damage and rutting. There are two test methods used in airport pavement to identify the distress types and the situation of the pavement, depending on the PCI. The test methods are ASTM D5340 and ASTM D6433. The APMS used different software programs such as PAVER and Road-SIT Airport PMS, the programs help in the management, investigated, Analysing and maintenance of the pavement. The APMS still needs more studies in general and especially in the cost subject, most of the current studies show the benefits of using APMS in different locations of the airports around the world, but it does not show the details of the input and output costs of the APMS. It shall be their new studies by using different new software that is suitable for the case study. The studies for the pavement condition take years, but the new software that includes service life estimation SLT for the different types of construction may help in solving the problem of the distress in the pavement. It helps in saving time by knowing the suitable time for maintenance, rehabilitation and the end life of the pavement.

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