ACCURACY OF PAVEMENT MANAGEMENT PREDICTIONS
A CASE STUDY AT WASHINGTON DULLES INTERNATIONAL AIRPORT

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Abstract

In 1982 a Pavement Management program was undertaken on the airfield pavements at Washington Dulles International Airport to establish rate of pavement deterioration, predict remaining service life, formulate a pavement rehabilitation program and estimate rehabilitation cost.

Based on three prediction models, two levels of pavement quality and the time phase for rehabilitation was predicted. The prediction models took into account the Pavement Condition Index (PCI), slab cracking and aircraft traffic.

During the 25 years since the Pavement Management program, the airport has continued maintenance programs, including a several panel replacement programs and complete reconstruction of several airfield pavements.

This paper describes the predictions methods and compares the time period predicted for reconstruction with the actual year the pavements were reconstructed.

Introduction

In 1982 the Federal Aviation Administration (FAA) undertook a comprehensive Pavement Management (PM) study at Washington Dulles International Airport. The FAA, owners of Washington Dulles International Airport, had previously undertaken an evaluation of the airfield pavements in 1978, but the 1982 study included a Pavement Condition Index (PCI) survey and non-destructive testing using the falling weight deflectometer.

The PCI method of determining the pavement condition was developed by the Corps of Engineers in the mid 1970's and adopted by the FAA in 1982. Dynatest Consulting, Inc introduced the Falling Weight Deflectometer to North America in the late 1970's. Thus, this was one of the first PM studies at an airport using techniques that are standard investigative procedures today.

Two of the PM study objectives were:

- To establish the rate of deterioration and predict the remaining service live of the airfield pavements
- To formulate a pavement rehabilitation and maintenance program including an estimated timetable and cost estimate.

Three methods were used to predict the end of service life. Based on these three prediction models, for each pavement feature the "best" estimate of the remaining service life and time period for rehabilitation was identified.

This paper presents the three prediction models, their predicted periods of rehabilitation and the "best" estimate of remaining life of those pavements. The actual rehabilitation date of those pavements during the 25 years since the PM study and dates of major rehabilitation are presented.

Washington Dulles International Airport In 1982

In 1982, Washington Dulles International Airport consisted of three runways, three air carrier ramps and connecting taxiways, as shown in Figure 1.

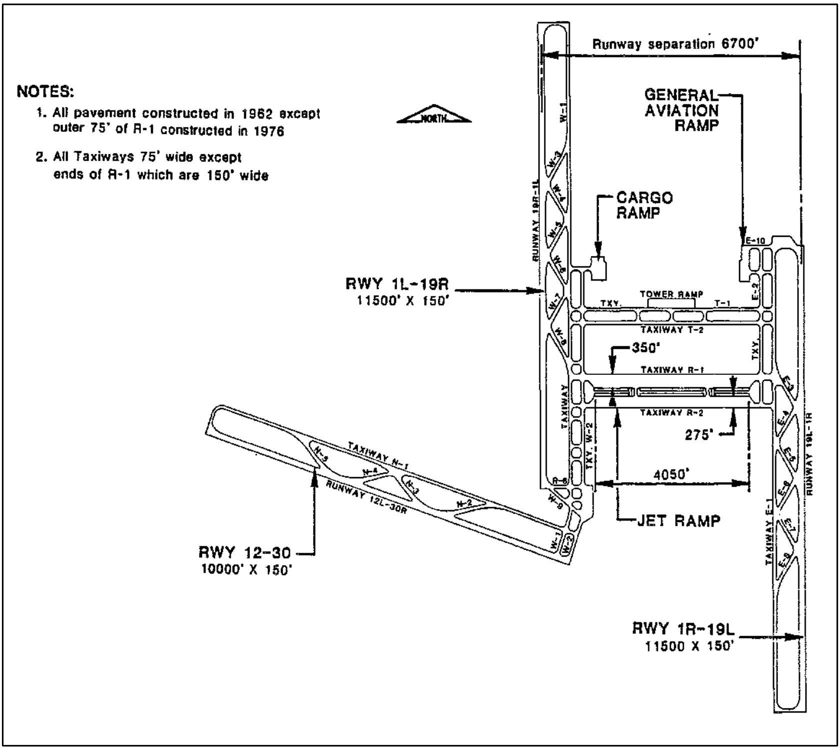

Figure 1. Washington Dulles International Airport in 1982

Construction of Washington Dulles International Airport was begun in 1958 and the airport was opened to traffic in 1962. Between 1962 and 1982, when this PM study was undertaken, the only major improvement to the airfield was the expansion of the jet ramp in 1976 to accommodate larger aircraft. In 1982, none of the pavements constructed in 1962 had been reconstructed; however several panel replacement projects had occurred.

Essentially all of the pavements included in the 1982 Pavement Management study at Washington Dulles International Airport were constructed at the same time, by the same contractor, to the same design details, and with the same materials. These pavement details are shown in Figure 2.

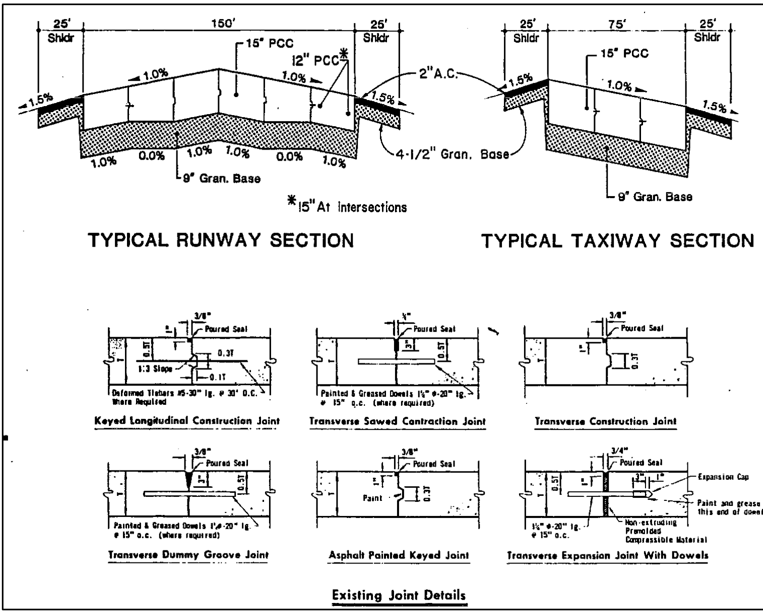

Figure 2. Paving Details, Pavements Constructed in 1958

All of the airfield pavements were surveyed in 1982, but only the most heavily trafficked pavements were subjected to a detailed PCI and NDT surveys. The high-speed taxiways and several connecting taxiways were only visually surveyed.

Pavement Life Prediction Methods

Three approaches were used to estimate the remaining life of each feature:

- Straight-Line PCI Projection
- PCI-Fatigue Analysis
- Cracking-Fatigue Analysis

Figure 3 presents the pavement life prediction approaches in graphical format.

Straight-Line PCI Projection - Straight-Line PCI Projection assumes that all pavements have a PCI of 100 upon completion of construction. Based on the PCI of each pavement feature, an average annual PCI point loss was calculated and the future annual loss of PCI was extrapolated at the same rate.

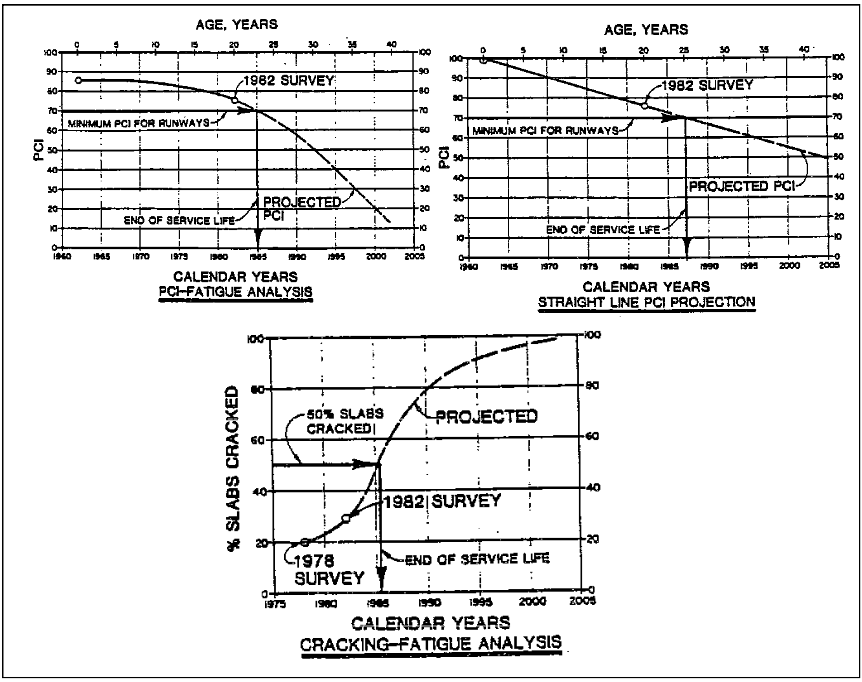

Figure 3. Graphically Representation of the Prediction Models

Straight line extrapolation is a simplistic procedure, valid only for high PCI and non-traffic load pavements. PCI deterioration is curve-linear. Since all of the pavements were of the same age, a "PCI family curve", (the PCI of similar pavements are plotted by age) could not be developed.

PCI-Fatigue Analysis – PCI-Fatigue Analysis relates pavement deterioration (PCI) to traffic loadings. The current PCI and traffic history were determined for each pavement feature. Mathematical models were developed by regression techniques to closely approximate the historic rate of pavement deterioration. The procedure that best fits actual conditions included separate equations for runways, taxiways and ramps.

Cracking-Fatigue Analysis - Cracking-Fatigue Analysis predicts the percentage of structurally cracked pavement panels over the analysis period based upon the Miner's fatigue damage number.

Laboratory and field pavement studies have shown that pavement panel cracking and the cumulative fatigue damage number can be represented by an S-shaped curve on a log-normal plot.

The shape of the curve indicates that cracking begins slowly but then accumulates rapidly before slowing down after a large percentage of slabs are cracked. The shape of the S-curve was determined for the Dulles pavements by analyzing the wide range of past traffic and corresponding observed cracking of the different pavement features.

The models developed for pavement life prediction are:

Runways

$$PCI = 86 - 0.000224 \sum \left(\frac{\sigma}{M_r}\right)^{4.0} \ast N_{departures} \qquad (1)$$

Taxiways

$$PCI = 79 - 0.000477 \sum \left(\frac{\sigma}{M_r}\right)^{5.5} \ast N_{departures} \qquad (2)$$

Aprons

$$PCI = 93 - 0.00529 \sum \left(\frac{\sigma}{M_r}\right)^{2.0} \ast N_{departures} \qquad (3)$$

σ = Critical stress induced by each individual aircraft, psi
M_r = Modulus of rupture of concrete of pavement feature, psi
departures = Total departures by each individual aircraft.

Failure Criteria

Failure criteria was established to determine the useful life of a pavement. For the two pavement life prediction models based on PCI values, two PCI values were selected to define end of service life. The two levels represent two different levels of pavement condition. A pavement with PCI above the High Pavement Quality level only preventative maintenance is required. A pavement with a PCI below the Acceptable Pavement Quality normally requires complete rehabilitation. A pavement with a PCI in-between these two levels requires concentrated maintenance effort to slow the rate of deterioration. If the rate cannot be slowed, rehabilitation is required.

The PCI minimum values for end of service life were:

Location	PCI Level to Maintain High Pavement Quality	PCI Level to Maintain Acceptable Pavement Quality
Runways	70	55
Taxiways	60	40
Ramps	50	40

For the fatigue cracking model, end of service life was represented by 50 percent of the slabs as being cracked. This is recognized in AC 150/5370-11, Appendix 1, page 11 paragraph 6.1.6, Step 6(2) that says "If more than 50 percent of the slabs show load-induced cracking, the pavement should be considered failed."

If only low severity cracks were found within the feature with 50% of the slabs being cracked, the equivalent PCI would be 78. If one assumes that 30% of the panels in the feature have low severity, 15% of the panels have medium severity cracks and 5% of the panels have high severity cracks, the equivalent PCI would be 46. This assumes no other distress is found in the panel.

Remaining Service Life Prediction

The remaining service life, predicted by each method, varies slightly between the models. To account for this variability, the predicted remaining service life were tabulated and an "end of service life time phase" was estimated. The time phases for reconstruction were:

Immediate	1984 – 1985
Short Range	1985 – 1988
Medium Range	1989 – 1993
Long Range	1994 – 2003
Beyond 2003	Reconstruction not predicted within 20 years

The End of Service Life Time Phase for each feature is presented in Table 1.

Table 1. End of Service Life for Each Feature

				HIGH QUALITY			ACCEPTABLE QUALITY		
Location	Pavement Element	Pavement Feature	Cracking Fatigue Analysis	Straight Line PCI Analysis	PCI-Fatigue Analysis	End of Service Life Phase	Straight Line PCI Analysis	PCI-Fatigue Analysis	End of Service Life Phase
Runways	1L-19R	B1	1987	1990	1987	**1986-1988**	>2003	1998	**1989-1993**
		B2	>2003	>2003	No Traffic	**1994-2002**	>2003	No Traffic	**>2003**
		B3	1991	2002	1991	**1989-1993**	>2003	>2003	**1994-2002**
	1R-19L	B1	>2003	>2003	>2003	**1994-2002**	>2003	>2003	**>2003**
		B2	>2003	>2003	No Traffic	**1994-2002**	>2003	No Traffic	**>2003**
		B3	>2003	2002	>2003	**1994-2002**	>2003	>2003	**>2003**
	12-30	B1	1982	1982	1982	**1984-1985**	1988	1988	**1986-1988**
		B2	1994	>2003	>2003	**1994-2002**	>2003	>2003	**1994-2002**
		B3	>2003	>2003	>2003	**1994-2002**	>2003	>2003	**>2003**
		B4	1991	1982	>2003	**1989-1993**	>2003	>2003	**1989-1993**
Taxiways	W-1	W11	1996	>2003	>2003	**1994-2002**	>2003	>2003	**1994-2002**
		W12	>2003	1987	2001	**1986-1988**	2000	>2003	**1994-2002**
		W13	>2003	>2003	>2003	**>2003**	>2003	>2003	**>2003**
	W-2	W21	1998	1990	1995	**1986-1988**	>2003	>2003	**1989-1993**
		W22	1982	1982	1982	**1984-1985**	1982	1982	**1984-1985**
		W23	1991	>2003	>2003	**1989-1993**	>2003	>2003	**1989-1993**
	E-1	E11	1991	1998	>2003	**1989-1993**	>2003	>2003	**1989-1993**
		E12	1988	1982	1982	**1984-1985**	1989	>2003	**1986-1988**
	E-2	E21	1984	1987	>2003	**1986-1988**	2000	>2003	**1986-1988**
	N-1	N11	1997	1982	>2003	**1989-1993**	>2003	>2003	**1994-2002**
		N12	>2003	>2003	>2003	**>2003**	>2003	>2003	**>2003**
	T-1	T11	1988	1995	>2003	**1989-1993**	>2003	>2003	**1989-1993**
		T12	1989	>2003	>2003	**>2003**	1986	>2003	**>2003**
		T13	1999	1994	>2003	**1994-2002**	>2003	>2003	**1994-2002**
	T-2	T21	>2003	>2003	>2003	**>2003**	>2003	>2003	**>2003**
		T22	>2003	>2003	>2003	**>2003**	1987	>2003	**>2003**
		T23	1997	>2003	>2003	**1994-2002**	>2003	>2003	**1994-2002**
Aprons	R-1	A1A1	1997	>2003	1989	**1994-2002**	2002	1991	**1994-2002**
		A1B1	1987	1989	1988	**1989-1993**	1994	1993	**1989-1993**
		A1C1	>2003	1985	1984	**>2003**	1989	1992	**>2003**
		A1DE1	>2003	>2003	1997	**1994-2002**	>2003	1998	**1994-2002**
	R-2	A2AC1	2002	>2003	1994	**1994-2002**	>2003	1998	**1994-2002**
		A2D1	1982	1982	1982	**1984-1985**	1982	1982	**1984-1985**
		A2D2	1982	1982	1982	**1984-1985**	1983	1983	**1984-1985**
	Tower	ATWRP	>2003	>2003	>2003	**>2003**	>2003	>2003	**>2003**

The years included in the time phase for reconstruction increases with future years, reflecting the accuracy of the approaches and changes in traffic, environmental factors and unknown factors.

Anomalies that were noted include:

Subsurface Moisture – Pavement stains were observed during the PCI field surveys and noted as pumping. However since no debris was found and the stains were found where aircraft infrequently travel, it was concluded that this was not pumping. The End of Service life predicted by the Cracking Fatigue Analysis was favored.

Key-Way Failure – One feature had substantial key-way failure, although cracked panels were not observed. The End of Service life predicted by the Straight Line PCI and PCI-Fatigue Analysis were favored.

Cracked Slabs – The Cracking-Fatigue Analysis was based on changes in cracking between 1978 and 1982. Features with a large increase in the number of cracked slabs were examined in more detail, and the End of Service Life was adjusted accordingly.

Replaced Slabs – Had the PCI approach included replaced slabs, the PCI value would have been lower and end of service life reduced. The Cracking-Fatigue Analysis includes replaced panels in the prediction model. The End of Service Life for features with a high number of replaced panels is more in line with the Cracking-Fatigue Analysis.

Pavement Repair and Performance, 1982 – Present

Washington Dulles International Airport has a maintenance staff that does temporary repairs, such as filling spalls and cracks, on a nightly basis. However, the crew does not have the money nor the equipment to perform permanent repairs such as permanent spall repair and replace PCC panels.

During the past 25 years, the permanent spall repairs have been contracted out. These repairs have been included with other projects, such as new taxiways, and included in projects that consist primarily of removal and replacement of cracked panels.

The determination of the repair projects and their effectiveness in increase the airfield pavement condition is the subject of another paper.

However, the extent and year of the removal and replacement of the PCC panels can be used as an indicator of End of Service Life – High Quality pavement condition and End of Service Life – Acceptable Quality pavement condition.

Between 1982 and 2007 there were approximately 16 projects that included panel removal and replacement projects. Nine of those projects included complete reconstruction of the pavement feature, including subbase, subgrade and portions of the shoulder.

The dates of the panel replacement and reconstruction projects, along with the projected End of Service Life (presented in Table 1) are shown in Table 2.

The dates of the panel replacement and reconstruction projects, along with the estimated remaining service life predicted by the three pavement life prediction models are shown in Table 3.

Comparison – Time Period for Rehabilitation to Rehabilitation Date

Table 2 presents a comparison of the End of Service Life predictions with actual rehabilitation date. The End of Service Life was predicted for some pavements 'within 5 years' and '20 years or greater'. Repairs predicted to occur in the '5 to 20 year' time frame did not often occur.

One feature on Runway 12-30 and two features on Taxiway W2 (now Taxiway Y) were required immediately repairs and were repaired. These features also had low PCI values and a high number of cracks.

Pavement repairs that occurred after 17 years, correlated better with the time period predicted for Acceptable Pavement Quality than with High Pavement Quality.

The Time Period for Rehabilitation, an estimate based on three prediction models, did not consistently predict rehabilitation in the 5 to 15 year range.

Table 2. Time Period Predicted Performance Compared to Rehabilitation Date

			Feature Designation		1982 Pavement Management Study		Rehabilitation Date	
Projected End of Service Life	Actual Panel Replacement	Pavement Element	1982 Pavement Management Study	Present Pavement Management System	End of Service Life Phase	End of Service Life Phase	Date of Panel Replacement Projects	Date of Complete Reconstrcution
Within 5 Years	Within 5 Years	12-30	B1	R12-2	1984-1985	**1986-1988**	**1987, 1991**	2004
		W-2	W21	TWZ-01	**1986-1988**	1989-1993	**1987, 1993, 1999**	2003
		W-2	W22	TWZ-02 &	**1984-1985**	**1984-1985**	**1987, 1993**	2003
5 <	> 20	E-1	E12	TWK-02A	1984-1985	1986-1988		2005
5 <	> 20	E-1	E12	TWK-02B	1984-1985	1986-1988		2002
5 <	> 20	E2	E21	TWJ-3	1986-1988	1986-1988		2007
5 <	9	R-2	A2D1	TL-E	1984-1985	1984-1985	1991, 2004	
5 <	9	R-2	A2D2	TL-D	1984-1985	1984-1985	1991, 2004	
5-10	20	1L-19R	B1	RW1L-01	1986-1988	1989-1993	2003	2009 (e)
5 - 10	> 20	12-30	B4	R12-4	1989-1993	1989-1993		2004
5 - 10	> 20	W-2	W23	TWZ-03A	1989-1993	1989-1993		
5 - 10	> 20	E-1	E11	TWK-01	1989-1993	1989-1993		2006
5 - 10	> 20	T-1	T11	TL-A	1989-1993	1989-1993		
5 - 10	17	R-1	A1B1	TL-D2	1989-1993	1989-1993	1999	2001
5 - 20	> 20	1L-19R	B3	RW1L-03	1989-1993	1994-2002		2009 (e)
10 - 20	11	1R-19L	B1	RW1R-01	**1994-2002**	>2003	**1993**	
10 - 20	11	1R-19L	B2	RW1R-02	**1994-2002**	>2003	**1993**	
10 - 20	11	1R-19L	B3	RW1R-03	**1994-2002**	>2003	**1993**	
20 <	> 20	N-1	N11	TWQ-2	1989-1993	1994-2002	2007	
20 <	> 20	T-1	T13	TL-A	1994-2002	1994-2002		
20 <	> 20	T-2	T23	TL-B	1994-2002	1994-2002		
20 <	> 20	R-2	A2AC1	TL-E	1994-2002	1994-2002		
> 20	17	R-1	A1C1	TL-D	>2003	>2003	1999	2001
5 - 20	18	W-1	W12	TWY-02	1986-1988	**1994-2002**		**2000**
10 - 20	20	1L-19R	B2	RW1L-02	**1994-2002**	**>2003**	**2003**	2009 (e)
10 - 20	22	12-30	B2	R12-3	**1994-2002**	**1994-2002**		**2004**
10 - 20	22	12-30	B3	R12-3	**1994-2002**	**>2003**		**2004**
10 - 20	18	W-1	W11	TWY-01	**1994-2002**	**1994-2002**		**2000**
10 - 20	17	R-1	A1A1	TL-D	**1994-2002**	**1994-2002**	**1999**	2001
10 - 20	17	R-1	A1DE1	TL-D	**1994-2002**	**1994-2002**	**1999**	
> 20	> 20	W-1	W13	TWY-03S & TWY-03N	**>2003**	**>2003**		
> 20	25	N-1	N12	TWQ-3	**>2003**	**>2003**	**2007**	
> 20	> 20	T-1	T12	TL-A	**>2003**	**>2003**		
> 20	> 20	T-2	T21	TL-B	**>2003**	**>2003**		
> 20	> 20	T-2	T22	TL-B	**>2003**	**>2003**		
> 20	> 20	Tower	ATWRP		**>2003**	**>2003**		

Comparison – Straight Line PCI Analysis to Rehabilitation Date

Table 3 compares predicted Straight Line PCI Analysis End of Service Life with actual rehabilitation date.

The Straight Line PCI Analysis predicted two pavements would need immediate repairs and they were repaired within five years. However two features projected to need immediate repairs were not repaired within six years and three features needing immediate repairs were not repaired for over 17 years.

The Straight Line PCI Analysis predicted 27 pavement features would need repairs in the 20 year range. 23 of the features were repaired after 17 years. Four of the features were repaired after 11 years.

Ten features were not repaired within four years of the year predicted by the Straight Line PCI Analysis.

Straight Line PCI Analysis did not consistently predict rehabilitation in the 5 to 15 year range.

Table 3. St. Line PCI Predicted Performance Compared to Rehabilitation Date

Location	Pavement Element	Feature Designation		1982 Predicted Performance					Rehabilitation Date	
					High Quality		Acceptable Quality			
		1982 Pavement Management Study	Present Pavement Management System	Cracking Fatigue Analysis	Straight Line PCI Analysis	PCI-Fatigue Analysis	Straight Line PCI Analysis	PCI-Fatigue Analysis	Date of Panel Replacement Projects	Date of Complete Reconstrcution
Runways	1L-19R	B1	RW1L-01	1987	1990	1987	>2003	1998	2003	2009 (e)
		B2	RW1L-02	>2003	>2003	No Traffic	>2003	No Traffic	2003	2009 (e)
		B3	RW1L-03	1991	2002	1991	>2003	>2003		2009 (e)
	1R-19L	B1	RW1R-01	>2003	>2003	>2003	>2003	>2003	1993	
		B2	RW1R-02	>2003	>2003	No Traffic	>2003	No Traffic	1993	
		B3	RW1R-03	>2003	2002	>2003	>2003	>2003	1993	
	12-30	B1	R12-2	1982	1982	1982	1988	1988	1987, 1991	2004
		B2	R12-3	1994	>2003	>2003	>2003	>2003		2004
		B3	R12-3	>2003	>2003	>2003	>2003	>2003		2004
		B4	R12-4	1991	1982	>2003	>2003	>2003		2004
Taxiways	W-1	W11	TWY-01	1996	>2003	>2003	>2003	>2003		2000
		W12	TWY-02	>2003	1987	2001	2000	>2003		2000
		W13	TWY-03S &TWY-03N	>2003	>2003	>2003	>2003	>2003		
	W-2	W21	TWZ-01	1998	1990	1995	>2003	>2003	1987, 1993, 1999	2003
		W22	TWZ-02 & TWZ-03	1982	1982	1982	1982	1982	1987, 1993	2003
		W23	TWZ-03A	1991	>2003	>2003	>2003	>2003		
	E-1	E11	TWK-01	1991	1998	>2003	>2003	>2003		2006
			TWK-02A							2005
		E12	TWK-02B	1988	1982	1982	1989	>2003		2002
	E2	E21	TWJ-3	1984	1987	>2003	2000	>2003		2007
	N-1	N11	TWQ-2	1997	1982	>2003	>2003	>2003	2007	
		N12	TWQ-3	>2003	>2003	>2003	>2003	>2003	2007	
	T-1	T11	TL-A	1988	1995	>2003	>2003	>2003		
		T12	TL-A	1989	>2003	>2003	1986	>2003		
		T13	TL-A	1999	1994	>2003	>2003	>2003		
	T-2	T21	TL-B	>2003	>2003	>2003	>2003	>2003		
		T22	TL-B	>2003	>2003	>2003	1987	>2003		
		T23	TL-B	1997	>2003	>2003	>2003	>2003		
Aprons	R-1	A1A1	TL-D	1997	>2003	1989	2002	1991	1999	2001
		A1B1	TL-D2	1987	1989	1988	1994	1993	1999	2001
		A1C1	TL-D	>2003	1985	1984	1989	1992	1999	2001
		A1DE1	TL-D	>2003	>2003	1997	>2003	1998	1999	
	R-2	A2AC1	TL-E	2002	>2003	1994	>2003	1998		
		A2D1	TL-E	1982	1982	1982	1982	1982	1991, 2004	
		A2D2	TL-D	1982	1982	1982	1983	1983	1991, 2004	
	Tower	ATWRP		>2003	>2003	>2003	>2003	>2003		

Comparison – PCI-Fatigue Analysis to Rehabilitation Date

Table 4 compares predicted PCI-Fatigue Analysis End of Service Life with actual rehabilitation date.

The PCI-Fatigue Analysis predicted two pavements would need immediate repairs and they were repaired within five years. However two features projected to need immediate repairs were not repaired within nine years and one was not repaired for 17 years.

The PCI-Fatigue Analysis predicted 23 pavement features would need repairs in the 20 year range. 21 of the features were repaired after 16 years. Two of the features were repaired after 11 years.

Eleven features were not repaired within four years of the year predicted by the PCI-Fatigue Analysis.

PCI-Fatigue Analysis did not consistently predict rehabilitation in the 5 to 15 year range.

Table 4. PCI-Fatigue Predicted Performance Compared to Rehabilitation Date

				Feature Designation		Predicted		Rehabilitation Date	
Projected End of Service Life - High Quality (Years)	Projected End of Service Life - Acceptable Quality (Years)	Actual Panel Replacement (Years)	Pavement Element	1982 Pavement Management Study	Present Pavement Management System	PCI-Fatigue Analysis - High Quality	PCI-Fatigue Analysis - Acceptable Quality	Date of Panel Replacement Projects	Date of Complete Reconstrcution
No Traffic	No Traffic	21	1L-19R	B2	RW1L-02	No Traffic	No Traffic	2003	2009 (e)
No Traffic	No Traffic	11	1R-19L	B2	RW1R-02	No Traffic	No Traffic	1993	
0	0	5	W-2	W22	TWZ-02 & TWZ-03	1982	1982	1987, 1993	2003
0	6	5	12-30	B1	R12-2	1982	1988	1987, 1991	2004
0	0	9	R-2	A2D1	TL-E	1982	1982	1991, 2004	
0	1	9	R-2	A2D2	TL-D	1982	1983	1991, 2004	
2	10	17	R-1	A1C1	TL-D	1984	1992	1999	2001
5	16	21	1L-19R	B1	RW1L-01	1987	1998	2003	2009 (e)
6	11	17	R-1	A1B1	TL-D2	1988	1993	1999	2001
7	9	17	R-1	A1A1	TL-D	1989	1991	1999	2001
9	> 20	27	1L-19R	B3	RW1L-03	1991	>2003		2009 (e)
13	> 20	5	W-2	W21	TWZ-01	1995	>2003	1987, 1993, 1999	2003
12	16	> 20	R-2	A2AC1	TL-E	1994	1998		
> 20	> 20	11	1R-19L	B3	RW1R-03	>2003	>2003	1993	
> 20	> 20	11	1R-19L	B1	RW1R-01	>2003	>2003	1993	
0	> 20	23	E-1	E12	TWK-02A	1982	>2003		2005
0	> 20	20	E-1	E12	TWK-02B	1982	>2003		2002
15	16	17	R-1	A1DE1	TL-D	1997	1998	1999	
19	> 20	22	W-1	W12	TWY-02	2001	>2003		2000
> 20	> 20	22	12-30	B2	R12-3	>2003	>2003		2004
> 20	> 20	22	12-30	B3	R12-3	>2003	>2003		2004
> 20	> 20	22	12-30	B4	R12-4	>2003	>2003		2004
> 20	> 20	22	W-1	W11	TWY-01	>2003	>2003		2000
> 20	> 20	24	E-1	E11	TWK-01	>2003	>2003		2006
> 20	> 20	25	E2	E21	TWJ-3	>2003	>2003		2007
> 20	> 20	25	N-1	N11	TWQ-2	>2003	>2003	2007	
> 20	> 20	25	N-1	N12	TWQ-3	>2003	>2003	2007	
> 20	> 20	> 20	W-1	W13	&TWY-03N	>2003	>2003		
> 20	> 20	> 20	W-2	W23	TWZ-03A	>2003	>2003		
> 20	> 20	> 20	T-1	T11	TL-A	>2003	>2003		
> 20	> 20	> 20	T-1	T12	TL-A	>2003	>2003		
> 20	> 20	> 20	T-1	T13	TL-A	>2003	>2003		
> 20	> 20	> 20	T-2	T21	TL-B	>2003	>2003		
> 20	> 20	> 20	T-2	T22	TL-B	>2003	>2003		
> 20	> 20	> 20	T-2	T23	TL-B	>2003	>2003		
> 20	> 20	-1982	Tower	ATWRP		>2003	>2003		

Comparison – Cracking Fatigue Analysis to Rehabilitation Date

Table 5 compares predicted Cracking Fatigue Analysis End of Service Life with actual rehabilitation date. Two pavement features were predicted to need immediate repairs and they were repaired within five years. However, two features predicted to need immediate repairs were not repaired for nine years.

The Cracking Fatigue Analysis predicted nineteen features would need repairs after 15 years; fifteen of these features were repaired after 15 years. Three of the features were repaired after 11 years and one after five years.

Nineteen features were not repaired within four years of the year predicted by the Cracking Fatigue Analysis.

Cracking Fatigue Analysis did not consistently predict rehabilitation in the 5 to 15 year range.

Table 5. Cracking Fatigue Predicted Performance Compared to Rehabilitation Date

			Feature Designation		Predicted	Rehabilitation Date	
Projected End of Service Life - High Quality (Years)	Actual Panel Replacement (Years)	Pavement Element	1982 Pavement Management Study	Present Pavement Management System	Cracking Fatigue Analysis	Date of Panel Replacement Projects	Date of Complete Reconstrcution
0	5	12-30	B1	R12-2	1982	1987, 1991	2004
0	5	W-2	W22	TWZ-02 & TWZ-03	1982	1987, 1993	2003
0	9	R-2	A2D1	TL-E	1982	1991, 2004	
0	9	R-2	A2D2	TL-D	1982	1991, 2004	
2	25	E2	E21	TWJ-3	1984		2007
5	17	R-1	A1B1	TL-D2	1987	1999	2001
5	21	1L-19R	B1	RW1L-01	1987	2003	2009 (e)
6	20	E-1	E12	TWK-02B	1988		2002
6	23	E-1	E12	TWK-02A	1988		2005
6	> 20	T-1	T11	TL-A	1988		
7	> 20	T-1	T12	TL-A	1989		
9	22	12-30	B4	R12-4	1991		2004
9	24	E-1	E11	TWK-01	1991		2006
9	27	1L-19R	B3	RW1L-03	1991		2009 (e)
9	> 20	W-2	W23	TWZ-03A	1991		
12	22	12-30	B2	R12-3	1994		2004
14	18	W-1	W11	TWY-01	1996		2000
16	5	W-2	W21	TWZ-01	1998	1987, 1993, 1999	2003
> 20	11	1R-19L	B1	RW1R-01	>2003	1993	
> 20	11	1R-19L	B2	RW1R-02	>2003	1993	
> 20	11	1R-19L	B3	RW1R-03	>2003	1993	
15	17	R-1	A1A1	TL-D	1997	1999	2001
15	25	N-1	N11	TWQ-2	1997	2007	
15	> 20	T-2	T23	TL-B	1997		
17	> 20	T-1	T13	TL-A	1999		
20	> 20	R-2	A2AC1	TL-E	2002		
> 20	17	R-1	A1DE1	TL-D	>2003	1999	
> 20	17	R-1	A1C1	TL-D	>2003	1999	2001
> 20	18	W-1	W12	TWY-02	>2003		2000
> 20	21	1L-19R	B2	RW1L-02	>2003	2003	2009 (e)
> 20	22	12-30	B3	R12-3	>2003		2004
> 20	25	N-1	N12	TWQ-3	>2003	2007	
> 20	> 20	W-1	W13	TWY-03S &TWY-03N	>2003		
> 20	> 20	T-2	T21	TL-B	>2003		
> 20	> 20	T-2	T22	TL-B	>2003		
> 20	> 20	Tower	ATWRP		>2003		

Summary and Discussion

Based on the predicted performance compared to actual rehabilitation date, the three End of Service Life prediction models all produced similar results.

- The prediction models can predict where pavement repairs were required immediately, though not consistently
- The prediction models were capable of predicting when repairs would not be required for over 15 years.
- The prediction models did not consistently predict rehabilitation in the 5 to 15 year range.

Repairs to pavements with a predicted service life between 5 and 15 years may not have been required due to:

- Change in aircraft traffic
- Change in traffic patterns
- New pavement construction
- The Airport's maintenance effort

Likewise, a pavement with a predicted 20 years service life may not last for 20 years due to these same reasons.

Actual rehabilitation date correlated with the Acceptable Pavement Quality, as predicted by the Straight Line PCI (Table 4) and PCI-Fatigue (Table 5) prediction models.

Concluding Remarks

At Washington Dulles International Airport many variables have affected pavement performance. Attempts at predicting remaining pavement life based on pavement condition, slab cracking and traffic have had limited success due to changes in traffic and maintenance.

The three prediction models described herein appear capable of predicting pavements that need immediate repairs and predicting pavements that will last over 15 years. Attempts to predicting pavements that would require repairs in 5 to 15 did not produce consistent results.

One of the products of the 1982 Pavement Management Study was an estimated budget of pavement repair and rehabilitation costs. The PCI survey results were used to estimate a repair budget. Based on the airport's experience with the prediction models for immediately repair, the airport has confidence in a repair budget based on PCI surveys. Presently, Washington Dulles International Airport uses annual PCI surveys to define rehabilitation projects. This program is discussed in further detail in a paper presented at this conference.

In-house maintenance has been successful in extending the service life of a pavement, but this success is limited. Eventually the pavement will need to be reconstructed.

A PCI in the range between High Quality and Acceptable Quality indicates a pavement where in-house maintenance should concentrate its effort and provisions for eventual rehabilitation should be planned and budgeted.

Based on the rehabilitation date compared to the three prediction models and Time Period for Rehabilitation, the time period for rehabilitation indicates need and the associated rehabilitation cost is just a planning budget. Frequent PCI surveys track the pavement performance and alerts the airport when the pavement condition has fallen into the need to be repaired within five years.

The time periods for rehabilitation are thresholds set by the airport. Pavement rehabilitation may not occur during these time periods since pavement condition is not the controlling factor that determines when rehabilitation actually occurs.

References

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