8. Metropolitan Washington Airport Policy--Aviation Forecast, Final Report. Federal Aviation Administration, U.S. Department of Transportation, Aug. 1980.
9. Draft Final Master Plan Report, Dulles International Airport. Peat, Marwick, Mitchell & Company, Washington, D.C., Sept. 1977.
10. Aircraft Activity Update, Dulles International Airport. Peat, Marwick, Mitchell & Co., Washington, D.C., June 1983.
11. Airport Activity Statistics of Certified Route Air Carriers. Civil Aeronautics Board, Washington, D.C., 1985.

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Comparing Different Strategies for Selecting Pavement Sections for Major Repair

D. R. UZARSKI and M. I. DARTER

ABSTRACT

The U.S. Navy Public Works Center (PWC), which is located in Great Lakes, Illinois, successfully completed implementation of the PAVER Pavement Maintenance Management System in September 1982. As part of the implementation, a priority scheme for the selection of pavement sections needing major repair was created. The scheme developed was a "worst-first" priority strategy based on pavement condition and rank. A shortcoming to this scheme, however, is that cost and benefit of repair are not considered as criteria. Accordingly, the effects of incorporating cost and benefit criteria as additional parameters to be used in the selection of pavement sections for major repair are studied in this paper. Six strategies are compared--(a) do nothing, (b) use the existing priority scheme, (c) use a revised priority scheme that takes cost into account, (d) repair when needed, (e) use section benefit-cost optimization with variable utility, and (f) use section benefit-cost optimization with constant utility. The results concluded that by revising the priority strategy or by using benefit-cost optimization techniques, an improved network condition can result at a lower overall cost.

The PAVER Pavement Maintenance Management System (1,2), which was developed by the U.S. Army Corps of Engineers at the Construction Engineering Research Laboratory in Champaign, Illinois, is gaining widespread acceptance throughout all branches of the military service and in civilian communities as well. Where implemented, public works managers have found PAVER to be a valuable tool in managing their pavement network.

Pavement management is accomplished at two distinct levels--network and project--and each involves many specific tasks. A major task at the network level is the selection or programming of candidate pavement sections for major maintenance repair and rehabilitation. Because repair needs almost always exceed available funds, the engineer is tasked with deciding which sections will be repaired in a given year and which sections will be deferred to future years. Studied in this paper are the effects of employing different selection strategies on both overall network condition and the overall cost for repairs.

BACKGROUND

The U.S. Navy Public Works Center (PWC), which is located in Great Lakes, Illinois, successfully completed implementation of the PAVER Pavement Maintenance Management System for the Naval Training Center (NTC) (also located in Great Lakes) in September 1982. The implementation was accomplished via an architect-and-engineer (A&E) contract with the contractor and the Navy working in close harmony. One of the implementation tasks was the development of a priority scheme for selecting pavement sections needing major repair. The scheme ultimately adopted is shown in Figure 1a and the reverse of this scheme

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(a) EXISTING

PCI	RANK		
	PRIMARY	SECONDARY	TERTIARY & PARKING
GOOD 60-56	10	13	X
FAIR 55-41	7	11	X
POOR 40-26	4	8	12
VERY POOR 25-11	2	5	9
FAILED 10-0	1	3	6

(b) REVERSE

PCI	RANK		
	PRIMARY	SECONDARY	TERTIARY & PARKING
GOOD 60-56	1	3	X
FAIR 55-41	2	5	X
POOR 40-26	4	7	10
VERY POOR 25-11	6	9	12
FAILED 10-0	8	11	13

FIGURE 1 Existing and reverse priority schemes.

is shown in Figure 1b. A complete description on how the priority scheme was developed can be found in the final A&E report (3).

The use of the priority scheme is simple. Once a pavement section deteriorates to the point that its Pavement Condition Index (PCI) falls below the minimum acceptable, that section is a candidate for major repairs. The minimum PCIs can be of any value that the engineer deems appropriate. At PWC-Great Lakes, the values of 60 for primary and secondary roadways and 40 for tertiary roadways and parking lots were chosen. Thus, a section needing repair will fall somewhere on the priority chart. Sections that fall on Block 1 are chosen first for repair and sections falling on Block 2 are chosen second, and so forth. This process continues until all available funds have been allocated. This priority matrix has been used to successfully develop several repair projects at PWC-Great Lakes and similar priority schemes have been adopted by other military bases and cities. It is a popular method because of its simplicity and because it focuses on criteria of great importance to engineers--minimum acceptable criteria, pavement condition, and pavement rank (or average daily traffic counts).

The shortcoming(s) of this scheme is (are) that cost and benefit are not considered as criteria. Although the priority scheme is a vast improvement over past subjective methods, it is simply a "worst-first" method. If cost were also considered in the selection process, an improvement would result by taking advantage of the fact that as PCI drops, cost for repair increases. The cost of repair versus PCI relationship has been developed for representative sections at PWC-Great Lakes and is shown in Figure 2. A detailed discussion on the relationship between cost and condition has been published by the American Public Works Association (4). Accordingly, in order to take advantage of the cost and benefit, different selection strategies were studied and compared to determine whether an improvement in the decision-making process could be made.

ANALYSIS

An analysis was conducted to determine whether or not there was any advantage in using a revised priority strategy or employing optimization techniques as compared to the method of selecting sections from the existing priority strategy. The following six strategies are compared:

1. Do nothing,
2. Use the existing priority scheme,
3. Use the revised priority scheme,
4. Repair when needed,
5. Use section benefit-cost optimization with variable utility, and
6. Use section benefit-cost optimization with constant utility.

The "do-nothing" alternative is not a desirable strategy and, as such, is not used. It is used in this analysis, however, for the purpose of establishing a baseline for comparing the relative network benefits of using the three viable selection strategies. In this study, benefit is used at two levels (section and network). The optimization techniques used section-level benefits. Network-level benefits are used only for the purpose of comparing the effect of different strategies.

Definitions

Before section-level benefits can be calculated for any given section, certain parameters need to be

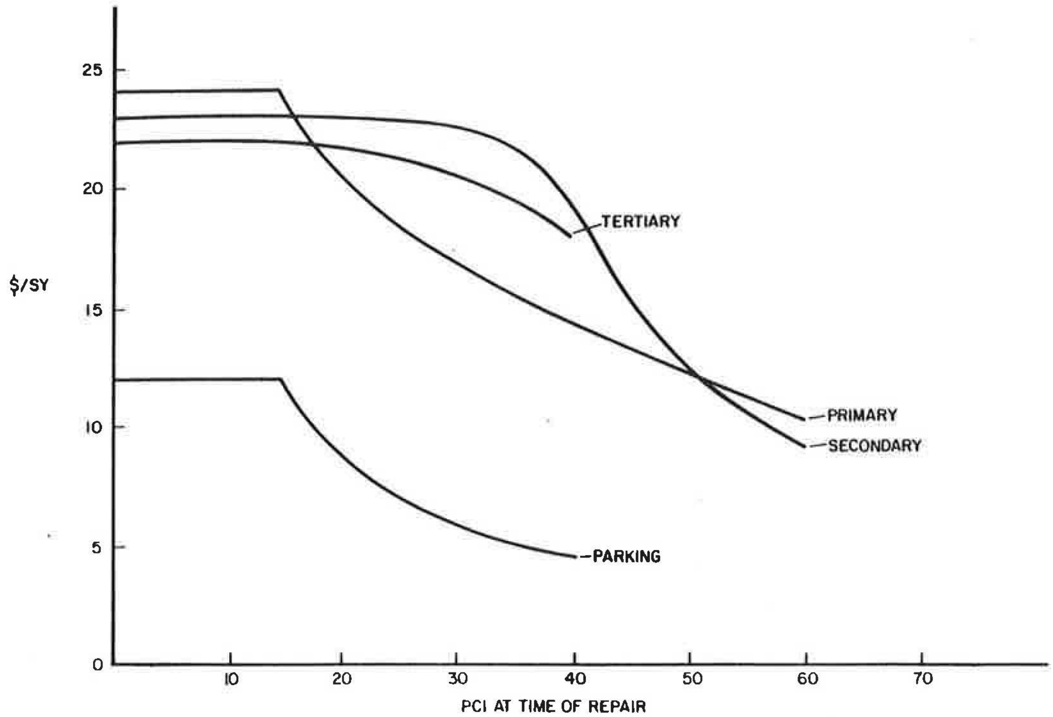

FIGURE 2 Cost versus PCI for AC pavements, NTC-Great Lakes.

identified and defined. The term "benefit," when used in this context, is a nonmonetary term. It is simply the performance area or the area under the PCI-time curve as shown in Figure 3. A large performance area is most desirable as it implies that the overall condition is remaining good over a period of time thereby providing the user with a more desirable surface to ride on.

For a benefit to be an effective management tool, it must be adjusted to accommodate the relative importance of one pavement section to the next. Accordingly, a subjective relative weight factor from 0 to 1 is multiplied by the calculated performance area for different categories of pavement sections. This ensures that more benefit is derived from repairing more important pavement sections than those that are least important.

A final factor that can be applied to the benefit

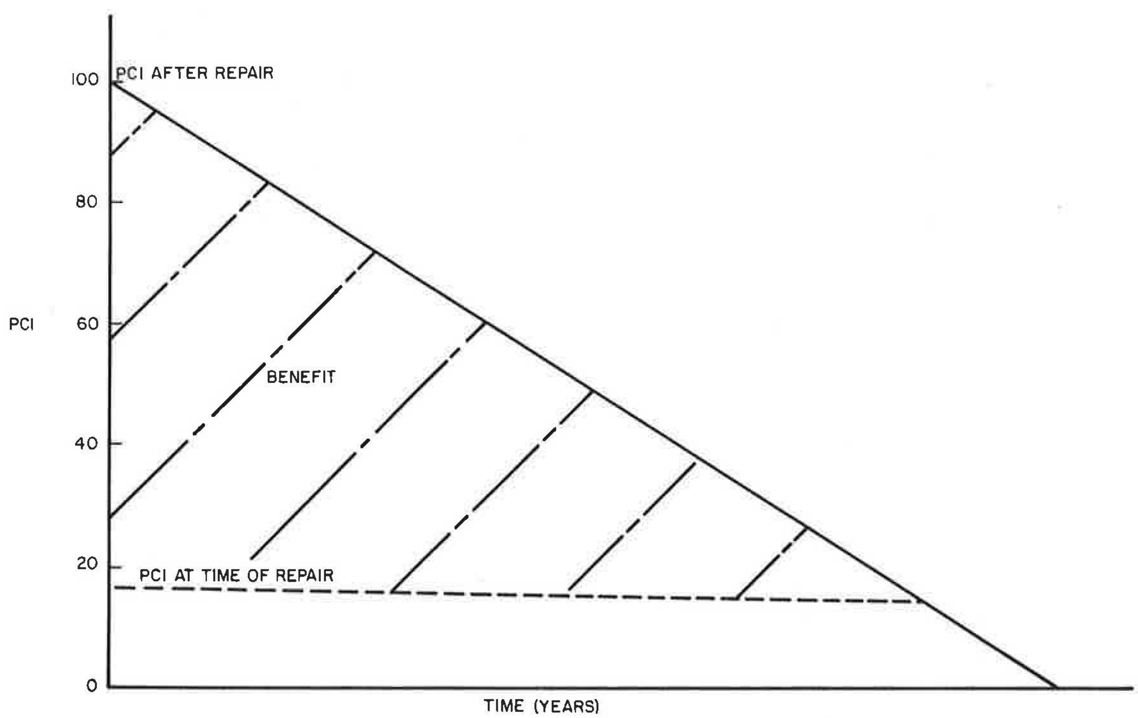

FIGURE 3 Definition of benefit (or performance area).

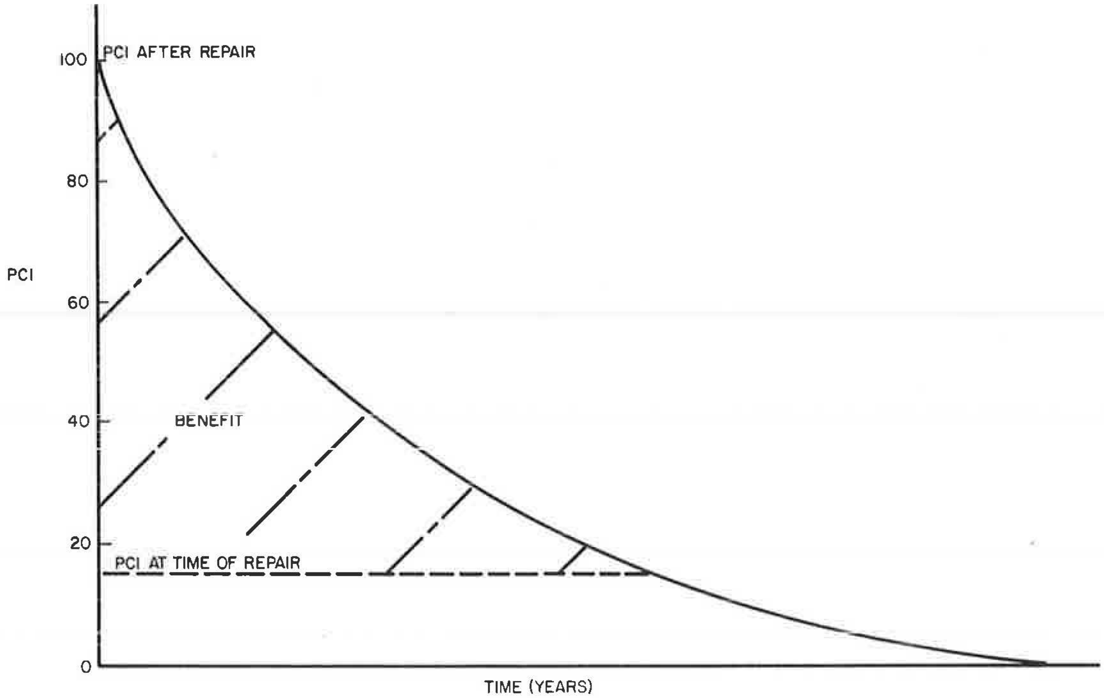

FIGURE 4 Performance area (or benefit) adjusted for utility.

analysis is utility. This is also a subjective rating between 0 and 1 and is used to adjust to the shape of the PC time curve. This rating is applied at different PCI levels for different pavement categories. It takes into account the generally accepted philosophy of being more willing to spend money on pavement section when the PCI is low than when the PCI is high (5) as shown in Figure 4.

All of the preceding values were developed for roads and streets using engineering and management judgment and are summarized in Table 1. These values have been entered into the PAVER data base for the pavement network of PWC-Great Lakes, which was used in this analysis. These values only represent a first cut of suggested values and can be adjusted as appropriate. Of the values developed, the least confidence is placed on the utility values. Accordingly, the analysis used in this paper considers the developed utility values, referred to as variable utility, and also an analysis wherein all the utility values are equal to 1 (referred to as constant utility) (see Table 1).

Evaluation of Strategies

The pavement sections in the PWC-Great Lakes network, along with the corresponding 1983 conditions (the baseline representing known conditions), are given in Table 2.

The next step in the analysis was to target sections for repair in a given year for the various strategies. A limit of approximately $50,000 was assumed for each program year for the purpose of comparing the other selection strategies, with the exception of the repair-when-needed strategy, which

TABLE 1 Minimum PCI Values, Relative Weights, and Utility Values Used in the Analysis

SECTION TYPE	MINIMUM-PCI	RELATIVE-WEIGHT FACTOR
PR : PRIMARY ROADWAY (MAIN GATE)	60	1.00
SR : PRIMARY ROADWAY	60	.90
PT : SECONDARY ROADWAY	60	.70
ST : TERTIARY ROADWAY	40	.60
PA : PRIMARY PARKING LOT	40	.80
SA : SECONDARY PARKING LOT	40	.50

UTILITY VALUES:

PCI:= 0	10	20	30	40	50	60	70	80	90	100
PR 1.00	.95	.90	.75	.60	.45	.30	.25	.15	.10	0.00
SR 1.00	.95	.90	..75	.60	.45	.30	.25	.15	.10	0.00
PT 1.00	.90	.80	.65	.50	.35	.25	.15	.10	.05	0.00
ST 1.00	.85	.75	.60	.45	.30	.20	.10	.05	0.00	0.00
PA 1.00	.90	.80	.65	.50	.35	.25	.15	.05	0.00	0.00
SA 1.00	.80	.70	.60	.45	.30	.15	.05	0.00	0.00	0.00

TABLE 2 PWC-Great Lakes Network and 1983 Condition

Branch Number	Section Number	Section Area (yd^2)	PCI	PCI Area[a] (yd^2)
I12AW	01	287	0	0
I12SQ	01	314	0	0
I14AW	01	322	0	0
P1600	01	951	0	0
P0106	02	2,347	0	0
PW12A	01	236	13	3,068
IIOWA	02	642	19	12,198
P210B	01	3,030	21	63,630
P2023	04	1,411	36	50,796
P210B	02	2,100	34	71,400
PCONF	02	4,371	37	161,727
IAR11	01	820	53	43,460
I13AW	01	310	60	18,600
P3223	01	2,047	62	126,914
P0103	01	4,682	68	318,376
IIOWA	01	3,742	71	265,682
PB88H	01	795	65	51,675
PAR11	01	347	75	26,025
PW01A	01	7,423	75	556,725
IWALB	01	858	76	65,208
PAR11	02	365	78	28,470
P0104	01	2,577	82	211,314
IR45E	01	392	74	29,008
IR45N	01	60	87	5,520
IAR11	02	633	92	58,236
P2023	03	1,974	99	195,426
Total		43,036		2,363,458

Note: The section average PCI = 49 and the average PCI per yd^2 = 55.

[a]PCI multiplied by section area.

assumed that funding would be made available when the sections needed repairing. This limit was set because a construction cost ceiling of some dollar amount is a typical funding and management constraint. The use of the $50,000 ceiling was arbitrarily chosen so that a 5 to 6-year period would be needed to restore the network into an acceptable condition with the backlog of repairs completed. That is considered a realistic management strategy.

Also, the cost for the repairs in future years was computed in terms of fiscal 1984 constant dollars and in terms of inflated dollars assuming a 10 percent inflation rate. This dual costing permits a comparison of cost changes attributable to worsening condition and a comparison of expected actual construction and costs. To make the costs easier to follow, all calculations have been accomplished in constant dollars. The total summaries for each year were then inflated in terms of program or fiscal year (FY) dollars.

Existing and Revised Priority Strategies

For the strategies of utilizing the existing and the revised priority schemes, candidate sections were applied to the priority matrix shown in Figure 1a and to a revised matrix shown in Figure 1b. Pavement sections were chosen until the budget limitation was met. This was done in each year until the backlog of repairs was eliminated and no candidate sections remained. Tables 3 and 4 give the year in which sections will be repaired and the cost for that year for each respective priority strategy.

"Repair-When-Needed" Strategy

Because several sections were well below the minimum acceptable PCI, FY 1984 (the first year of repair) is a relatively high-cost year. (The costs by year are given in Table 5.)

TABLE 3 Repair Costs, Existing Priority Strategy With a $50,000 Limit on Annual Cost

Fiscal Year and Branch Number	Section Number	Area (yd^2)	Unit Cost (\$/yd^2)	Total Cost (FY 84 \$)	Total Cost (program year \$)
1984					
I12AW	01	287	23.03	6,609.61	
I12SQ	01	314	21.87	6,867.18	
I14AW	01	322	21.87	7,042.14	
P0106	02	2,347	11.99	28,140.53	
Total				48,659.46	48,659.46
1985					
P1600	01	951	11.99	11,402.49	
PW12A	01	236	11.99	2,829.64	
IAR11	01	820	22.12	18,138.40	
IIOWA	02	642	21.87	14,040.54	
Total				46,411.07	51,052.18
1986					
P210B	01	3,030	11.99	36,329.70	43,958.94
1987					
P2023	04	1,411	11.99	16,917.89	
P210B	02	2,100	8.00	16,800.00	
IR45E	01	392	21.50	8,428.00	
Total				42,145.89	56,096.18
1988					
PCONF	02	4,371	6.50	28,411.50	
PE88H	01	795	8.00	6,360.00	
PAR11	02	365	7.00	2,550.00	
Total				37,321.50	54,642.41
1989					
PAR11	01	347	6.50	2,255.50	
P3223	01	2,047	5.85	11,974.95	
Total				14,230.45	22,918.28
Grand Total				225,098.07	277,327.45

TABLE 4 Repair Costs, Reverse Priority Strategy With a $50,000 Limit on Annual Budget

Fiscal Year and Branch Number	Section Number	Area (yd^2)	Unit Cost (\$/yd^2)	Total Cost (FY 1984 \$)	Total Cost (program year \$)
1984					
IAR11	01	820	16.47	13,735.00	
PCONF	02	4,371	5.38	23,515.98	
P210B	02	2,100	5.75	12,075.00	
Total				49,325.98	49,325.98
1985					
I12AW	01	287	23.03	6,609.61	
P2023	04	1,411	8.75	12,346.25	
IIOWA	02	642	21.87	14,040.54	
PW12A	01	236	11.99	2,829.64	
P1600	01	951	11.99	11,402.49	
Total				47,228.53	51,951.38
1986					
PE88H	01	795	4.55	3,617.25	
IR45E	01	392	19.50	7,644.00	
PO106	02	2,347	11.99	28,140.53	
Total				39,401.78	47,676.15
1987					
PAR11	02	365	5.10	1,861.50	
P210B	01	3,030	11.99	36,329.70	
Total				38,191.20	50,832.49
1988					
P3223	01	2,047	5.10	10,439.70	
PAR11	01	347	5.10	1,769.70	
I12SQ	01	314	21.87	6,867.18	
I14AW	01	322	21.87	7,042.14	
Total				26,118.72	38,240.42
Grand Total				200,266.21	238,026.42

TABLE 5 Repair Costs, Repair-When-Needed Strategy With No Limit on Annual Budget

	Fiscal Year					
Cost	1984	1985	1986	1987	1988	Total Cost
Fiscal Year 1984 $	164,910.48	None	11,261.25	1,861.50	12,209.40	190,242.63
Future Year $	164,910.48	None	13,626.11	2,477.66	17,875.78	198,898.03

Optimization Strategies

The two different optimization strategies (variable utility and constant utility) require that benefit be calculated for each candidate pavement section each year until it is selected for repair. The benefit-analysis feature of PAVER was used for that computation. The computed benefit was then divided by the construction unit cost/yd² of that section to obtain the benefit-cost ratio. Integer linear programming techniques were then applied to selected pavement sections. The objective function was to maximize the benefit-cost ratios in a given year. The constraint was the budgetary amount available in a given year. To develop and run the integer linear programming model, the MPOS computer program developed by Northwestern University was run on the University of Illinois CYBER 175 computer. The model was reformulated and run each year for the analysis period. The results of each computer run were carefully studied to determine whether or not an additional pavement section could be added to the list if the budget were raised a small amount. This was accomplished because it is usually within the purview of a public works director to adjust his budget slightly and to make sure it makes sense to do so. Tables 6 and 7 give the associated repair costs for each year until no candidate sections remain for repair.

Comparison of Strategies

To compare the effects of each strategy, network level benefits had to be calculated. To do this, network PCIs were calculated for each strategy. When an individual section was repaired, the PCI was assumed to be 100 in the year of repair. Sections were assumed to reach their minimum acceptable PCIs in 15 years, which results in a rate deterioration of 4 points per year for tertiary roads and parking lots and 3 points per year for primary and secondary pavements. From experience, the rates of deterioration would be on the low side of normal at PWC-Great Lakes, which is the desired result with proper design.

Section and overall network PCIs for all of the strategies are given in Table 8. Projected PCIs for the do-nothing strategy were obtained by using the forecasting features of the PAVER system (1,2,6). It should be noted, however, network PCI is normally computed as the average of the section PCIs, but for this analysis, the average PCI weighted by the square-yard area was computed (see Table 3 for procedure). Section averages are valid only for a network with several sections and sections of approximately equal size, or both. This network had only 26 sections and sizes varied greatly, so the weighted area PCI was used as a more accurate representation of the true network condition (7).

TABLE 6 Repair Costs—Benefit-Cost Optimization (Variable Utility) Strategy With a $50,000 Limit on Annual Budget

	Fiscal Year						
Cost	1984	1985	1986	1987	1988	1989	Total Cost
Fiscal Year 1984 $	43,569.81	42,181.07	37,095.25	37,389.00	36,329.70	14,230.45	210,795.28
Future Year $	43,569.81	46,399.18	44,885.25	49,704.76	53,190.31	22,918.28	250,727.59

TABLE 7 Benefit-Cost Optimization (Constant Utility) Strategy With a $50,000 Limit on Annual Budget

	Fiscal Year					
Cost	1984	1985	1986	1987	1988	Total Cost
Fiscal Year 1984 $	48,602.67	44,684.08	39,401.78	38,191.20	31,094.00	201,973.73
Future Year $	48,602.67	49,152.49	47,676.15	50,832.49	45,524.73	241,778.53

TABLE 8 Network Condition for Various Strategies

	Average PCI					
Strategy	1984	1985	1986	1987	1988	1989
Do nothing	52	49	46	44	41	39
Use existing priority	60	62	65	70	76	77
Use reverse priority	63	68	72	76	78	75
Repair when needed	83	80	78	76	76	74
Use section benefit-cost optimization (variable utility)	59	63	67	72	76	77
Use section benefit-cost optimization (constant utility)	62	68	72	76	78	76

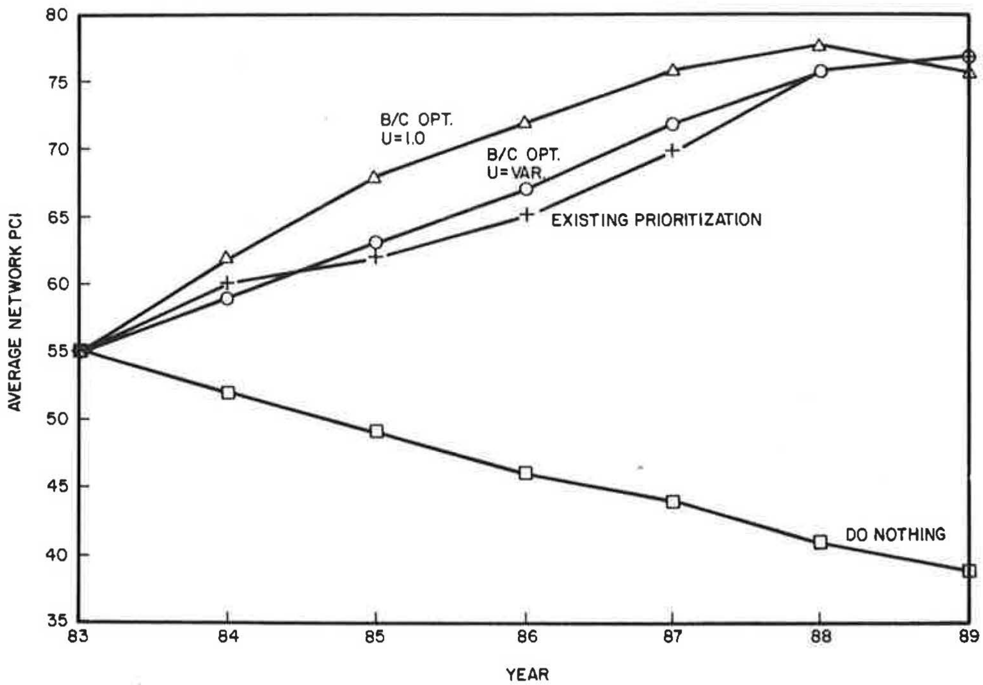

FIGURE 5 Projected network condition: comparison, PWC-Great Lakes.

The results from these PCI calculations were then plotted. Figure 5 represents a comparison of the priority determination and the repair-when-needed strategies. Figure 6 shows the optimization strategies and Figure 7 compares the reverse priority determination and the optimization method with constant utility. From each, the overall network benefit for each strategy was computed. The benefit is taken as the area below the PCI time curve for each funded strategy and above the do-nothing strategy. This is considered an effective benefit because it only considers the benefit that is attributable to a

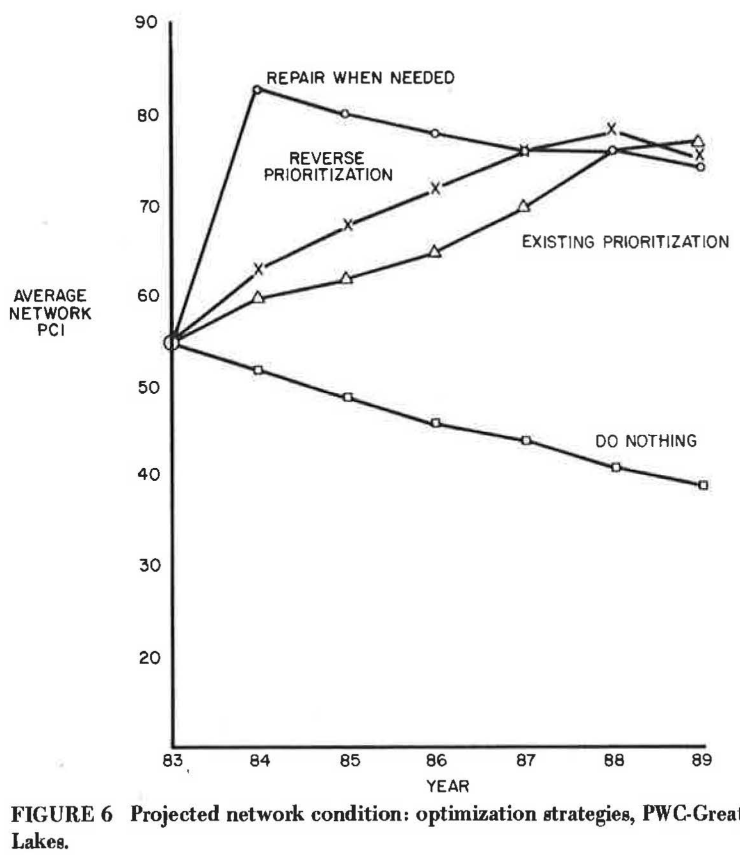

FIGURE 6 Projected network condition: optimization strategies, PWC-Great Lakes.

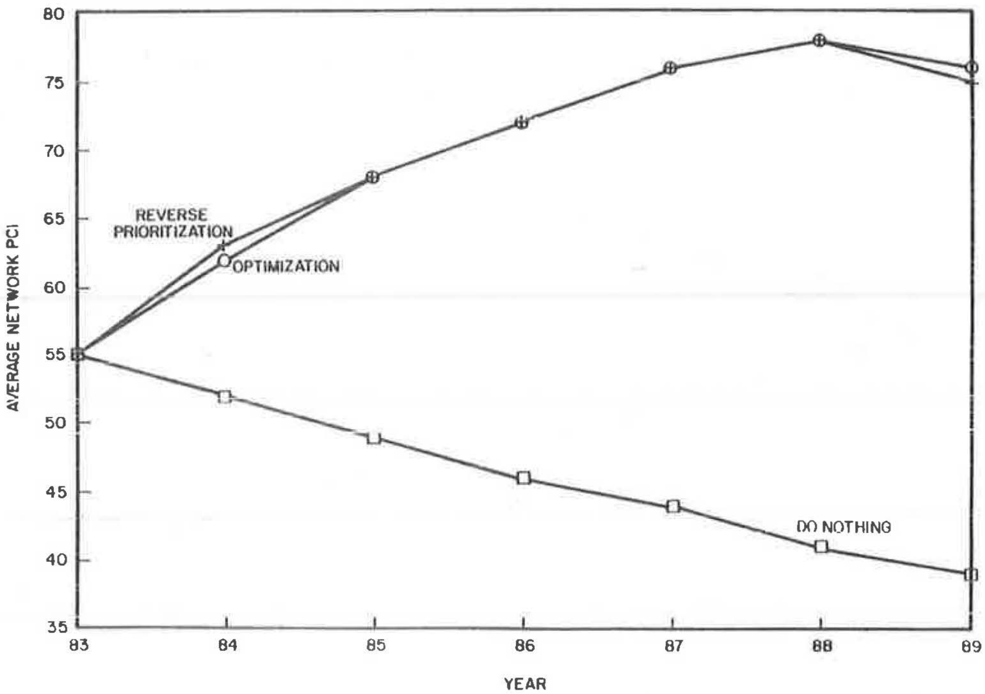

FIGURE 7 Sample network condition—reverse priority determination versus optimization.

given pavement selection strategy. The results are given in Table 9 under the heading "Effective Benefit."

Benefit-Cost Ratio

Also included in Table 9 are computed benefit-cost ratios at the network level for each strategy. Before Benefit-Cost (B-C) ratios were calculated, one final cost not previously considered had to be computed. Because some poor and failed pavement sections are required to have their repairs deferred, it is assumed that certain stop-gap repairs would be needed to keep the pavements in at least a passable condition. This would be in the form of temporary patches in potholes and locally failed areas. Pavements with PCIs at or below 25 would be assumed to need these temporary repairs. Two percent of the area is assumed to be patched annually at a cost of approximately one-half of that for a high-quality permanent patch. The cost figure used is $25/yd^2$. From experience, these are slightly conservative figures. These costs need not be funded against the available repair budget in a given year because these repairs are typically funded from the maintenance budget and not the budget allocated for major repair. The costs associated with the different selection strategies are shown in Table 10. The stop-gap repair costs along with the section major repair costs given in Tables 3 through 7 represent the total cost associated with repairing the given pavement sections.

Thus, the network benefit cost ratios of the different selection strategies are given in Table 9. In each case, the effective benefit of each strategy was divided by both the constant cost in terms of FY 1984 dollars and the inflated cost in program year dollars and the benefit-cost ratios resulted. Table 9 also includes a comparison of these benefit-cost ratios for the different selection strategies on a relative basis. Displayed are the benefit-cost ratios for the various strategies compared to the existing priority strategy where the existing priority is 1.0.

CONCLUSIONS

The following conclusions are made:

1. The repair-when-needed strategy represents the best strategy in terms of maximizing network benefit and minimizing cost.
2. Efforts should be undertaken to obtain repair funds in the earliest possible year. Spreading

TABLE 9 Network Benefit-Cost Ratios of Different Selection Strategies

Strategy	Effective Benefit	Constant Cost (FY 1984 thousand $)	Benefit-Cost (FY 1984 thousand $)	Inflated Cost (PY 1984[a] thousand $)	Benefit-Cost (PY 1984[a] thousand $)
Use existing priority	120	231.5	.52 (1.0)	284.3	.42 (1.0)
Use reverse priority	143	209.5	.68 (1.31)	248.0	.57 (1.36)
Repair when needed	178.5	190.2	.94 (1.81)	198.9	.90 (2.14)
Use section benefit-cost optimization (variable utility)	124	218.4	.57 (1.10)	269.3	.46 (1.10)
Use section benefit-cost optimization (constant utility)	142.5	210.2	.68 (1.31)	250.8	.57 (1.36)

Note: Numbers in parentheses are relative to existing priority strategy.
[a]PY = Program year.

TABLE 10 Stop-Gap Repair Costs

	Total Cost (FY 1984 $)				
Strategy	1984	1985	1986	1987	1988
Use existing priority scheme	2,425 (2,425)	2,225 (2,448)	1,750 (2,118)	0 (0)	0 (0)
Use reverse priority scheme	4,075 (4,075)	3,000 (3,300)	1,825 (2,208)	325 (433)	0 (0)
Use section benefit-cost optimization (variable utility)	3,000 (3,000)	1,525 (1,678)	1,525 (1,845)	1,525 (2,030)	0 (0)
Use section benefit-cost optimization (constant utility)	3,175 (3,175)	2,700 (2,970)	1,925 (2,329)	400 (532)	0 (0)

Note: Numbers appearing in parentheses are in program year dollars and predict inflated costs at a rate of 10 percent.

"catch-up" repair costs over several years resulted in decreased benefit and increased cost.

3. A reverse priority strategy represents an improvement over the existing worst-first priority strategy.

4. integer linear programming techniques represent an improvement in the selection procedure over existing worst-first priority methodologies.

5. The developed variable utility values that were based on traditional public works management philosophy do not lead to maximum optimization. Close scrutiny of these utility values reveals that this is logical. The values reflected the traditional worst-first strategy. Thus, sections with lower PCIs would be favored over sections with higher PCIs. Unfortunately, that is more costly and results in less pavement being repaired and more sections deteriorating further.

6. Based on these results, it would appear that using a constant utility value would provide for the most optimum selection strategy. This may not be true for all situations. When compared to the traditional utility weighing as described in this paper, however, it is true. Nevertheless, this does not rule out the possibility of gaining even greater optimization should a different weighing procedure be used (e.g., providing more utility to those pavement sections with mid-range PCIs).

7. The cost-benefit advantages of the reversed priority strategy or the optimization strategies are not to be taken as universal. A large range could result depending on construction costs, preferred repair alternatives, network size, and the condition of the sections. Further research in this area is needed.

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REFERENCES

1. M.Y. Shahin and S.D. Kohn. Overview of the "PAVER" Pavement Management System and Economic Analysis of Field Implementing the "PAVER" Pavement Management System. Tech. Manuscript M-310/ ADA 116311. Construction Engineering Research Laboratory, U.S. Army, Champaign, Ill., 1982.
2. M.Y. Shahin and S.D. Kohn. Pavement Maintenance Management for Roads and Parking Lots. Tech. Report M-294. Construction Engineering Research Laboratory, U.S. Army, Champaign, Ill., 1981.
3. R.E. Smith, M.I. Darter, T.R. Zimmer, and S.H. Carpenter. Implementation of the PAVER Pavement Management System and Development of the Maintenance and Repair Plan. Final Report, U.S. Navy, Great Lakes, Ill., 1983.
4. C. Johnson. Pavement (Maintenance) Management Systems, (American Public Works Association, Chicago, Ill., 1983).
5. M.Y. Shahin, S.D. Kohn, K.C. Lytton, and E.J. Japel. Development of a Pavement Maintenance Management System, Vol. VIII: Development of Airfield Pavement Maintenance and Repair Consequence Systems. Tech. Report ESL-TR-81-19/APA 114805. Engineering and Services Center, U.S. Air Force, Tyndall, Fla., 1982.
6. M.Y. Shahin. PAVER User's Guide. Report ADP-356-1. Construction Engineering Research Laboratory, U.S. Army, Champaign, Ill., Feb. 1986.
7. D.R. Uzarski and R.C. Soule. The Practical Use of PAVER in Planning, Programming and Developing Projects for Pavement Maintenance and Repair. Tech. Report M86/04. Construction Engineering Research Laboratory, U.S. Army, Champaign, Ill., 1986.

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