Pothole Repair: You Can't Afford Not To Do It Right

H. RANDOLPH THOMAS AND DAVID A. ANDERSON

Pothole repair has traditionally been done using a "throw-and-go" or a "run-and-dump" procedure. Many transportation agency administrators are of the opinion that correct procedures are too expensive and time consuming and not cost-effective. Correct procedures include paying proper attention to cutting, compaction, and the use of quality materials. The results of a comprehensive study of pothole repairs, their longevity, and their cost-effectiveness are reported in this paper. The results are directly applicable to northern snow-belt states. Life-cycle cost analysis was used to compare the cost-effectiveness of several different procedures for pothole repair. The conditions and practices analyzed in the paper are based on actual observations of repair operations and performance during a 2-year period. Mathematical models were used to calculate the annualized cost per ton for each repair method. Rigorous repair procedures that involve cutting, cleaning, and compacting are the most cost-effective ways to repair potholes. Throw-and-go procedures cost approximately three times more than do the more rigorous procedures. Material costs are a small percentage of the total cost for pothole repair, which implies that newer, more expensive materials that can provide greater repair longevity will be cost-effective.

The choice of an appropriate procedure for the manual repair of potholes in flexible- and rigid-base pavements has generated considerable discussion. The options range from rapid, inexpensive procedures that require no cutting or compactive effort to time-consuming procedures that call for cutting to sound pavement, cleaning the distressed area of loose debris and dirt, and compacting the new repair with a mechanical compaction device (*1*). The controversy is whether the more rigorous procedure results in a repair that lasts longer and thus provides a more cost-effective solution to the problem of pothole repair.

The results of a comprehensive study of pothole repair procedures and longevity are described in this paper, which represents the culmination of a much broader study of the overall repair practices of the Pennsylvania Department of Transportation (PaDOT) (*2*). A life-cycle analysis of several procedures was performed. The conditions and practices analyzed here are based on actual field observations of numerous repair operations during a 2-year period. Repair performance was monitored for 2 years thereafter, and the longevity of the repair is factored into the mathematical model to show the annualized cost per ton of material for each method. The four methods and results described are directly applicable to northern snow-belt states. The methodology for evaluating various repair strategies is applicable to all states.

METHODS OF REPAIR USED IN ANALYSIS

Establishing a Unit Cost for Repair

Before different methods can be evaluated, some basis of comparison must be established. The unit cost for placing patch material, based on dollars per ton, was chosen.

The unit cost approach requires that the number of hours charged per day be defined. As a general rule, those cost components charged on the basis of 7.5 hr per day (the full day) are total crew hours, including traffic control, and the hours for support equipment (e.g., crew cab and dump trucks).

Production equipment is charged for the entire day because it is not available for use elsewhere. Accordingly, the following equation is used to calculate the unit cost of repairing potholes in flexible- and rigid-base pavements:

$$\begin{aligned}\text{Cost/Ton} = {} & [(\text{Hourly crew cost} \\ & + \text{Hourly support equipment cost} \\ & + \text{Hourly production equipment cost}) \\ & \times (\text{Hours/Day})] \div \text{Tons/Day} \\ & + \text{Material cost}\end{aligned} \tag{1}$$

Method 1—Performance Standard and Roads with a High Frequency of Potholes

The following data are for Method 1, the method described in PaDOT performance standard 711–121–01.

Application
Repair of numerous holes that are close together
Workday
7.5 hr (450 min)
Production time
5.58 hr (335 min)
Procedure
PaDOT 711–121–01
Manpower
1 foreman @ \$14.97/hr = \$14.97
2 operators @ \$13.74/hr = 27.48
4 HMWs (includes 2 flagmen) @ \$10.93/hr = 43.72
Hourly crew cost = \$86.17/hr
(base wages plus fringe benefits)
Support equipment
Crew cab @ \$6.04/hr = \$6.04
Two 33,000-lb GVW dump trucks @ \$14.80/hr = 29.60
Total cost of support equipment = \$35.64/hr

The Pennsylvania Transportation Institute, Pennsylvania State University, University Park, Pa. 16802.

Production equipment

Air compressor @ $12.88/hr	=	$12.88	
Poinjar cutting tool @ $6.35/hr	=		$6.35
Essick roller @ $3.54/hr	=	3.54	3.54
Total cost of production equipment	=	$16.42/hr	$9.89/hr

Material
  Plant mix @ $31.00/ton
Production
  6.0 tons/day

A seven-man crew, which includes two highway maintenance workers (HMWs) for traffic control, is used. If this crew is properly deployed, the production rate in the performance standard can be achieved (*3*). Therefore it is assumed that a standard size crew can place 6.0 tons per day regardless of the makeup of the equipment fleet. This assumption is believed to be realistic because daily production is more likely to be controlled by the amount of material in the truck than by the cutting tool used.

A summary of the results of applying Equation 1 and the preceding data is given in Table 1. Obviously, if the crew can place more than 6 tons per day, the cost per ton will be reduced.

Method 2—Repair Practices During Initial Study (1979–1980)

Data on Method 2 are as follows:

Application
  Repair of numerous holes that are close together
Workday
  7.5 hr (450 min)
Production time
  4.75 hr (285 min)
Procedure
  PaDOT 711–121–01 except for crew size
Manpower
  1 foreman @ $14.97/hr = $14.97
  2 operators @ $13.74/hr = 27.48
  6 HMWs (includes 2 flagmen) @ $10.93/hr = 65.58
  Hourly crew cost = $108.03/hr
  (base wages plus fringe benefits)

Support equipment
  Crew cab @ $6.04/hr = $6.04
  Two 33,000-lb GVW dump trucks @ $14.80/hr = 29.60
  Total cost of support equipment = $35.64/hr

Production equipment

Air compressor @ $12.88/hr	=	$12.88	
Poinjar cutting tool @ $6.35/hr	=		$6.35
4- to 6-ton roller @ $9.40/hr	=	9.40	9.40
Total cost of production equipment	=	$22.28/hr	$15.75/hr

Material
  Plant mix @ $31.00/ton
Production
  Repair density
    120 lb/ft^3
  Daily production
    4 tons/day

Method 2 is identical to Method 1 except that (*a*) the crew size is increased by two additional HMWs, (*b*) the daily production rate is reduced to 4 tons per day, (*c*) the crews do not spend as much actual production time in the field, and (*d*) the equipment fleet is not the same. These adjustments to Method 1 are consistent with the observations made during the 1979–1980 repair season (initial study). This was the first year that the vigorous do-it-right procedure was instituted, but departmental training efforts had not yet been fully effective. Also, the equipment fleet had not been standardized. Using Equation 1 yields the results shown in Table 1.

The cost per ton in place observed in the initial study is considerably higher than that required to achieve the goals in the performance standard. The chief reasons are increased crew size, more costly compaction equipment, and reduced daily output.

Method 3—Performance Standard and Roads with a Low Frequency of Potholes

The third repair method is unlike the first two in that the potholes are widely spaced, which makes it impossible to work in an "assembly-line" fashion. Nevertheless, repairs are made in accordance with standard procedure. Determining daily pro-

TABLE 1 SUMMARY OF COST PER TON FOR EACH METHOD

Method No. and Cutting Tool	Crew Size (total)	Daily Production (tons/day)	Hourly Crew Cost ($/hr)	Support Equipment ($/hr)	Production Equipment ($/hr)	Material Cost ($/ton)	Cost per Ton ($/ton)
1, AC	7	6.00	86.17	35.64	16.42	31.00	203.79
1, P	7	6.00	86.17	35.64	9.89	31.00	195.63
2, AC	9	4.00	108.03	35.64	22.28	31.00	342.16
2, P	9	4.00	108.03	35.64	15.75	31.00	329.91
3, P	5	2.51	61.50	20.84	9.89	31.00	329.16
4	5	7.28	61.50	20.84		31.00	115.83
5	5	3.40	61.50	20.84		31.00	212.64

Note: AC = air compressor and P = Poinjar gasoline-powered cutting tool.

duction must be approached differently because the manpower and production data in the performance standard do not apply. Data on Method 3 follow:

Application
Widely spaced holes
Workday
7.5 hr (450 min)
Production time
5.58 hr (335 min)
Procedure
PaDOT 711–121–01
Manpower
1 foreman @ $14.97/hr = $14.97
1 operator @ $13.74/hr = 13.74
3 HMWs (includes 2 flagmen) @ $10.93/hr = 32.79
Hourly crew cost = $61.50/hr
(base wages plus fringe benefits)
Support equipment
Crew cab @ $6.04/hr = $6.04
One 33,000-lb GVW dump truck @ $14.80/hr = 14.80
Total cost of support equipment = $20.84/hr
Production equipment
Poinjar cutting tool @ $6.35/hr = $6.35
Essick roller @ $3.54/hr = 3.54
Total cost of production equipment = $9.89/hr
Material
Plant mix @ $31.00/ton
Production
Assume 23 min for actual repair
7 min for setting up and removing traffic control devices
5 min travel to next hole
35 min/repair
Repair density
135 lb/ft^3
Hole volume
3.60 ft^3
Daily production
[(5.58*60)/35][(3.60*135)/2000] = 2.32 tons/day

A five-person crew, including the foreman, one operator, one HMW, and two flagmen, is used. The assumptions relative to repair time are consistent with field observations. The density of repair is assumed to be 135 lb/ft^3, and the volume of the hole is assumed as 3.60 ft^3. Thus, on average, the crew will place 0.24 ton of material every 35 min or 2.32 tons per day. The production rate is based on the crew spending 5.58 hr (335 min) engaged in actual work.

Method 3 is used when conditions do not allow the work to be done in an assembly-line fashion. Accordingly, crew size is reduced. Considerable travel time is involved in going from hole to hole. Therefore a mobile crew can use a Pionjar, which is a gas-operated cutting tool, much more effectively than an air compressor. Table 1 gives a summary of the cost per ton using Equation 1.

Methods 4 and 5—Nonstandard Throw-and-Go Method

The final method to be examined is the nonstandard throw-and-go method that was widely practiced in Pennsylvania before 1979. The particular characteristics of this method are as follows:

Application
Initial repair in a given year
Workday
7.5 hr (450 min)
Production time
4.75 hr (285 min)
Procedure
Nonstandard (throw and go)
Manpower
1 foreman @ $14.97/hr = $14.97
1 operator @ $13.74/hr = 13.74
3 HMWs (includes 1 flagman) @ $10.93/hr = 32.79
Hourly crew cost = $61.50/hr
(base wages plus fringe benefits)
Support equipment
Crew cab @ $6.04/hr = $6.04
One 33,000-lb GVW dump truck @ $14.80/hr = 14.80
Total cost of support equipment = $20.84/hr
Production equipment
None
Material
Plant mix @ $31.00/ton
Production
Assume 3 min for actual repair
3 min for setting up and removing traffic control devices
1 min travel to next hole
7 min/repair
Repair density
110 lb/ft^3
Hole volume
3.25 ft^3
Daily production
[(4.75*60)/7][(3.25*110)/2000] = 7.28 tons/day

A five-person crew that includes one flagman is used. Because foreman and crew training has not been initiated, an assumed production day of 4.75 hr is used. Because the crew is comparatively small, a crew cab and one dump truck are considered sufficient. The holes are not squared, so no cutting equipment is needed. Compaction is performed with a truck tire, a shovel, or not at all.

Actual repair time is assumed to be 3 min per hole. This is considerably less than with the first three methods because there is no cutting or cleaning operation, and compaction time is minimal. There was an acute pothole problem at the time the throw-and-go method was being used; crews spent little time traveling from one pothole to the next. The time to set up and remove traffic control devices could also be distributed over a large number of holes.

Finally, repair density is assumed to be 110 lb/ft^3, which is about 10 percent less than was observed in field observations in 1979–1980 when compaction equipment was used. The hole volumes are also smaller because there is no cutting. The net result is that each hole repaired using this method contains about 1/4 less material than do holes repaired using Methods 1 and 3.

It is a matter of record that the same pothole was often repaired several times in the same year when the throw-and-go method was used. It is also realistic to assume that, on average, such repairs took longer because there was more travel time involved. The time requirements for traffic control are also distributed over a smaller number of holes. Subsequent repairs using the nonstandard method are denoted as Method 5 and are summarized as follows:

Application
  Subsequent repairs in a single year using the same procedures as in Method 4
Workday
  7.5 hr (450 min)
Production time
  4.75 hr (285 min)
Procedure
  Nonstandard (throw and go)
Manpower
  1 foreman @ \$14.97/hr = \$14.97
  1 operator @ \$13.74/hr = 13.74
  3 HMWs (includes 1 flagman) @ \$10.93/hr = 32.79
  Hourly crew cost (base wages plus fringe benefits) = \$61.50/hr
Support equipment
  Crew cab @ \$6.04/hr = \$6.04
  One 33,000-lb GVW dump truck @ \$14.80/hr = 14.80
  Total cost of support equipment = \$20.84/hr
Production equipment
  None
Material
  Plant mix @ \$31.00/ton
Production
  Assume 3 min for actual repair
  7 min for setting up and removing traffic control devices
  5 min travel to next hole
  15 min/repair
  Repair density
  110 lb/ft^3
  Hole volume
  3.25 ft^3
  Daily production
  [(4.75*60)/15][(3.25*110)/2000] = 3.40 tons/day

Method 5 is essentially the same as Method 4 except that the daily production rate is substantially reduced because the holes are more widely dispersed.

Table 1 gives a summary of the cost per ton for each repair method. On the basis of placement costs alone, the nonstandard method has the least cost per ton. It should also be noted that the percentage contribution to the total cost per ton of each of the various resources is as follows:

	Manpower	*Equipment*	*Material*
Method 1	54	30	16
Method 2	60	31	9
Method 3	60	31	9
Method 4	55	18	27

When standard procedures are used, material costs represent only a small portion of the total cost per ton.

COMPARISON OF METHODS USING ANNUAL COST

Any comparison of pothole repair methods would be incomplete if it did not take into account the longevity of the repair. Generalized cash flow diagrams were developed to show an initial expenditure (P_0) at the end of year zero. The uniform annual cost that is equivalent to an expenditure P_0 is designated A. Comparisons of the various repair methods are made on the basis of a 10 percent interest rate. The analysis period is 3 years.

Method 1—Using an Air Compressor

Equivalent annual costs are calculated by assuming that a repair will be performed annually, every 2 years, and every 3 years. Subsequent calculations will also be made for repairs performed two and four times in the same year. It is assumed that, in each instance, the repair will be made according to Method 1.

For a repair that lasts 1 year or longer, the following generalized equation can be developed:

$$A_{i,j} = P_0(A/P,\ 10\%,\ n) \tag{2}$$

where i represents the method used for the initial repair, j represents the longevity of the repair in years, and n represents the period of analysis. The capital recovery factor (A/P, 10%, n) converts the present worth value to uniform series payments lasting n years based on 10 percent interest. The various factors are tabulated in numerous engineering economy texts. Substituting the appropriate factors and the cost per ton figures determined earlier into Equation 2 yields the following annual costs for Method 1:

$$\begin{aligned} A_{1,1} &= 203.79\ (A/P,\ 10\%,\ 1) \\ &= 203.79\ (1.1000) \\ &= \$224.16/\text{ton} \end{aligned} \tag{3}$$

$$\begin{aligned} A_{1,2} &= P_0\ (A/P,\ 10\%,\ 2) \\ &= 203.16\ (0.5762) \\ &= \$117.06/\text{ton} \end{aligned} \tag{4}$$

$$\begin{aligned} A_{1,3} &= P_0\ (A/P,\ 10\%,\ 3) \\ &= 203.16\ (0.4021) \\ &= \$81.69/\text{ton} \end{aligned} \qquad (5)$$

If the repair is made more than once annually, the calculations take on a slightly different form. Two assumptions are made. The first is that the repair season lasts only 4 months. When a repair is made four times a year, it will be made at the end of months 0, 1, 2, and 3. The effective interest rate per month is $^{10}/_{12}$ or 0.83 percent. Repairs made twice a year will be made at the end of months 0 and 3. The second assumption is that when more than one repair is made in a given year, all subsequent repairs are performed using a more streamlined method. In this case, subsequent repairs are made with Method 3. Thus the initial and subsequent repairs are made according to the performance standard.

The present worth equation for repairs made four times a year is as follows:

$$\begin{aligned} P'_{i,1/12} = P_0 &+ F_1(P/F,\ 0.83\%,\ 1) \\ &+ F_2(P/F,\ 0.83\%,\ 2) \\ &+ F_3(P/F,\ 0.83\%,\ 3) \end{aligned} \qquad (6)$$

where F represents the cost of the subsequent repairs.

For repairs made twice a year, the following expression applies:

$$P'_{i,3/12} = P_0 + F_2(P/F,\ 0.83\%,\ 3) \qquad (7)$$

Notice that when the two present worth values have been calculated, they become present worth payments that can be substituted in Equation 2. Substituting the appropriate values for Method 1 into Equations 6 and 7 yields:

$$\begin{aligned} P'_{i,1/12} &= 203.79 + 329.16\ (0.9234) \\ &\quad + 329.16\ (0.8526) \\ &\quad + 329.16\ (0.7873) \\ P'_{i,1/12} &= \$1{,}047.53/\text{ton} \end{aligned} \qquad (8)$$

and

$$\begin{aligned} P'_{i,3/12} &= 203.79 + 329.16\ (0.7873) \\ P'_{i,3/12} &= \$462.94/\text{ton} \end{aligned} \qquad (9)$$

The costs calculated for Equations 8 and 9 can now be substituted into Equation 2. For repairs that are made four times a year,

$$\begin{aligned} A_{1,1/12} &= 1047.53\ (1.100) \\ &= \$1{,}152.28/\text{ton} \end{aligned} \qquad (10)$$

For repairs that are made twice a year,

$$\begin{aligned} A_{1,3/12} &= 462.94\ (1.100) \\ &= \$509.23/\text{ton} \end{aligned} \qquad (11)$$

Summary of the Various Methods

Similar calculations were performed using Equations 2, 6, and 7 for the remaining methods. For Methods 1 and 2, separate calculations were made for an air compressor and the gas-operated cutting tool (Pionjar). The results are shown in Figure 1 and summarized in Table 2. Notice the dramatic decline in annual cost per ton as the longevity of the repair increases. As can be seen, if longevity of repair is not a function of the method, Method 2 is always the most expensive and Method 4 is the least expensive.

LONGEVITY OF REPAIR

Obviously it is not possible to compare repair strategies without considering the longevity of the repair. Field evaluations were used to calculate this information. Because no discernible

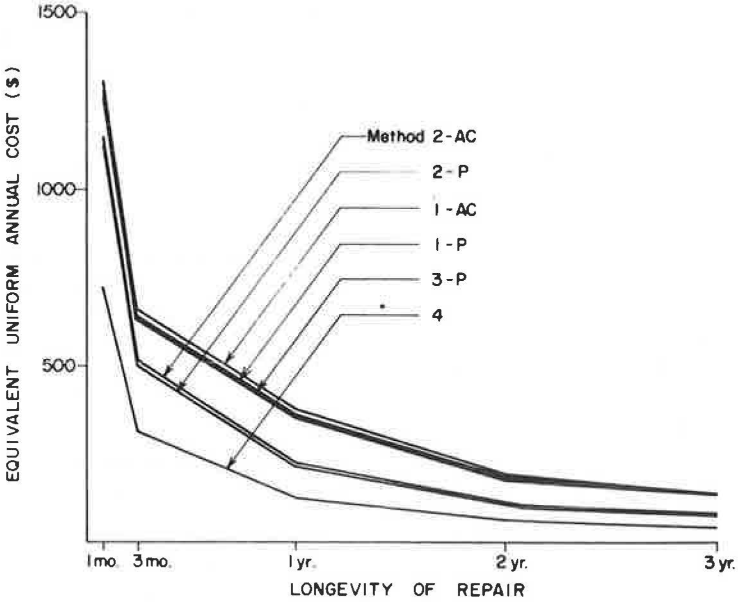

FIGURE 1 Equivalent uniform annual cost for different repair procedures.

TABLE 2 EQUIVALENT UNIFORM ANNUAL COST ($)

Method No. and Cutting Tool	Longevity of Repair 1 Month (4 times annually)	3 Months (2 times annually)	1 Year	2 Years	3 Years
1, AC	1,152.28	509.23	224.16	117.06	81.69
1, P	1,143.40	500.26	215.19	112.72	78.66
2, AC	1,304.49	661.44	376.38	197.15	137.58
2,P	1,291.01	647.96	362.90	190.09	132.66
3, P	1,290.19	647.14	362.08	189.66	132.36
4	726.95	311.56	127.41	66.74	46.58

Note: AC = air compressor and P = Poinjar gasoline-powered cutting tool.

differences were noted in longevity between repairs made with the air compressor and the hand-held gas-operated cutting tool (Pionjar), the two data sets were grouped together. Thus two sets of longevity calculations were performed, one with the initial study data and the other with data collected the following year (denoted as the foremen study data).

The initial study data were collected the first year the do-it-right philosophy was adapted. This data set corresponds to Method 2. The foremen study data were collected the following year when an effective training program had been implemented, material problems corrected, and new equipment purchased. The foremen study data are used in conjunction with Methods 1 and 3.

3-Year Forecast

Field evaluation data were collected for 650 days after the repair was made, whereas the life-cycle analysis in this paper is based on a 3-year analysis period. Therefore it was necessary to smooth the data and forecast the results for a 3-year period. Four statistical forecasting routines were tried. Based on the average error and the mean squared error, an exponential function was identified as the best. Table 3 gives a summary of the results. Note that after 22 time periods or 1,100 days it is predicted that 47 percent of the initial study repairs will remain in service compared with 62 percent of the foremen study repairs.

Average Longevity

The data in Table 3 provide the information needed for calculating the average longevity for each data set. Let $(PR)_i$ be the predicted percentage of repairs in service at the end of time period i. Then $(PR_{i-1} - PR_i)$ represents the predicted percentage of repairs that failed during that time period. This percentage is denoted as $(PF)_i$. The average longevity for repairs that fail in that period is $[(D_i - D_{i-1})/2]$ where D_i is the number of cumulative days at the end of the time period i. Thus the average longevity for each data set can be calculated using the following equation:

$$\text{Average longevity} = \sum_{i=1}^{n+1} [(PF)_i L_i/100]$$

where

n = number of time periods;
$(PF)_i$ = percentage of repairs failing during time period i [e.g., $(PF)_i = (PR_{i-1} - PR_i)$; and
L_i = average longevity for repairs failing during time period i [e.g., $L_i = (D_i - D_{i-1})/2$].

As can be seen from the data in Tables 4 and 5, the average longevity of repairs in the initial data set was 820 days and 899 days for the repairs included in the foremen study. No longevity data were available for repairs performed using the throw-and-go technique; however, an earlier study (*4*) indicated that repairs using this method lasted from 1 to 2 months. For comparative purposes, it will be assumed that repairs will be required twice a year, which means that the average longevity is 2 months.

Cost per Ton as a Function of Repair Method

The longevity values calculated previously were used in conjunction with Figure 1 to determine the cost per ton for making a repair using a particular procedure and crew makeup. The results are summarized in Table 6.

SYNOPSIS OF RESULTS

A review of Table 6 indicates that there are several observations worth noting. First, it should be quite clear that the nonstandard throw-and-go method is not cost-effective compared with the standard method using proper procedures and equipment in a well-organized manner. Although administrators of state highway agencies may claim that they cannot afford to use such a demanding procedure, the data show that they cannot afford not to use the do-it-right procedure.

The return on investment is long term, but it can be achieved. This is made clear by the data in Table 7, which gives the number of tons of material used in manual pothole repair in Pennsylvania Engineering District 3-0 for the period

TABLE 3 PERCENTAGE OF REPAIRS IN SERVICE AS A FUNCTION OF TIME

		Percentage of Holes Remaining in Service			
		Initial Studies		Foremen Studies	
Time Period i	Days, D_i	Actual %	Predicted PR_I %	Actual %	Predicted PR_F %
1	50	100	100	100	99
2	100	98	100	79	97
3	150	94	97	96	95
4	200	94	94	96	93
5	250	96	90	96	91
6	300	91	87	96	89
7	350	91	84	96	87
8	400	86	80	88	85
9	450	77	77	88	83
10	500	68	75	87	81
11	550	68	72	72	80
12	600	68	69	72	78
13	650	68	67	73	76
14	700	--	64	--	74
15	750	--	62	--	73
16	800	--	59	--	71
17	850	--	57	--	70
18	900	--	55	--	68
19	950	--	53	--	67
20	1000	--	51	--	65
21	1050	--	49	--	64
22	1100	--	47	--	62
Average Error		0.0908		0.2857	
Mean Squared Error		18.7114		51.0202	
Mean Absolute Error		3.6961		5.6489	

Initial Study Equation $(PR_I)_i = e^{(4.6917-0.0379i)}$

Foreman Study Equation $(PR_F)_i = e^{(4.6223 - 0.0223i)}$

1978–1983. The 1978–1979 data represent tonnage placed using the nonstandard approach. The first year in which the standard procedure was enforced was 1979–1980, and, as expected, the tonnage dropped to 75.1 percent or 24,135 tons. However, the procedure was effective, as is made evident by the further reductions in annual tonnage. The downward trend in tons per year is a strong indicator that pothole repairs that were previously made several times a year now have much greater longevity. By applying the dollar figures for Methods 1 and 4 in Table 5 to the tonnage figures for 1978–1979 and 1982–1983, an annual dollar savings of approximately $8,797,800 for this one district can be calculated. Statewide, the savings are perhaps 10 times greater.

Training and management emphasis is an important part of any effective organization, yet the economic benefits of training are often difficult to quantify. In Table 6, the data for Methods 1 and 2 primarily reflect differences in training and a management emphasis that resulted in better material and equipment. It can be seen that the return on investment is about $80 per ton.

CONCLUSIONS

The following conclusions can be drawn:

1. Rigorous procedures that involve cutting, cleaning, and compacting are the most cost-effective way to repair potholes. Nonstandard throw-and-go procedures cost about three times more than rigorous standard PaDOT procedures.
2. Training programs and the proper selection and standardization of equipment can significantly reduce overall costs.
3. The factors that have the greatest influence on total repair costs are repair longevity (procedures), daily production, and crew deployment practices. Material costs account for less than 20 percent of the total cost when standard procedures are used. The implication is that if newer, more expensive materials can

TABLE 4 AVERAGE LONGEVITY CALCULATIONS FOR INITIAL STUDY

Time Period i	Days (D_i)	Percent Remaining $(PR_I)_i$	Percent Failed $(PF_I)_i$	Average Longevity $(L_I)_i$	$\frac{(PF_I)_i \times (L_I)_i}{100}$
1	50	100	0	--	0
2	100	100	0	--	0
3	150	97	3	125	3.75
4	200	94	3	175	5.25
5	250	90	4	225	9.00
6	300	87	3	275	8.25
7	350	84	3	325	9.75
8	400	80	4	375	15.00
9	450	77	3	425	12.75
10	500	75	2	475	9.50
11	550	72	3	525	15.75
12	600	69	3	575	17.25
13	650	67	2	625	12.50
14	700	64	3	675	20.25
15	750	62	2	725	14.50
16	800	59	3	775	23.25
17	850	57	2	825	16.50
18	900	55	2	875	17.50
19	950	53	2	925	18.50
20	1000	51	2	975	19.50
21	1050	49	2	1025	20.50
22	1100	47	2	1075	21.50
23	1150	0	47	1125	528.75
			$\sum = 100$		$\sum = 819.50$

TABLE 5 AVERAGE LONGEVITY CALCULATIONS FOR FOREMEN STUDY

Time Period i	Days (D_i)	Percent Remaining $(PR_F)_i$	Percent Failed $(PF_F)_i$	Average Longevity $(L_F)_i$	$\frac{(PF_F)_i \times (L_F)_i}{100}$
0	0	100	0	--	0
1	50	99	1	25	0.25
2	100	97	2	75	1.50
3	150	95	2	125	2.50
4	200	93	2	175	3.50
5	250	91	2	225	4.50
6	300	89	2	275	5.50
7	350	87	2	325	6.50
8	400	85	2	375	7.50
9	450	83	2	425	8.50
10	500	81	2	475	9.50
11	550	80	1	525	5.25
12	600	78	2	575	11.50
13	650	76	2	625	12.50
14	700	74	2	675	13.50
15	750	73	1	725	7.25
16	800	71	2	775	15.50
17	850	70	1	825	8.25
18	900	68	2	875	17.50
19	950	67	1	925	9.25
20	1000	65	2	975	19.50
21	1050	64	1	1025	10.25
22	1100	62	2	1075	21.50
23	1150	0	62	1125	697.50
			$\sum = 100$		$\sum = 899.00$

TABLE 6 COST PER TON AS A FUNCTION OF REPAIR METHOD

Method	Description	Longevity in Days	Cost Per Ton ($/Ton)
1	Standard procedure using air compressor, after training emphasis	899	100.68
	Standard procedure using Pionjar, after training emphasis	899	96.95
2	Standard procedure using air compressor, before training emphasis (1979-80)	820	182.46
	Standard procedure using Pionjar before training emphasis (1979-80)	820	175.93
3	Standard procedure for complaint crew or widely scattered holes, after training emphasis	899	163.13
4	Nonstandard "throw and go" procedure	60	311.56

TABLE 7 TONNAGE OF MATERIAL PLACED IN MANUAL POTHOLE REPAIR, DISTRICT 3-0.

Fiscal Year	Tons	Fiscal Year	Tons
1978–1979	32,146	1981–1982	13,635
1979–1980	24,135	1982–1983	12,322
1980–1981	18,403		

provide longer repair longevity, then they potentially can be less costly overall.

4. State DOTs should consider all cost components in deciding on a strategy for pothole repair. The methodology described in this paper is a valid way to evaluate total repair costs and can be used in selecting an equipment fleet and in developing new repair materials. The methodology can also be extended to other types of maintenance activities.

REFERENCES

1. D. A. Anderson and H. R. Thomas. Pothole Patching in Pennsylvania. *APWA Reporter*, Vol. 51, No. 6, 1984, pp. 8–9.
2. D. A. Anderson, H. R. Thomas, and W. P. Kilareski. *Pothole Repair Management: An Instructional Guide.* PTI Report 8202. The Pennsylvania Transportation Institute, Pennsylvania State University, University Park, 1982, 136 pp.
3. H. R. Thomas, Z. Siddiqui, and D. A. Anderson. Cost-Effective Use of Manpower for Manual Pothole Repair. In *Transportation Research Record 985*, TRB, National Research Council, Washington, D.C., 1985, pp. 1–8.
4. L. G. O'Brien. *Value Engineering as Applied to Pothole Patching.* AASHTO, Washington, D.C., Nov. 1976.

Publication of this paper sponsored by Committee on Pavement Maintenance.