PART 2: PAVEMENT PRESERVATION

Study of the Cost-Effectiveness of Various Flexible Pavement Maintenance Treatments

C. JOEL SPRAGUE, SR.
TRI/Environmental, Inc.

Debate over the various treatments for extending the life of deteriorated flexible pavements has taken place for several decades. Yet, there is little consensus on the relative merits of each treatment. Thus, there has been an on-going need for objective performance information on the various available treatments. Recently, the Greenville County, South Carolina, Department of Public Works facilitated a comprehensive review of pavement performance under the county's pavement maintenance program. The review provided the potential to independently quantify the relative benefits of various maintenance techniques, including in-place cold mill recycling, full-depth patching, and paving fabric—all followed by an asphalt overlay—as well as the use of only an asphalt overlay. This paper presents the tabulation of data for the 1997–1998 maintenance year that included maintenance of 370 roads. The data includes the pavement condition at time of maintenance, the selected pavement maintenance technique and associated costs, and the recent condition of the maintained roads. Using all available information, an evaluation of the data was made to assess the post-maintenance pavement performance and the cost-effectiveness of the various treatments used.

BACKGROUND

Greenville County, South Carolina, currently maintains approximately 1,600 centerline miles of road, and due to significant growth in the county, more mileage is being added every year. Greenville County has over a decade of documented experience with a variety of rehabilitation and resurfacing techniques, including a road improvement program known as Prescription for Progress (PFP), Paving County Roads initiated by Greenville County in 1997.

In 2002, Greenville County Department of Public Works (GCDPW) decided that there was a need for a periodic evaluation of current road improvement methods and proposed an independent study of available information. A desired scope of study was developed by the GCDPW and provided the basis for this investigation. Paving fabric has been commonly used as one of the road improvement techniques in Greenville County. Because of this, the Geosynthetic Materials Association agreed to fund the study and retained the author to perform the study.

Because of the uncertainty of the quality and quantity of available data, the study was undertaken in two phases. Phase 1 was essentially a pilot study that included only 34 roads. The Phase 1 study suggested that the cost effectiveness and performance-enhancing capability of various treatments is related to the pavement condition at the time of the maintenance treatment. The follow-up Phase 2 study expanded the evaluation to include all 370 roads receiving maintenance treatments in the first year (1997–1998) of the PFP. In this study the term "road" refers to a road or portion of a road receiving a specific maintenance treatment and characterized by a single pavement condition rating.

PHASE 1 (PILOT) STUDY FINDINGS

The primary objective of the Phase 2 study was to expand the data included in the evaluation in order to validate (or refute) the findings of Phase 1. The limited data evaluated in Phase 1 suggested the following:

- In-place cold mill recycling and an overlay is most cost effective and produces the greatest reduction in the rate of road degradation when used with pavements that have surface condition ratings below 30 on a 100-point scale.
- When the pavement surface condition rating is between approximately 35 and 65, the use of paving fabric with a minimum 1½-in. overlay appears to provide the greatest cost-effectiveness and reduction in the rate of road degradation.
- When the pavement surface condition rating is above 70, both a simple asphalt overlay and a fabric–overlay system appear to provide comparable performance and cost effectiveness.

SCOPE OF WORK FOR PHASE 2

All roads included in the Phase 2 study received one of the following maintenance treatments in the first year of the PFP: in-place cold mill recycling (full-depth rehabilitation) and an overlay; patching followed by paving fabric and an overlay; paving fabric and an overlay; or overlay only. The Phase 2 study included the following five steps:

1. Compile a listing of roads rehabilitated or resurfaced in the 1997–1998 PFP programs including the actual associated maintenance treatment costs.
2. Add the most recent pavement condition index (PCI) assessment and the associated date.
3. Estimate (project) the actual road condition (PCI) at the time of 1997–1998 maintenance.
4. Calculate a cost-effectiveness value for each road based on the cost of the maintenance treatment used and the amount of degradation occurring between the time of maintenance and the 2003 road evaluation.
5. Identify trends in the data related to performance of the various rehabilitation–resurfacing techniques.

For the comprehensive review, the following sources of information were used:

- Pavement evaluation reports by Eckrose–Green for years 1994–1996;
- Characteristic pavement degradation curves for Greenville County roads;
- 1997–1998 PFP database;
- Database of 2003 road condition ratings for the roads included in the 1997–1998 PFP.

The results of the Phase 2 study were used to assess the performance and cost effectiveness of currently used road rehabilitation–resurfacing techniques.

DATA REVIEW AND TABULATION

The 1997–1998 PFP program database provided a detailed record of the types of maintenance treatment used on each road, along with actual cost and quantity data. Several three-ring binders of pavement condition data generated between 1994 and 1996 provided relatively recent objective measures of actual road conditions. In cases where roads received different treatments at different segments along the road's length as part of the 1997–1998 program, the different segments were treated as individual roads and assigned different condition ratings, if available. The following information was compiled into detailed tables to facilitate the evaluation.

- Road number;
- Pavement maintenance method and unit costs (1997–1998 are shown in Table 1);
- Road condition rating (1994–1996 rating);
- Projected road condition rating at the time of the 1997–1998 maintenance; and
- 2003 road condition rating.

TABLE 1 Typical Maintenance Treatment Unit Costs

Maintenance Treatment (Material + Labor)	Unit	Unit Price ($)
*Surface, Type 1, 1c, 3 or Binder	ton	38.90
Full-depth asphalt patching	square yard	19.38
B S T, single treatment, Type 3	square yard	0.75
Cold process recycling	square yard	2.14
Crusher run for cold recycling	ton	11.00
Ashpalt emulsion CRS-2 for recycle	gallon	0.66
Maintenance stone	ton	14.55
Set up stone base	square yard	3.00
Backfill material for shoulders	cubic yard	22.00
Grade shoulders	foot	0.68
Ditchline regrading	foot	0.92
Milling, curb reveal	square yard	4.40
Nonwoven paving fabric	square yard	0.72
AC-20 asphalt for paving fabric	ton	165.00
Paving markings	foot	0.15
Water valve adjustment	each	25.00
Manhole adjustment	each	50.00
18-in. RCP, >24 ft	foot	69.00
18-in. RCP, <24 ft	foot	75.00
Seeding	square yard	0.45

* Approximate conversion: 0.1–0.11 T/sy (2.25–2.5 in.)

DATA EVALUATION

The compiled data facilitated the following evaluations:

- Rate of road surface degradation between the last available road condition survey (Eckrose–Green 1994–1996) and the 1997–1998 PFP maintenance;
- Rate of road surface degradation between the 1997–1998 PFP maintenance and the comprehensive 2003 road condition surveys;
- Unit cost of each pavement maintenance technique (in 1997–1998);
- Rate of depreciation of maintenance costs (1997–1998–2003) based on road surface degradation.

1997–1998 Premaintenance Condition

The contractor recommended—and the county approved—the maintenance treatment to be used for each road (i.e., recycle–overlay versus patching–paving fabric–overlay versus overlay only) based on the condition of the pavement at the time of maintenance. The contractor was required to warrant the road performance for a 5-year period. The only available quantitative assessment of the existing pavement condition, and the ratings used to guide the county's selection of roads for the program, was the 1994–1996 Eckrose–Green ratings. No maintenance had been performed on these roads since the last condition survey. Unfortunately, this means that as many as 4 years could have passed since the last quantitative road evaluation. This required the road condition (PCI/OCI) at the time of maintenance to be projected from the known 1994–1996 conditions. Assumed degradation rates were used in the Phase 1 study. Characteristic pavement degradation curves specific to Greenville County were used for Phase 2. The characteristic curves were developed by the county engineering office in 1991 as part of an earlier research project. Individual characteristic curves were generated for new roads and for existing roads. An average characteristic curve was derived from these two curves for use in the Phase 2 study, since it was not known which roads had had previous maintenance. The characteristic pavement degradation curve used to project the 1997–1998 premaintenance pavement condition from the last available documented condition determined at various times between 1994 and 1996 is shown in Figure 1.

Projecting the pavement condition at the time of maintenance based on the county's characteristic degradation curve produced a large number of roads with ratings of zero. This was considered consistent with the PFP's stated intent to deal with the worst roads first.

Measuring Performance

In the Phase 1 study, two measures of performance were used to evaluate the data. First, a depreciation cost was used to determine the cost effectiveness of each type of treatment and represents the value of the treatment "used up" over the time period. Second, a degradation ratio was used to evaluate the improved rate of reduction in the pavement condition after the 1997–1998 treatment as compared to the rate prior to 1997–1998, and, theoretically, facilitates an assessment of "before versus after" performance for each treatment technique. The Phase 2

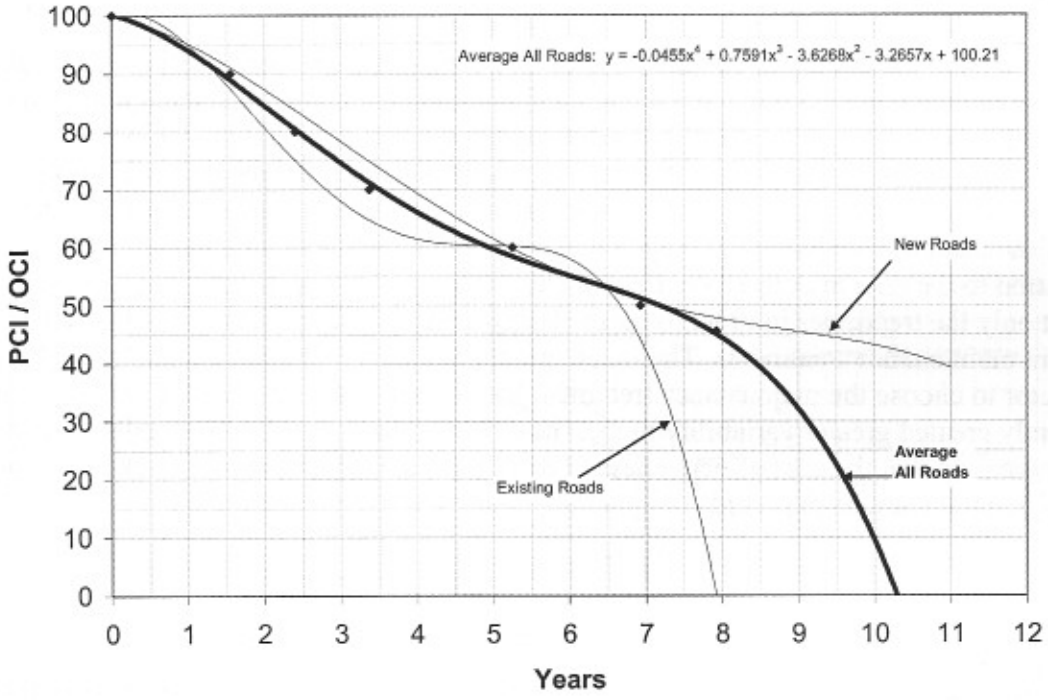

FIGURE 1 Greenville County characteristic pavement degradation curve—average of new and existing roads.

study used only the depreciation cost as the measure of performance, since "before" performance proved much less certain to determine. The depreciation cost in cost per square yard per year was calculated as follows:

Depr. Cost = Unit Cost * {[(100 – latest rating)/100] / (latest rating date – maintenance date)}

Summary performance data have been tabulated in Table 2. The evaluation included dividing the roads that received patching, fabric, and overlay into subsections that received patching along with the fabric and overlay and those that received only fabric and overlay.

TABLE 2 Summary of All Road Performance Data

Summary Data	Recycle and Overlay Roads (R/O)	Patch–Fabric–Overlay (PFO)		Fabric–Overlay (FO)			Overlay Only Roads
		Entire PFO Roads	PFO-only Subsections	FO-only Subsections	FO-only Roads	Avg. All FO	
Number of roads	146	177	177	177	28	205	19
Average initial condition (PCI)	16	20	0	20	23	21	37
Average depreciation cost ($/sy/yr)	0.18	0.16	0.55	0.11	0.11	0.11	0.10

Depreciation Costs

The relationship for each type of maintenance treatment between the depreciation cost and the initial pavement condition were determined, using the characteristic pavement degradation curve (Figure 1) for projecting the initial pavement condition at the time of the 1997–1998 maintenance. The depreciation cost for each road versus its initial pavement condition is presented in Figures 2, 3, and 4. A third order polynomial trendline was fitted to the data for each type of maintenance treatment. This type of trendline was found to provide the highest correlation to the data in both Phase 1 and 2 studies. Figures 3 and 4 remove the data points and present only the trendlines in order to more clearly demonstrate the relative performance of the different maintenance treatments. The much greater size of the database, along with allowing the contractor to choose the maintenance treatment based on a visual (qualitative) assessment, has apparently created greater variability in the Phase 2 data. Still, the chosen trendlines provide a clear indication that the cost-effectiveness of each treatment is related to the road condition at the time of maintenance, as expected.

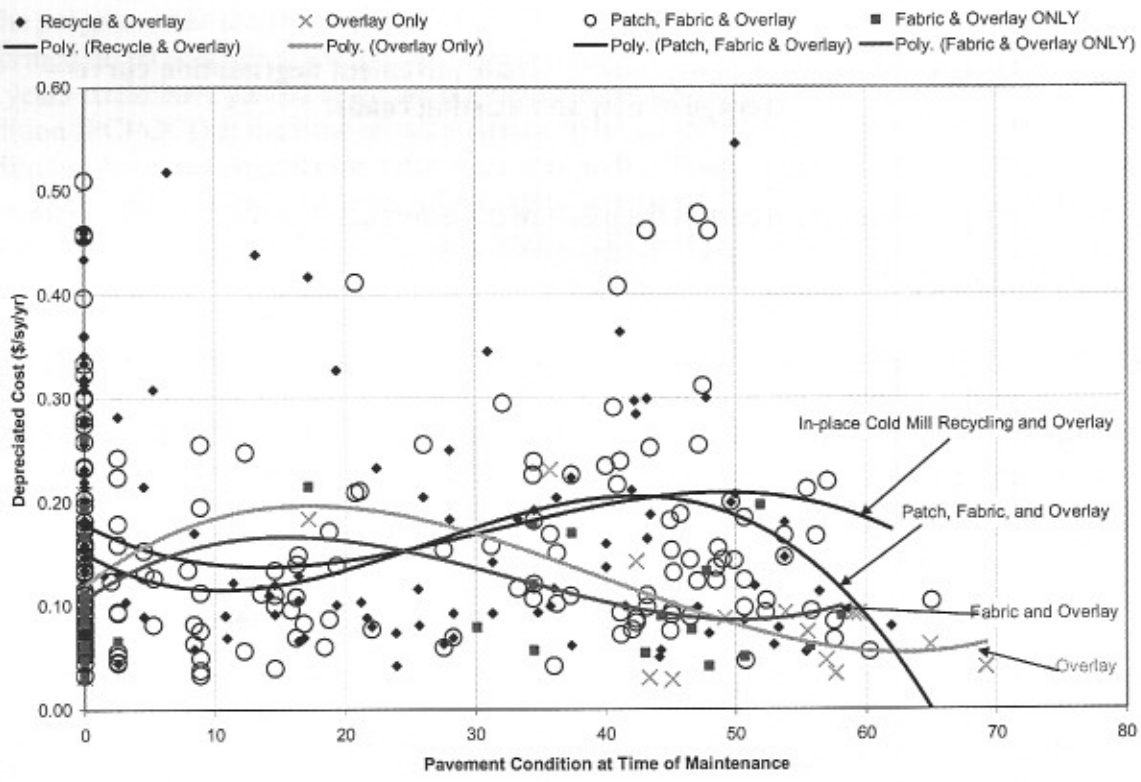

FIGURE 2 1997–1998 and 2003–2004 PFP data and treatment trends.

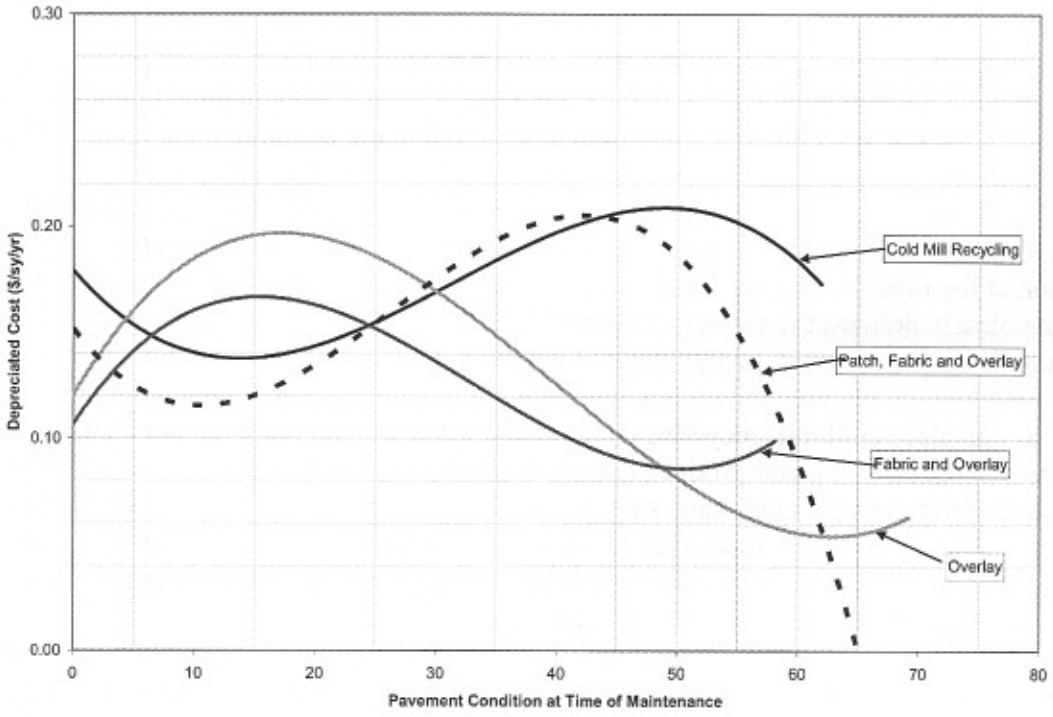

FIGURE 3 1997–1998 and 2003–2004 PFP treatment trends only.

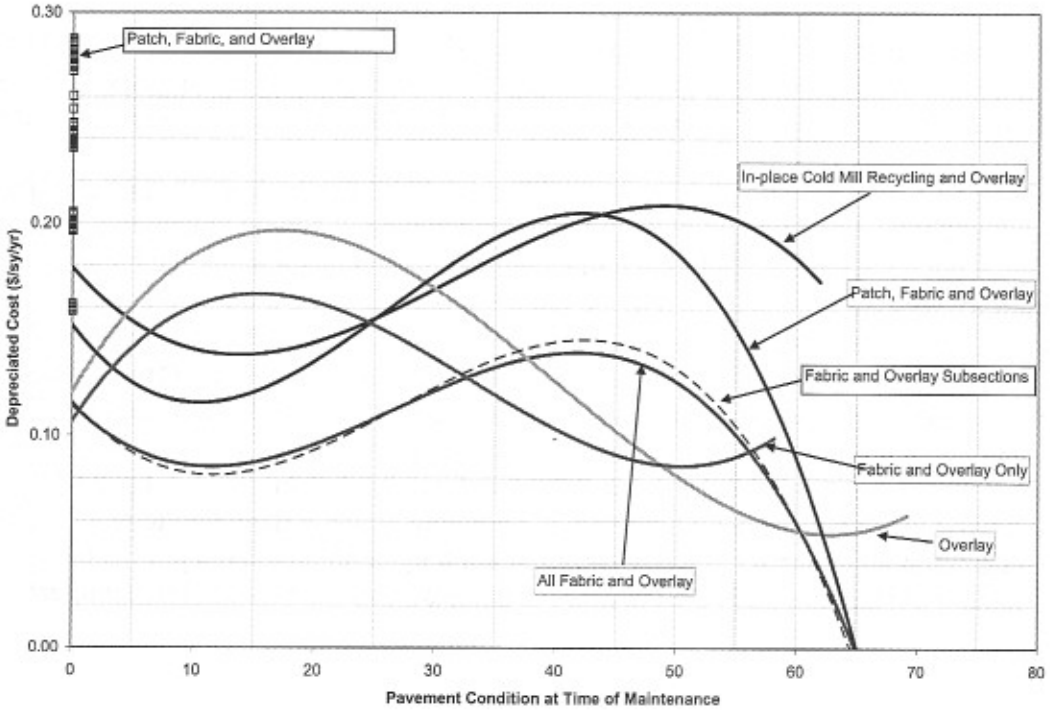

FIGURE 4 1997–1998 and 2003–2004 PFP treatment trends only (including subsections).

CONCLUSIONS

The data compiled and evaluated in the Phase 1 (pilot) study focused on only 34 roads that had received a maintenance treatment as part of the county's 1997–1998 pavement maintenance program. The subsequent Phase 2 study, reported herein, was designed to validate (or refute) the Phase 1 indications by evaluating the entire 1997–1998 PFP database of 370 roads.

The Phase 2 study appears to validate the Phase 1 conclusion that the cost-effectiveness and performance-enhancing capability of various treatments is indeed related to the pavement condition at the time of the maintenance treatment. The more extensive data involved in Phase 2 has more clearly defined the cost-effectiveness of the various treatment types as follows, based on Figure 3:

- In-place cold mill recycling–overlay and patching–fabric–overlay strategies are comparably cost effective and produce the greatest cost effectiveness of the treatments evaluated when used with pavements that have surface condition ratings below 25 on a 100-point scale.
- When the pavement surface condition rating is between approximately 25 and 50, the use of paving fabric with a 1½- to 2-in. thick overlay appears to provide the greatest cost effectiveness and reduction in the rate of road degradation.
- When the pavement surface condition rating is above 50, both a simple asphalt overlay and a fabric–overlay system appear to provide comparable performance and cost effectiveness. Further study of the relative cost effectiveness of treatments when the existing pavement condition is above 50 is needed because this evaluation included very few roads in this condition as a result of the county's "worst first" strategy.

Figure 4 breaks out the fabric–overlay subsections from the roads that received local areas of patching along with fabric and an overlay. When this subsection data is combined with that from roads that received only fabric–overlay, the resulting curve fit suggests it may always be more cost effective to use fabric rather than in-place cold mill recycling when patching is not required.

As can be seen in Figure 2, there is much scatter in the data. Yet, the data may be quite accurate considering that the decision of which maintenance treatment to use was, by contract, left up to the contractor based on his judgment and willingness to warrant the results. Another contributor to the scatter in the data may be the uncertainties associated with assigning a pavement condition and, further, with estimating the pavement condition at the time of maintenance. Ideally, an accurate pavement condition survey would be performed immediately prior to maintenance and an objective decision made as to what treatment to use. Finally, it must be noted that, although a target overlay thickness of 2.25 to 2.5 in. (0.1 to 0.11 T/sy) was expected by the county, the actual thickness frequently ranged as low as 1.9 in. (0.85 T/sy), or lower. This wide range in the actual overlay thickness no doubt contributed to the variability in the data and could be expected to significantly affect long-term pavement performance.

It is hoped that this study will encourage more objective maintenance treatment decision making.

ACKNOWLEDGMENT

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REFERENCE

Sprague, C. J. *The Study of Pavement Maintenance Techniques Used on Greenville County Maintained Roads*. Report to the Greenville County Department of Public Works, 2005.