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16. Abstract

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Although attempts during this project to establish a detailed project level management system for Virginia's surface-treated secondaries were unsuccessful, a viable economic analysis program has been established to analyze the costs of a particular resealing cycle for use in comparing various cycles. This program includes a function that models the effects of delaying resurfacing with an increase in required ordinary maintenance.

Using the developed computer spreadsheet to analyze Virginia's alternatives led to the finding that a 4-year resealing cycle was optimal with a 5-year cycle only 1 percent higher. Unfortunately, since many assumptions were made and many cost estimates used, it is not surprising that a 4- or 5-year cycle was selected--Virginia currently uses a 5-year cycle. However, the analysis program is sound and may prove to be quite useful at the network level to other states that have much better cost and condition data.

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FINAL REPORT

A SURFACE TREATMENT MANAGEMENT SYSTEM

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Research Scientist

and

Phillip L. Melville
Research Consultant

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation
and the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

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ABSTRACT

A brief survey presented in this report illustrates the variability in management practices for the surface treatment of secondary roads across the country. In Virginia, an informal process that uses the experience of field engineers working within budgetary limitations has evolved. This has resulted in a cyclic resurfacing approach. As a general rule, Virginia's surface-treated secondary roads are resurfaced every 5 years.

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FINAL REPORT

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INTRODUCTION

Ongoing efforts in Virginia aimed at the development and implementation of a comprehensive pavement management system (PMS) for all hard-surfaced roadways in the state have resulted in a highly functional, nearly complete system. The output from this system provides management with an invaluable tool to be used in priority programming and the long-range assessment of needs. For major highways, the only incomplete portion of the system is the inclusion of rigid pavements. Since these pavements comprise just over 1 percent of all hard-surfaced roads and since the first phase of incorporating them has been completed, Virginia's PMS will soon be extended to all pavements.

The foundation of Virginia's PMS is the evaluation and projection of pavement service condition. For flexible pavements in the primary and interstate systems, the PMS provides information on both the network and project levels. One hundred percent of these pavements are evaluated, thereby permitting the determination of project level output.

Application of pavement management to the secondary system's hard-surfaced roads has, thus far, only been at the network level because the secondary system has over 32,000 mi of hard-surfaced pavements (more than three times the number of miles in the primary and interstate combined). Because of the excessive manpower required to rate 100 percent of the secondary system in a timely manner, a 5 percent random sampling approach has been employed. The condition data obtained with this approach is used in the allocation of pavement maintenance replacement (resurfacing) funds over political subdivisions. Monitoring the condition of pavements over subsequent ratings helps determine if maintenance levels are adequate.

The original objective of this project was to establish project level pavement management for the approximately 20,000 mi of surface-treated secondary roads. Unfortunately, it was soon found that the availability of reliable ordinary maintenance cost data was in extremely short supply. The availability of this data in a usable form was critical to enabling the authors to establish a solid foundation for a surface treatment management system. This lack of data led to a number of assumptions and a great deal of estimation, which in turn produced results that were somewhat less defensible than originally desired.

Under the original objective of this project, two different systems of warrants for selecting and prioritizing pavement sections for surface treatment were developed. The first system of warrants was based on design criteria. This approach was deemed much too involved for field use, and much of the required input would not be readily available. The other approach was based on pavement performance. Although this system was much more practical, the manpower requirements for evaluating all the pavements on a continuing basis were considered impractical.

Although the original objective of developing a system of warrants has not been fully realized, it is felt that some of the work that has gone into this project has been quite worthwhile and should be reported. It was therefore decided that this report would focus on one of the more definitive findings of the project: the development of an economics-based method of determining the optimum surface treatment cycle, which takes into account the effects of delayed resurfacing on ordinary maintenance costs. From these findings, conclusions can be drawn concerning the best way to approach surface treatment programming.

PURPOSE

The purpose of this study is to examine the current programming practices for the surface treatment of secondary roads, and as a first step in looking at alternate management approaches, this study includes the development of a computer program for the life-cycle analysis of various scheduling alternatives.

BACKGROUND

It is difficult if not impossible to describe a local rural secondary road in Virginia from an engineering point of view. Many of them have evolved from trails, farm roads, access to local resources, and sometimes in response to military requirements. Consequently, many have grown with adverse grades and alignments. The thickness of the pavement is usually unknown, and so is the foundation except in very general terms.

It is commonly accepted that most rural roads were built on an existing location by adding aggregate. The section was compacted by traffic, repaired after spring breakups or overusage, and surface treated. Surface treatments, or chip seals as they are sometimes called, were the technical answer to keep travelers out of dust and mud. Whenever the seal was broken from inside because support failure or from above because of wear, patches and a new chip seal were applied. The frequency of sealing historically has been tied to a funding cycle. From a social and environmental point of view, the repeated application of chip seals has been a successful response to the dust and mud problem. A surface treatment is of no structural value except in retaining fines and preventing water penetration. Thus, although the treatment imparts only limited (if any) strength to the pavement, it can be beneficial in maintaining a desirable gradation with nonplastic fines and in maintaining a dry California bearing ratio (CBR) strength rather than much lower wet CBR values for the foundation (1, 2).

Other State's Practices

The authors discussed this research project with the highway agencies of Minnesota, Idaho, Washington, California, New York, Iowa, and North Carolina. They provided helpful and constructive notes. For example, the Iowa Department of Transportation remarked that

> the County Engineer drives each of his candidate roads for seal coating accompanied by his Maintenance Superintendent. This is generally done in the spring as the harshness of the winters vary greatly from year to year. A plan for surface treating is thus arrived at for one and sometimes two years hence. The plan is influenced by such things as available funds, budget restraints, amount of maintenance patching or spot sealing, etc. Generally the decision to surface treat is based on the amount of traffic, the appearance of the surface, amount of "dryness" or oxidation, presence of raveling, presence and size of cracks, etc.

The California Department of Transportation reported good success with its system in which a study of four counties, each geographically typical of its region, produced a 4-year maintenance plan to establish priorities and strategies: The proposed plan is designed to have a review team select strategies for every mile of roadway for a four-year period. The results were low maintenance cost, few pavement problems, and a roadway that had the appearance of being maintained. The 4-year cycle is primarily derived from good annual records (by mile post) of past problems and work performed.

The Washington State Department of Transportation appears to use a similar procedure. Their program is used for predicting by regression analysis performance from weighted ratings. The information is in turn used to establish the most probable period of rehabilitation for each project. The entire system uses an analysis of performance and historical data with budget constraints to recommend anticipated action, cost, and performance.

The Minnesota Department of Transportation does not have any special surface maintenance programming practice for its lower volume roads. About 70 percent of the criteria for resurfacing and reconditioning is established by the condition rating, low-volume roadways are not seriously penalized by their lack of traffic and functional rating. Actual guidelines for county roads are left up to the county engineers, the county board, and sometimes a consulting engineer. It is not known to what extent counties are influenced by the state project selection system. The state gives a 70 percent weight to condition ratings (an average of the AASHTO surface rating and present serviceability rating) kept in a database, 20 percent relates to traffic, and 10 percent to the functional class.

The North Carolina procedure is built around its pavement condition survey, which has been in use since 1982 and is conducted on a 2-year cycle. The survey has been accomplished by visual observation driving at speeds around 10 to 20 miles per hour with stopping as required for detailed observations of the pavement. A rating system was developed such that a pavement in excellent condition rated as 100. Deduct points ... would then be subtracted. The entire system (which is very similar to the Virginia rating system) was computerized because of its complexity, having to rate over 60,000 sections, and personnel not always having the experience to make judgments. It should be noted that, of all the agencies surveyed, North Carolina most closely parallels Virginia's highway system in that both agencies have responsibility for county roads.

Table 1 presents expected or assumed average lives of chip seals for low volume roads reported by several highway agencies.

Table 1

Average Life Expectancy of
Low Volume Rural Chip Seals

State	Years
California	4
Washington	7
North Carolina	10
Indiana	5
Iowa	8 to 10
Arizona	10
Virginia	5
FHWA	3+
Manitoba	7
New Zealand	13

Current Virginia Practice

A randomly selected 5 percent sample of all hard-surfaced roadways (plant mix, surface treatments, and slurry seals) in the secondary system is rated on a biennial basis. Pavement section ratings are based on the observed severity and frequency of occurrence of certain key distress types. Like the North Carolina procedure, each section is slowly driven over by a rating team stopping as required for more detailed observations. A numerical assessment of serviceability known as a DMR (distress maintenance rating) is determined for each section by making deductions based on distress occurrence from a "perfect" score of 100. The results of these ratings are used to estimate the condition of the entire hard-surfaced pavement mileage. From this estimate, specifically from the percentage of roads that fall below a certain deficiency rating threshold, the distribution of maintenance replacement funds among the districts is determined. Once the funds have been allocated, the selection of which pavements to spend the money on is left up to the field personnel most familiar with the pavements in a specific jurisdiction. In the case of surface-treated roads, a common practice has evolved whereby these roads are resurfaced on the average every 5 years.

In order to gain an appreciation of the current condition of some of the surface-treated secondary roads, the authors conducted a cursory field survey in the Fredericksburg, Suffolk, Culpeper, Salem, and Bristol districts. Roads due to be resurfaced in 1985 were driven over at 20 to 25 mph with occasional stops. All surveys were conducted from March through August 1985.

The authors found that surface-treated secondary roads were in excellent condition overall. They do have some weak spots and show occasional distress, but overall they appear to be in remarkably good condition. This is a tribute to the existing management system and the experienced field personnel who make it work. Then one may ask: If it works, why disturb it? This question may be answered with two more questions. Are we reasonably sure that "it" will remain unbroken for the foreseeable future? And is it unbroken because we pay excessively--maybe wastefully--for the convenience or luxury of avoiding visible breaks?

ECONOMIC ANALYSIS

Available cost data on the surface treatment program for existing hard-surfaced secondary roads in Virginia indicate that the Department has been spending between $15 and $18 million on chip seals annually for the past few years. For the purpose of this study, a gross average figure of $17 million per year has been retained and it is assumed that the number of miles of surface-treated roads has remained constant.

The lack of recent variation in cost of chip seals is reflected by steady prices per square yard of the materials. Asphalt cost remains at about 28 cents per square yard and #8 aggregate at about 12 cents per square yard in place. In other words, seals have cost 40 cents per square yard in place. These costs may rise as much as 10 percent because of a change in the Department's specifications; however, this may be offset by predicted lower asphalt costs as petroleum prices decline. Surface treatment costs per district (assuming a $17 million state wide total) are shown in Table 2.

Table 2

Typical Annual Cost of Surface Treatment by District

Virginia - statewide	$17,000,000
Bristol	1,552,000
Salem	2,840,000
Richmond	3,326,000
Lynchburg	2,591,000
Suffolk	1,476,000
Fredericksburg	1,411,000
Culpeper	1,546,000
Staunton	1,628,000
Northern Virginia	630,000

It is interesting to note that an expenditure of $17 million per annum to seal an average pavement 18 ft wide with a treatment costing 40 cents per square yard means that about 4,000 mi of secondary roads are chip-seal-treated per year. Assuming a 5-year cycle (20 percent of the mileage treated each year), the total 5-year mileage of surface-treated secondary roads would be 4,000 x 5 = 20,000 mi. This should be compared against the 32,000 mi of hard-surfaced roads in the secondary system. The difference (32,000 - 20,000 = 12,000 mi) represents the roads covered with slurry seals and plant mix. The Department records 6,151 lane mi with plant mix, and it is not unreasonable to assign about 6,290 mi to slurry sealing. This exercise bears out the current practice of generally resealing surface-treated roads every 5 years.

For the purpose of this study, it is considered that there is only one possible change to the current policy: either increase or decrease the length of time between seal applications. Evaluating the economic impact of changing the sealing cycle should pinpoint the optimum cycle. As the cycle is increased, less sealing money is spent per year, but more ordinary maintenance money must be spent per year for maintenance of equal levels of pavement serviceability.

In attempting to model this scenario an economic analysis period of 20 years was selected. A salvage value was calculated using the percentage of a given sealing cycle that extends beyond the 20-year life cycle. The present worth or value of the costs of maintaining and resealing the state's surface-treated roads was computed for various resealing cycles then discounted back to time zero. These calculations were done using a basic present worth computer spreadsheet set up by Dr. Gary R. Allen of the Research Council but modified by the authors for this project. The general form of the present worth equation can be expressed as follows:

$$TPWC_{x1},\ n = (IC)_{x1} + \Sigma\ pwf_{i,t}\ [(MO)x_1,\ t] - (SV)\ x_1\ n\ pwf,\ i,n$$

where:

$TPWC\ x_1,\ n$ = total present worth costs for alternative x_1-year cycle for period of n years

$(ICC)x_1$ = initial capital costs of construction, etc. for alternative x_1, in year t, where $t < n$

$pwf_{i,t}$ = present worth factor for discount rate i for t years = $1/(1 + i)^t$

$(MO)x_1\ t$ = maintenance plus operation costs for alternative x_1 in year t

$(SV)x_{1,n}$ = salvage value, if any, for alternative x_1 at the end of the design period, n years

Although the present worth method is directly comparable to the equivalent uniform cost method, it is only in recent years that it has begun to be applied in the pavement field. The present worth cost is used in the equivalent uniform annual cost method when additional capital expenditures occur before the end of the analysis period--that is, where the service life is less than the analysis period and future rehabilitation, such as overlays or seal coats, is needed. By determining the lowest total present worth among several alternative cycles, the most cost efficient trade off between resealing and ordinary maintenance may thus be determined. The analysis can be applied to as small an administrative unit as desired. However, this is, in fact, limited by the availability and reliability of data. In this study, the program was used for the state at large and for each of the nine districts.

It is important to assign maintenance costs in a rational and consistent manner. Unfortunately, no detailed, site-specific, cost data are available, but gross records are kept by maintenance areas for two activities that relate to surface maintenance of secondary roads. They are activities 111 "skin patching" and 112 "premix patching." The sums of the costs attributable to these were chosen to be a rough approximation of true maintenance expenditures. The patching activities were not differentiated as to whether they were applied to chip-sealed, slurry-sealed, or hot-mix-surfaced secondary roads. This makes a significant difference in Northern Virginia and other urbanized areas that have appreciable mileage of plant-mix-surfaced secondary roads. In addition, using expenditures attributed to activities 111 and 112 as the maintenance cost surrogate was an over simplification since other activities such as drainage improvements directly relate to chip seal performance. However, using these activities was reasonable and the only viable approach.

A look at the average expenditures for maintenance activities 111 and 112 for 1982, 1983, and 1984 shows that about $15 million is being spent per year statewide to maintain secondary road surfaces. The breakdown of the use of activities 111 and 112 by district is shown in Table 3.

Table 3

Estimated Costs of Maintenance by District

Virginia	$15,000,000	x 81%	12,150,000
Bristol	3,382,000	x 82%	2,773,000
Salem	2,171,000	x 88%	1,910,000
Richmond	2,054,000	x 88%	1,808,000
Lynchburg	1,459,000	x 91%	1,328,000
Suffolk	809,000	x 90%	728,000
Fredericksburg	996,000	x 85%	847,000
Culpeper	1,077,000	x 85%	915,000
Staunton	1,548,000	x 76%	1,176,000
Northern Virginia	1,504,000	x 31%	466,000

These maintenance monies were used on all secondary roads. Since this study is limited to chip sealed surfaces, the maintenance costs need to be prorated by surface type. No exact costing breakdown was found available. Mileage tabulations of the secondary system by county and district yielded lane-miles of plant mix. It was assumed that maintenance money was expended as a direct function of lane-miles to be maintained regardless of road surface type. Therefore, the percentages used in Table 3 approximate the costs of maintaining secondary surface-treated roads by eliminating the percentage of plant mix. These values are obviously not exact and unfortunately like most of the cost data used in this project of somewhat questionable accuracy, but they are the best that could be developed. If they are used consistently, they should result in acceptable values for this study.

Another important concern was the distribution of maintenance costs over time. It was assumed the maintenance money for each road will vary from zero at the time of resurfacing to a statistical maximum at the time of the next resurfacing. The rate of change in ordinary maintenance required to maintain an acceptable serviceability level will vary inversely with the rate of change in pavement service condition. Because a pavement's surface will deteriorate over time, maintenance costs will have to increase over time.

A number of proposed variation rates are cited in the literature. Among the functions considered for this project where y is the expenditure and x is the number of 12-month periods, were straight line ($y = x$), parabolic ($y = x^2$), cubic ($y = x^3$), and exponential ($y = e^x$). No hard data were available to guide the selection of the most appropriate function. The parabolic function was selected because it seemed to most closely show the inverse of the pavement performance curve. The parabolic curve is relatively asymptotic at first, followed by a dramatic increase. Unfortunately, the pure form of the function ($y = x^2$) yielded unrealistically high maintenance expenditures in the early years of the cycle. The solution to this problem was to add a constant to the equation changing the form to $y = ax^2$.

In selecting a constant it was necessary to consider realistic boundary conditions. As such, it was assumed that the current maintenance expenditures along with a 5-year sealing cycle provide pavements with acceptable levels of serviceability. Also, little or no maintenance is required at the time of resealing (time zero) and for the ensuing 12 months (year 0). The 12-month periods considered are neither fiscal nor calendar years, but simply 12 months from the initial seal. The constant should adjust the pure parabolic curve so that maintenance costs are minimized during year zero and the total maintenance expenditure over the next 4 years closely matches the sum of 4 years of expenditure at the current annual rate of $12,150,000. The mathematical solution for the constant under these constraints for a 5-year cycle is shown below.

$$3{,}037{,}500\ [C(1)^2 + C(2)^2 + C(3)^2 + C(4)^2] = 12{,}150{,}000$$

$$C\ (1 + 4 + 9 + 16) = 4$$

$$30C = 4$$

$$C = 7.5$$

The resulting form of the equation is $y = x^2/7.5$. Figure 1 shows a comparison of all the curve representations of the functions considered, using the constant of 1/7.5. It could be advocated that this equation should be different for each construction district since the basic data are different. However, from an administrative point of view it was felt that a statewide uniform rate of maintenance growth was preferable. For purposes of this study a uniform rate of growth was used; but it should be noted that the best management approach would be to use variable rates of growth.

The computer spreadsheet developed herein used the data gathered and the maintenance cost increase function selected to calculate the present worth or value of costs for surface treatment cycles ranging from 3 to 10 years. Comparison of the present value cost of each cycle allows the selection of the most economical cycle. Table 4 shows the results of the analysis for the entire state. Depending on the cycle selected, the surface-treated roads are divided into portions. For example, in Alternative 1, a 3-year cycle, the miles of roads are divided into thirds (one third of the roads are resealed annually). Therefore the initial action shows the cost of resealing one third of the roads. The annual

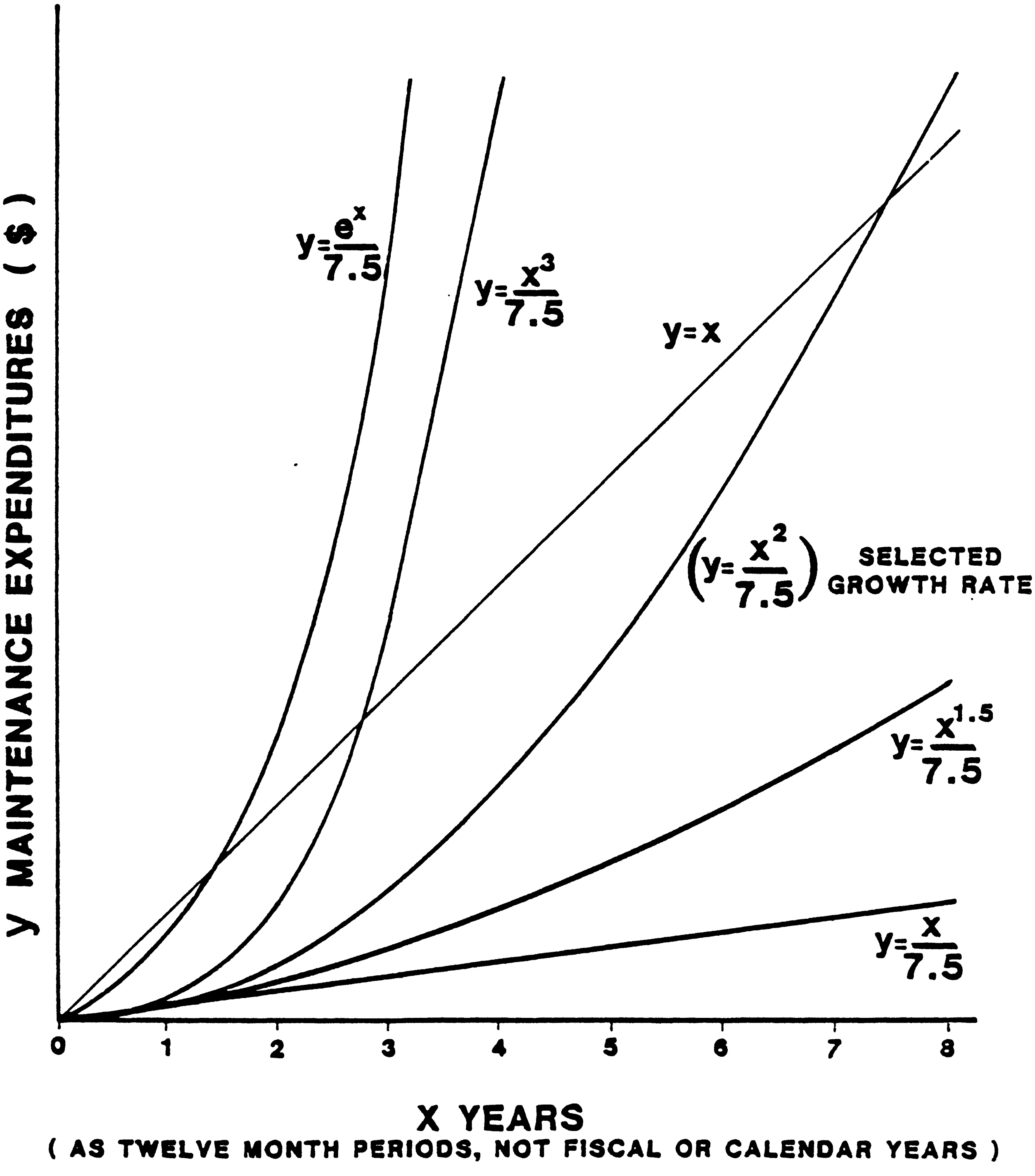

Figure 1. Maintenance cost vs. time.

Table 4

Optimum Seal Coat Frequency Study, Entire State

BASE MAINTENANCE FUNDS: $12,150,000
BASE RESURFACING FUNDS: $17,000,000

Discount Rate 6.00%
Analysis Period 20

Alternative	Alt. 1	Alt. 2	Alt.3
Description	3-Year Cycle	4-Year Cycle	5-Year Cycle
Initial Action	$28,330,500	$21,250,000	$17,000,000
Life Beyond 20 Years	1	0	0
Salvage Value (After 20 Years)	$1,416,525	$0	$0
Prorated Maintenance Funds:	$6,075,000	$4,049,595	$3,037,500

	Total Expenditure Expected After This Year	(33.3% of Mileage)	(Total for System)	(25.0% of System)	(Total for System)	(20.0% of System)	(Total for System)
		+++++++++++++++++++++++		+++++++++++++++++++++++		+++++++++++++++++++++++	
X**2/7.5	1	$807,975	$32,376,450	$538,596	$28,806,544	$403,988	$29,146,963
	2	$3,237,975	$32,376,450	$2,158,434	$28,806,544	$1,618,988	$29,146,963
	3	$28,330,500	$32,376,450	$4,859,514	$28,806,544	$3,645,000	$29,146,963
	4	$807,975	$32,376,450	$21,250,000	$28,806,544	$6,478,988	$29,146,963
	5	$3,237,975	$32,376,450	$538,596	$28,806,544	$17,000,000	$29,146,963
	6	$28,330,500	$32,376,450	$2,158,434	$28,806,544	$403,988	$29,146,963
	7	$807,975	$32,376,450	$4,859,514	$28,806,544	$1,518,988	$29,146,963
	8	$3,237,975	$32,376,450	$21,250,000	$28,806,544	$3,645,000	$29,146,963
	9	$28,330,500	$32,376,450	$538,596	$28,806,544	$6,478,998	$29,146,963
	10	$807,975	$32,376,450	$2,158,434	$28,806,544	$17,000,000	$29,146,963
	11	$3,237,975	$32,376,450	$4,859,514	$28,806,544	$403,988	$29,146,963
	12	$28,330,500	$32,376,450	$21,250,000	$28,806,544	$1,618,988	$29,146,963
	13	$807,975	$32,376,450	$538,596	$28,806,544	$3,645,000	$29,146,963
	14	$3,237,975	$32,376,450	$2,158,434	$28,806,544	$6,478,988	$29,146,963
	15	$28,330,500	$32,376,450	$4,859,514	$28,806,544	$17,000,000	$29,146,963
	16	$807,975	$32,376,450	$21,250,000	$28,806,544	$403,988	$29,146,963
	17	$3,237,975	$32,376,450	$538,596	$28,806,544	$1,618,988	$29,146,963
	18	$28,330,500	$32,376,450	$2,158,434	$28,806,544	$3,645,000	$29,146,963
	19	$807,975	$32,376,450	$4,859,514	$28,806,544	$6,478,988	$29,146.963
	20	($1,416,525)	($1,416,525)	$0	$0	$0	$0
Present Value Cost		$110,939,904	$360,818,521	$70,636,495	$321,426,777	$56,557,971	$325,225,203

Table 4 continued

Alt.4		Alt. 5		Alt. 6		Alt. 7	
6-Year Cycle		7-Year Cycle		8-Year Cycle		9-Year Cycle	
$14,169,500		$12,146,500		$10,625,000		$9,435,000	
4		1		4		7	
$2,833,900		$607,325		$2,125,000		$3,302,250	
$2,430,000		$2,025,405		$1,736,235		$1,518,750	
(16.7% of System)	(Total for System)	(14.3% of System)	(Total for System)	(12.5% of System)	(Total for System)	(11.1% of System)	(Total for System)
++++++++++++++++++++++		++++++++++++++++++++++		++++++++++++++++++++++		++++++++++++++++++++++	
$323,190	$31,986,260	$269,379	$36,718,713	$230,919	$43,031,826	$230,919	$56,657,120
$1,295,190	$31,986,260	$1,079,541	$36,718,713	$925,413	$43,031,826	$925,413	$56,657,120
$2,916,000	$31,986,260	$2,430,486	$36,718,713	$2,083,482	$43,031,826	$2,083,482	$56,657,120
$5,183,190	$31,986,260	$4,320,189	$36,718,713	$3,703,389	$43,031,826	$3,703,389	$56,657,120
$8,099,190	$31,986,260	$6,750,675	$36,718,713	$5,786,871	$43,031,826	$5,786,871	$56,657,120
$14,169,500	$31,986,260	$9,721,944	$36,718,713	$8,333,928	$43,031,826	$8,333,928	$56,657,120
$323,190	$31,986,260	$12,146,500	$36,718,713	$11,342,823	$43,031,826	$11,342,823	$56,657,120
$1,295,190	$31,986,260	$269,379	$36,718,713	$10,625,000	$43,031,826	$14,815,293	$56,657,120
$2,916,000	$31,986,260	$1,079,541	$36,718,713	$230,919	$43,031,826	$9,435,000	$56,657,120
$5,183,190	$31,986,260	$2,430,486	$36,718,713	$925,413	$43,031,826	$230,919	$56,657,120
$8,099,190	$31,986,260	$4,320,189	$36,718,713	$2,083,482	$43,031,826	$925,413	$56,657,120
$14,169,500	$31,986,260	$6,750,675	$36,718,713	$3,703,389	$43,031,826	$2,083,482	$56,657,120
$323,190	$31,986,260	$9,721,944	$36,718,713	$5,786,871	$43,031,826	$3,703,389	$56,657,120
$1,295,190	$31,986,260	$12,146,500	$36,718,713	$8,333,928	$43,031,826	$5,786,871	$56,657,120
$2,916,000	$31,986,260	$269,379	$36,718,713	$11,342,823	$43,031,826	$8,333,928	$56,657,120
$5,183,190	$31,986,260	$1,079,541	$36,718,713	$10,625,000	$43,031,826	$11,342,823	$56,657,120
$8,099,190	$31,986,260	$2,430,486	$36,718,713	$230,919	$43,031,826	$14,815,293	$56,657,120
$14,169,500	$31,986,260	$4,320,189	$36,718,713	$925,413	$43,031,826	$9,435,000	$56,657,120
$323,190	$31,986,260	$6,750,675	$36,718,713	$2,083,482	$43,031,826	$230,919	$56,657,120
($2,833,900)	($2,833,900)	($607,325)	($607,325)	($2,125,000)	($2,125,000)	($3,302,250)	($3,302,250)
$52,185,415	$356,022,792	$49,375,418	$409,522,315	$49,475,607	$479,491,545	$60,091,336	$631,157,083

Table 4 continued

Alt. 8		Alt. 9		Alt. 10	
10-Year Cycle		11-Year Cycle		12-Year Cycle	
$8,500,000		$7,726,500		$7,080,500	
0		2		4	
$0		$772,650		$1,416,100	
$1,348,650		$1,215,000		$1,105,650	
(10.0% of System)	(Total for System)	(9.1% of System)	(Total for System)	(8.3% of System)	(Total for System)
$230,919	$74,473,458	$230,919	$96,849,179	$230,919	$124,213,858
$925,413	$74,473,458	$925,413	$96,849,179	$925,413	$124,213,858
$2,083,482	$74,473,458	$2,083,482	$96,849,179	$2,083,482	$124,213,858
$3,703,389	$74,473,458	$3,703,389	$96,849,179	$3,703,389	$124,213,858
$5,786,871	$74,473,458	$5,786,871	$96,849,179	$5,786,871	$124,213,858
$8,333,928	$74,473,458	$8,333,928	$96,849,179	$8,333,928	$124,213,858
$11,342,823	$74,473,458	$11,342,823	$96,849,179	$11,342,823	$124,213,858
$14,815,293	$74,473,458	$14,815,293	$96,849,179	$14,815,293	$124,213,858
$18,751,338	$74,473,458	$18,751,338	$96,849,179	$18,751,338	$124,213,858
$8,500,000	$74,473,458	$23,149,221	$96,849,179	$23,149,221	$124,213,858
$230,919	$74,473,458	$7,726,500	$96,849,179	$28,010,679	$124,213,858
$925,413	$74,473,458	$230,919	$96,849,179	$7,080,500	$124,213,858
$2,083,482	$74,473,458	$925,413	$96,849,179	$230,919	$124,213,858
$3,703,389	$74,473,458	$2,083,482	$96,849,179	$925,413	$124,213,858
$5,786,871	$74,473,458	$3,703,389	$96,849,179	$2,083,482	$124,213,858
$8,333,928	$74,473,458	$5,786,871	$96,849,179	$3,703,389	$124,213,858
$11,342,823	$74,473,458	$8,333,928	$96,849,179	$5,786,871	$124,213,858
$14,815,293	$74,473,458	$11,342,823	$96,849,179	$8,333,928	$124,213,858
$18,751,338	$74,473,458	$14,815,293	$96,849,179	$11,342,823	$124,213,858
$0	$0	($772,650)	($772,650)	($1,416,100)	($1,416,100)
$73,099,755	$830,983,515	$77,876,017	$1,080,413,503	$86,283,234	$1,385,551,151

expenditures through year 20 just for that third of the miles are shown under the heading "33.3% of the Mileage." This is shown to illustrate the increasing maintenance expenditures as the resealing cycle increases. Note that for Alternative 1, there are 2 years of increasing maintenance following resealing. Resealing costs are the same as the initial action cost, and they occur every third year. The "Total for System" column is the total money required to operate under the 3-year cycle. Every year, one third of the system is resealed, one third needs its first year maintenance, and the other third needs its second year maintenance. Consequently, the annual expenditures in this column remain constant. The other cycles are shown in the same format.

For a given cycle, each portion is always being either maintained or resealed. The amount of money required to reseal or maintain each portion would obviously be dependent upon the number of miles in each portion. It was assumed that current expenditures in both maintenance and resurfacing are adequate to meet the needs of a 5-year cycle (portions of 20 percent). Changing the cycle necessitated prorating the available funds for both maintenance and resurfacing.

Analysis of the results shows that for the entire state, a 4-year cycle has least present value of $321,426,777 (see Figure 2). The second lowest present value was for a 5-year cycle as is currently used. It is only 1 percent higher. Optimum resealing cycles can also be determined using the appropriate inputs for maintenance and resurfacing for the districts, residencies, or even counties. This was not done for this study as there was considerable concern over the accuracy of the required inputs. It should be considered at least at the district level in future applications of this program.

A sensitivity analysis was conducted by varying the maintenance funds. The resurfacing funds were left unchanged. These latter numbers are considered quite reliable since they were based on actual contract awards, while the maintenance funds were based on averaged expenditures on activities 111 and 112 prorated to the seal coated mileages. It can be argued that these maintenance costs are subject to interpretation. Changing them did change the computed present values and the selection of the optimum cycle. Reducing the maintenance funds made the longer cycles more economical than the shorter ones. It should also be pointed out, however, that as maintenance money is reduced, the appearance and riding quality may become unacceptable to the public. As an extreme, if the maintenance is reduced to zero, theoretically it is more cost efficient to reseal when the road has completely failed. Obviously this is not an acceptable solution; nonetheless, one may speculate that if more detailed maintenance cost data were available, it might result in less money earmarked for surface maintenance than is shown in this report. In turn, this would result in a longer optimum cycle.

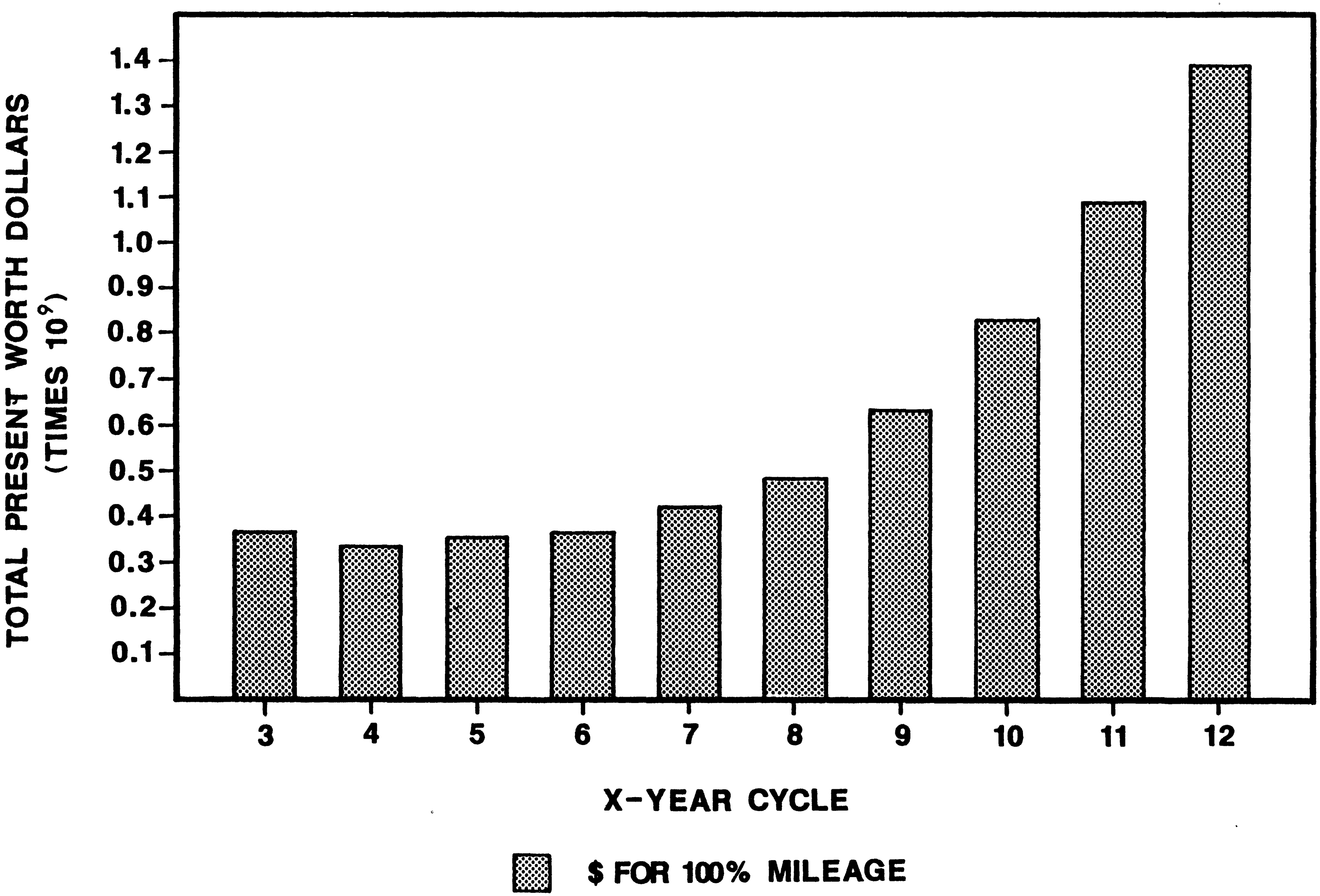

Figure 2. Optimum seal coat frequency, entire state.

CONCLUSIONS

Management practices for the surface treatment of secondary roads vary across the country. Although attempts to establish a detailed project level management system for Virginia's surface-treated secondary roads were unsuccessful, a viable economic analysis program has been established to analyze the costs of a particular resealing cycle for use in comparing various cycles. This program includes a function that models the effects of delaying maintenance replacement with an increase in required ordinary maintenance.

Using the developed computer spreadsheet to analyze Virginia's alternatives led to the finding that a 4-year resealing cycle was optimal with a 5-year cycle only 1 percent higher. Unfortunately, since many assumptions were made and many estimates used, it is not surprising that a 4- or 5-year cycle was selected--Virginia currently uses a 5-year cycle. However, the analysis program is sound and may prove to be quite useful at the network level when better cost and condition data are available.

RECOMMENDATIONS

It is recommended that a better system for maintaining cost records on secondary roads be explored because of the importance of this information to pavement management. Further, the merits of establishing project level management for Virginia's surface-treated secondaries should be carefully reviewed. Most likely the findings of such a review will lead to a concerted effort toward the development of such a system and the pursuit of management's support in order to obtain the necessary manpower to operate it.

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