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Final Report - Development of Computer Software for Pavement Life Cycle Cost Analysis

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Abstract

The life cycle cost analysis program (LCCA) is designed to automate and standardize life cycle costing in Virginia. It allows the user to input information necessary for the analysis, and it then completes the calculations and produces a printed copy of the results.

The program requires the user to input site-specific information as well as the initial costs for each alternative. It calculates user costs automatically and reduces all costs to their present value. It is these present value costs that are used in the final ranking of alternatives.

Although this program is not as sophisticated as some of the software currently in use, it is a step toward the completion of life cycle costing in Virginia's pavement management system. LCCA should be regarded as another tool in the pavement management decision-making process.

FINAL REPORT

DEVELOPMENT OF COMPUTER SOFTWARE FOR PAVEMENT LIFE CYCLE COST ANALYSIS

by

Catherine A. Cragg
Transportation Co-op Student

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

The life cycle cost analysis program (LCCA) is designed to automate and standardize life cycle costing in Virginia. It allows the user to input information necessary for the analysis, and it then completes the calculations and produces a printed copy of the results.

The program requires the user to input site-specific information as well as the initial costs for each alternative. It calculates user costs automatically and reduces all costs to their present value. It is these present value costs that are used in the final ranking of alternatives.

Although this program is not as sophisticated as some of the software currently in use, it is a step toward the completion of life cycle costing in Virginia's pavement management system. LCCA should be regarded as another tool in the pavement management decision-making process.

FINAL REPORT

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INTRODUCTION

This paper discusses life cycle cost analysis as it applies to Virginia's pavement management system (PMS). Life cycle costing is a method of computing initial costs and projected maintenance costs over a specified period of time known as the analysis period. It is an economic analysis and can be performed in several ways. The methods currently in use include equivalent annual cost, present worth, rate of return, benefit-cost ratio, and cost-effectiveness. Of these, the most commonly used method is present worth, which is a method of discounting future expenditures to present dollars using a discount rate.

In order to produce realistic results, any life cycle cost analysis must include an initial cost (construction or rehabilitation), projected maintenance costs, user costs, and salvage value (1). User costs are those incurred by the public as they use the highway system. The most common such costs are those associated with delays because of construction/maintenance-related traffic problems. These costs can be as complex as to include the cost of additional gasoline and tire wear or as simple as to include only time delays and their accompanying value. So-called running user costs, or those associated with vehicle operation and wear and tear as related to deteriorated pavements, were not considered in this study.

Salvage value can also take on several meanings. It can refer to simply the value of the material if it were to be recycled, or it can be considered the value of the years of serviceability remaining in the pavement at the end of the analysis period.

Life cycle cost analysis has become a necessary part of any PMS. Federal directives have mandated its use, and simple economics are making it more and more popular. As budget cuts decrease the funds available for highway construction and maintenance, agencies are looking for ways to get the maximum value for their money. Life cycle cost analysis is a step in that direction.

OBJECTIVE AND SCOPE

The purpose of this project was to develop a framework for an analysis of alternatives for pavement rehabilitation on asphalt pavements, jointed concrete pavements, and continuously reinforced concrete pavements. This framework is to be transcribed into a microcomputer program in BASIC. The program will include initial costs and projected maintenance costs (both including traffic control and user delay costs) and salvage value at the end of the analysis period.

APPROACH

This project began with an extensive literature review. Since many states are just beginning to use life cycle cost analysis as a part of their PMS, much of the literature is repetitive or outdated. Sufficient information was gathered to assemble an outline of the status of life cycle costs in today's highway agencies. This report is an extension of that outline.

A review of some of the existing software was also made. It was thought that this review might provide a starting point for the development of Virginia's life cycle cost analysis program (LCCA). LCCA is not as intricate as much of the existing software. However, seeing how other agencies have handled the automation of their PMSs was useful.

Once all of these reviews were made, the actual programming began. A very simple framework was established. Initially, all data were input by the user. This gradually changed, and more automation was included. Basic material costs were included with an edit routine built in in case adjustments were required. The user must still input the type of maintenance to be performed and the year in which it is needed, but the program will automatically calculate the cost for the maintenance and discount it to time zero. If other current research efforts are successful, later versions may provide for default maintenance actions and costs.

This project is only the first step toward the total automation of life cycle cost analysis. In time, the program can be expanded and improved upon until total automation is achieved.

LIFE CYCLE COST ANALYSIS

Life cycle cost analysis is not a new concept. It has been used, in one form or another, by state highway departments for many years. When

the federal directive requiring the implementation of a PMS including selection of cost-effective rehabilitation solutions after consideration of more than one alternative was proposed, agencies began taking a closer look at life cycle cost possibilities. According to an article in the July 1988 issue of Better Roads (2), most states favor the new mandated PMS. A study cited in the article found that 41 of the 45 states that responded already had a PMS in use (2).

The FHWA pavement policy for highways defines life cycle cost as "all ownership and user costs necessary to provide a serviceable pavement over the analysis period. These include construction, maintenance, rehabilitation, traffic disruption costs and salvage value, etc." (3). It likewise defines analysis period as "the period of time over which life cycle costs are assessed in the study of pavement design alternatives" (3). The proposed policy specifies a minimum analysis period of 30 years (3). Virginia has been working with a 25-year analysis period but intends to extend it to the mandated 30-year period in the near future.

Any decision drawn from a life cycle cost analysis must take several factors into consideration. A manual of pavement management (4) lists four such factors considered to be important. They are

1. relative importance of initial capital expenditure to future expected expenditures
2. which method is most clearly understood
3. which method best suits agency requirements
4. whether benefits are to be included (4).

An alternative that had a low cost but required equipment or staffing not available to the agency would obviously be a poor choice. Likewise, an alternative with a low overall cost but an initial cost beyond an agency's budget would be an equally poor choice. The alternative chosen must be a viable one.

The manual also lists four basic principles of economic analysis. They are (4):

1. Economic analysis is not intended to provide a decision, it is merely a tool to aid the decision-making process.
2. Any economic analysis must consider all viable alternatives.
3. The same analysis period must be used for all alternatives.

4. Agency and user costs, as well as benefits, if possible, should be included in the economic analysis.

Keeping these items in mind, there are several methods by which one can perform an economic analysis. These methods include equivalent annual cost (divides all costs into equal payments over the analysis period), present worth (discounts future sums to the present), rate of return (determines the discount rate at which costs and benefits are equal), benefit-cost ratio (ratio of present worth of benefits to present worth of costs), and cost-effectiveness (useful when significant nonmonetary outputs are involved) (4). Uddin et al. (5) recommended the present worth method for use in LCCA for pavement design and rehabilitation. They listed several advantages such as the ability to compare projects of differing service lives and provide the answer in a single, total cost. Present worth calculations are also relatively uncomplicated, easy to understand, and widely accepted. NCHRP synthesis 122 credits present worth with being the most common method of economic analysis chosen among agencies using life cycle cost analysis (1). This was the method chosen for use in this program.

Present Worth

In order to calculate the present worth of an expenditure, one must provide a discount rate. There are many theories regarding the correct value for the discount rate. Most agencies use a rate between 4 and 10 percent (4). It is important to understand that there is a difference between interest rate and discount rate. Interest rates are normally associated with the borrowing and lending of money, whereas discount rates are used to reduce future costs to present-day terms (4). Discount rates are, in effect, a means of getting a handle on inflation, which is, by its nature, difficult to forecast with any degree of accuracy. Because of this unavoidable inaccuracy, some people believe that inflation should be disregarded in engineering economic studies.

This program provides a discount rate default value of 6 percent but allows the user to adjust this value as desired. Sensitivity analyses have shown that changing the rate by ± 2 has little or no effect on the ranking of alternatives by present value (Appendix A).

The basic equation used for calculating present value is

$$P = C\,[1/(1 + R)^N]$$

where C is the cost being converted, R is the discount rate, and N is the number of years from the initial time until the money is to be spent. For example, if one plans to do $10,000 of joint sealing in year 10 with a discount rate of 6 percent, the equation would be as follows:

$$\underline{P} = 10{,}000\ [1/(1 + .06)^{10}]$$

or

$$\underline{P} = 5{,}583.95.$$

So, in terms of today's dollars, the joint sealing would cost $5,583.95.

User Costs

User costs are the most complex of the costs considered in a life cycle cost analysis. Because they are not actual expenditures by a highway agency, but rather costs incurred by the user, it is difficult to assign an exact dollar value to them.

There are several types of user costs that have been included in life cycle cost analyses. Running user costs are increased vehicle costs including fuel, tire, engine oil, and maintenance. Rough roads cause an increase in tire wear, and delays because of construction or maintenance cause the consumption of additional gasoline. The calculation of these costs becomes very subjective, and although these costs tend to be small on an individual vehicle basis, they add up quickly on roads that carry 30,000 to 40,000 vehicles per day. Since it would not be advantageous to have running user cost as the most prominent factor, it is often left out of life cycle cost analyses.

User delay costs are somewhat easier to get a handle on, but there are still some questions about their accuracy. User delay is the additional time it takes to travel through a construction/maintenance area because of reduced speeds and/or temporary stops. In order to calculate a cost for these delays, a monetary value must be assigned to a person's time. There has been much controversy concerning this. Some highway officials believe that driving time is personal time and therefore does not have a monetary value. Others believe that driving to and from work is an extension of one's job and, therefore, that the time spent driving should be assigned a value equal to wages earned at work. These two opinions represent opposite ends of the spectrum; there are many more that fall somewhere in between. An average hourly wage for Virginia residents was obtained from the Tayloe Murphy Institute in Charlottesville (6). It was this figure that was used in the program.

This wage combined with an average number of people per car (for this program a value of 1.6 was used) (7) and average daily traffic provides an estimate of user delay cost for a certain reduction in speed over a given length of time. The equation used in this program was:

$$\underline{UC} = (\underline{ADT}/24) \times (\underline{PPC}) \times (\text{Wage}) \times (\underline{TLC}) \times (1/\underline{RSL} - 1/\underline{SPL}) \times (\underline{HIE})$$

where ADT is average daily traffic, PPC is average number of people per car, wage is average hourly wage, TLC is typical length of lane closure,

RSL is reduced speed limit through a construction/maintenance zone, SPL is normal posted speed limit, and HIE is number of hours the detour is in effect.

Some highway officials are against the direct inclusion of user costs (especially running user costs). They believe that this assigns too much value to user costs and assumes that an agency has all the money it needs (5). Markow (8) stated in his report for M.I.T. that user costs can be as much as 100 x Agency costs. Given this fact, one would tend to believe that user costs would be the dominating factor and therefore govern any decisions made. Markow pointed out that it is not the magnitudes of the costs one is concerned with but rather the marginal costs. Total costs, as shown in Figure 1, are lowest when the marginal increase in cost for initial construction is equal to the marginal decrease in cost for maintenance and rehabilitation and user costs (8). Furthermore, when only agency costs are considered, additional user costs can be higher than the savings incurred by the agency (8). This places an unfair burden on the user. This shows, better than anything, just how important the inclusion of user costs is.

Salvage Value

Another very controversial aspect of life cycle cost analysis is the inclusion of salvage value. Salvage value has been given several different meanings. The first is the actual value of the materials if they were recycled minus the cost of reclamation. Salvage value is also used to refer to the value of the years of serviceability remaining in the highway at the end of the analysis period. It is this latter definition that is referred to in this program.

In order to calculate the value of the additional years of serviceability, one must first decide how many additional years are being provided by a given maintenance strategy. This might seem to be a complicated procedure but is actually quite simple. If concrete pavement restoration (CPR) with a design life of 10 years is done on a pavement in year 19 of a 25-year analysis period, one would expect the pavement to maintain an acceptable level of serviceability for 4 years beyond the analysis period. This extended life is then divided by the analysis period and multiplied by the initial reconstruction/rehabilitation cost (including traffic control cost). This value is then discounted to present worth to be included in the total cost of the alternative. Since it must be discounted over the entire length of the analysis period, salvage value generally does not have a large effect on the results. For example, a salvage value of $1,000,000, discounted over a 25-year analysis period, would subtract only $220,000 from the total present value cost. Regardless of its numerical significance, salvage value should be considered in any life cycle cost analysis because the omission of any factor before it has been considered will reduce the accuracy of the analysis.

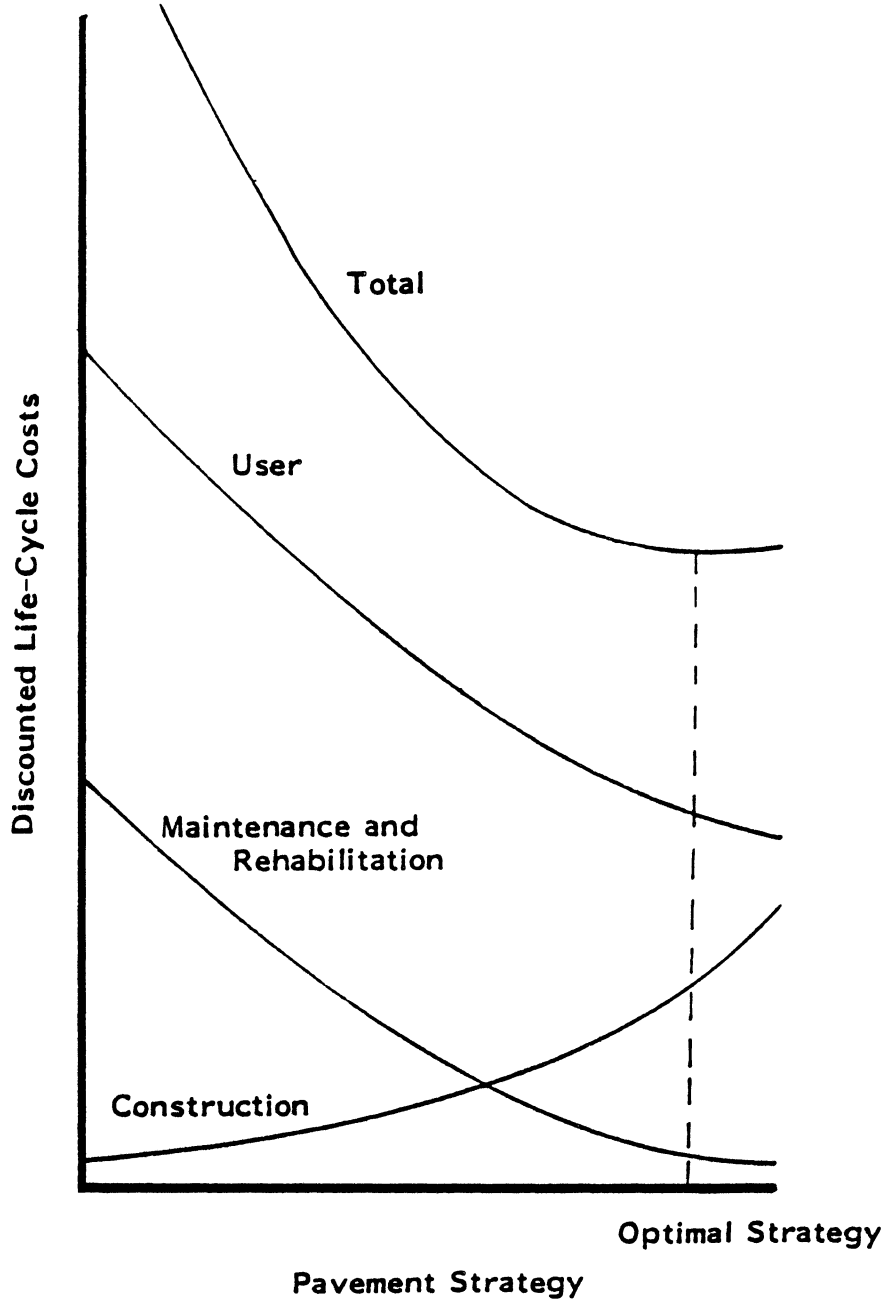

Figure 1 Analysis of pavement strategies using discounted costs. Source: Markow, Michael J. 1985. Demand responsive approach to highway maintenance and rehabilitation: Vol. 3. Applications to pavement type selection and alternate bidding. Cambridge: Massachusetts Institute of Technology, Center for Research and Education.

LCCA PROGRAM

The program developed provides a partial automation of the PMS in Virginia. It provides a means of standardizing a process that has been handled in many different ways in the past.

The program relies heavily on user inputs. Throughout the course of the program, the user will be asked to input initial cost, traffic control cost, type of maintenance and when it is required, and information regarding the detour area (work zone). For a more detailed explanation, refer to the User's Guide in Appendix B.

From these inputs, the program calculates user costs and maintenance costs and converts all costs to present value. The program then ranks the alternatives in order of both their initial and total present value costs. A printed summary of each alternative along with the two rankings is produced. A sample printout is included in Appendix C.

CONCLUSION

Life cycle cost analysis is a complicated process. Many variables must be considered, and judgments must be made concerning the importance of various factors. The most important point to remember when conducting a life cycle cost analysis is that it is not intended to provide a definite solution; it is meant to provide only a guideline with which an informed decision can be made.

The program developed over the course of this project was written in BASIC. It manipulates user inputs, including initial cost, traffic control cost, and necessary maintenance, into a total life cycle cost based on present worth. For the purpose of comparison, the alternatives are ranked on the basis of both initial cost and total life cycle cost. Although this program does fill a void in Virginia's PMS in the area of life cycle cost analysis, it provides only a means of comparison, not absolute answers.

The "bottom line" is that any life cycle cost analysis program, no matter how sophisticated, is only a tool. It is a framework that sorts information into a form that is easier to analyze. It cannot and must not take the place of sound engineering judgment.

ACKNOWLEDGMENTS

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APPENDIX A

SENSITIVITY ANALYSIS

VIRGINIA DEPARTMENT OF TRANSPORTATION

LIFE CYCLE COST ANALYSIS

COUNTY NUMBER- 40	AVERAGE DAILY TRAFFIC- 10000
ROUTE NUMBER- 95	SPEED LIMIT- 55 MPH
DIRECTION- 1	ANALYSIS PERIOD- 25 YEARS
BEGIN MP- 2	DISCOUNT RATE- 4 %
END MP- 3	NUMBER OF ALTERNATIVES- 3

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 1

INITIAL REHABILITATION COST	$645,676.00
TRAFFIC CONTROL COST	$60,831.00
USER COST	$13,036.88

MAINTENANCE REQUIRED IN YEAR 5
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $27,843.16

MAINTENANCE REQUIRED IN YEAR 10
TRANSVERSE JOINT SEALING(7000 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
FULL DEPTH PATCHING(3 %)
COST OF REQUIRED MAINTENANCE $85,526.14

MAINTENANCE REQUIRED IN YEAR 15
TRANSVERSE JOINT SEALING(7000 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $29,153.08

MAINTENANCE REQUIRED IN YEAR 19
CPR
COST OF REQUIRED MAINTENANCE $178,294.40

MAINTENANCE REQUIRED IN YEAR 24
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,605.36

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 1 $871,407.90

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 2

INITIAL REHABILITATION COST	$582,761.00
TRAFFIC CONTROL COST	$102,174.00
USER COST	$14,666.49

MAINTENANCE REQUIRED IN YEAR 5
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $27,843.16

MAINTENANCE REQUIRED IN YEAR 10
TRANSVERSE JOINT SEALING(6500 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
FULL DEPTH PATCHING(2 %)
COST OF REQUIRED MAINTENANCE $66,472.15

MAINTENANCE REQUIRED IN YEAR 15
TRANSVERSE JOINT SEALING(6500 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,403.08

MAINTENANCE REQUIRED IN YEAR 19
CPR
COST OF REQUIRED MAINTENANCE $178,294.40

MAINTENANCE REQUIRED IN YEAR 24
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,605.36

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 2 $839,421.90

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 3
INITIAL REHABILITATION COST $765,415.00
TRAFFIC CONTROL COST $200,396.00
USER COST $16,296.11

MAINTENANCE REQUIRED IN YEAR 8
OVERLAY (NEW OR RECYCLED)
COST OF REQUIRED MAINTENANCE $39,009.85

MAINTENANCE REQUIRED IN YEAR 16
MILLING(1.5 in.)
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $53,811.48

MAINTENANCE REQUIRED IN YEAR 24
MILLING(1.5 in.)
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $54,626.72

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3 $963,112.40

INITIAL COSTS IN ASCENDING ORDER
ALTERNATIVE 2 $582,761.00
ALTERNATIVE 1 $645,676.00
ALTERNATIVE 3 $765,415.00

PRESENT VALUE COSTS IN ASCENDING ORDER
ALTERNATIVE 2 $839,421.90
ALTERNATIVE 1 $871,407.90
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VIRGINIA DEPARTMENT OF TRANSPORTATION

LIFE CYCLE COST ANALYSIS

COUNTY NUMBER- 40	AVERAGE DAILY TRAFFIC- 10000
ROUTE NUMBER- 95	SPEED LIMIT- 55 MPH
DIRECTION- 1	ANALYSIS PERIOD- 25 YEARS
BEGIN MP- 2	DISCOUNT RATE- 6 %
END MP- 3	NUMBER OF ALTERNATIVES- 3

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 1

INITIAL REHABILITATION COST	$645,676.00
TRAFFIC CONTROL COST	$60,831.00
USER COST	$13,036.88

MAINTENANCE REQUIRED IN YEAR 5
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
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MAINTENANCE REQUIRED IN YEAR 10
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LONGITUDINAL JOINT SEALING(15840 ft.)
FULL DEPTH PATCHING(3 %)
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LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $29,153.08

MAINTENANCE REQUIRED IN YEAR 19
CPR
COST OF REQUIRED MAINTENANCE $178,294.40

MAINTENANCE REQUIRED IN YEAR 24
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,605.36

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 1 $841,417.80

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 2
INITIAL REHABILITATION COST $582,761.00
TRAFFIC CONTROL COST $102,174.00
USER COST $14,666.49

MAINTENANCE REQUIRED IN YEAR 5
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
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MAINTENANCE REQUIRED IN YEAR 24
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,605.36

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 2 $811,281.60

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 3
INITIAL REHABILITATION COST $765,415.00
TRAFFIC CONTROL COST $200,396.00
USER COST $16,296.11

MAINTENANCE REQUIRED IN YEAR 8
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OVERLAY (NEW OR RECYCLED)(1.5 in.)
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MAINTENANCE REQUIRED IN YEAR 24
MILLING(1.5 in.)
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $54,626.72

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3 $981,814.10

INITIAL COSTS IN ASCENDING ORDER
ALTERNATIVE 2 $582,761.00
ALTERNATIVE 1 $645,676.00
ALTERNATIVE 3 $765,415.00

PRESENT VALUE COSTS IN ASCENDING ORDER
ALTERNATIVE 2 $811,281.60
ALTERNATIVE 1 $841,417.80
ALTERNATIVE 3 $981,814.10

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DIRECTION- 1	ANALYSIS PERIOD- 25 YEARS
BEGIN MP- 2	DISCOUNT RATE- 8 %
END MP- 3	NUMBER OF ALTERNATIVES- 3

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 1

INITIAL REHABILITATION COST	$645,676.00
TRAFFIC CONTROL COST	$60,831.00
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MAINTENANCE REQUIRED IN YEAR 5
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TRANSVERSE JOINT SEALING(7000 ft.)
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MAINTENANCE REQUIRED IN YEAR 24
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,605.36

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 1 $817,839.50

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 2
INITIAL REHABILITATION COST $582,761.00
TRAFFIC CONTROL COST $102,174.00
USER COST $14,666.49

MAINTENANCE REQUIRED IN YEAR 5
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $27,843.16

MAINTENANCE REQUIRED IN YEAR 10
TRANSVERSE JOINT SEALING(6500 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
FULL DEPTH PATCHING(2 %)
COST OF REQUIRED MAINTENANCE $66,472.15

MAINTENANCE REQUIRED IN YEAR 15
TRANSVERSE JOINT SEALING(6500 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,403.08

MAINTENANCE REQUIRED IN YEAR 19
CPR
COST OF REQUIRED MAINTENANCE $178,294.40

MAINTENANCE REQUIRED IN YEAR 24
TRANSVERSE JOINT SEALING(6336 ft.)
LONGITUDINAL JOINT SEALING(15840 ft.)
COST OF REQUIRED MAINTENANCE $28,605.36

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 2 $789,301.60

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 3
INITIAL REHABILITATION COST $765,415.00
TRAFFIC CONTROL COST $200,396.00
USER COST $16,296.11

MAINTENANCE REQUIRED IN YEAR 8
OVERLAY (NEW OR RECYCLED)
COST OF REQUIRED MAINTENANCE $39,009.85

MAINTENANCE REQUIRED IN YEAR 16
MILLING(1.5 in.)
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $53,811.48

MAINTENANCE REQUIRED IN YEAR 24
MILLING(1.5 in.)
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $54,626.72

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3 $990,942.40

INITIAL COSTS IN ASCENDING ORDER
ALTERNATIVE 2 $582,761.00
ALTERNATIVE 1 $645,676.00
ALTERNATIVE 3 $765,415.00

PRESENT VALUE COSTS IN ASCENDING ORDER
ALTERNATIVE 2 $789,301.60
ALTERNATIVE 1 $817,839.50
ALTERNATIVE 3 $990,942.40

APPENDIX B

USER'S GUIDE

LCCA is a simple, user-friendly program written in BASIC. In order to maximize simplicity, it would be best to copy this program onto a disk that has been formatted with the proper operating system for your computer. You must also have access to BASICA in order to run LCCA. The most efficient way to obtain this access is to copy BASICA onto your program disk. You have been provided with a special file that will automatically begin the execution of the program when you type "LCCA." This file can be used only if BASICA has been saved on your disk. If you choose not to save the operating system and BASIC on your disk, you must boot the computer with your DOS disk. When you receive the A prompt, type "BASICA" and hit return. If you enter the BASICA operating mode in this manner, the function key assignments will appear at the bottom of the screen. Hit the F-3 (load) button and type LCCA.BAS; then hit "Enter." This will load the program. Then, simply hit the F-2 (run) button, and the program execution will begin. Either way you choose to get the program started, you will then be at the same place.

A VDOT heading will appear at the top of the screen. The program will then begin asking you to input information regarding the section under consideration. When the question appears, type in the correct response and hit "Enter." Default values are given for some items. If you wish to use the default value, simply hit "Enter." If you hit "Enter" where a value is necessary and a default value is not available, the program will continue asking for a value until you give it one.

Once the site information has been entered, the program will display a listing of materials costs used in the program. These costs are just average values, so it is very likely that they will not reflect material costs in your area. If it is necessary to change some or all of the costs, follow the instructions given by the program. Once these costs have been changed, the computer will remember only the new values. For a listing of the current values, please see Table B-1. The numbers at the far left of the table are the code numbers required to change the costs. It is necessary to change only those values that directly affect your project.

This program is designed to consider up to 10 alternatives. When the program asks you to input the number of alternatives, choose any number between 1 and 10. This tells the computer how many times it must repeat its analysis process. The program will then ask you to input the initial rehabilitation costs and traffic control costs. These costs refer to the maintenance done in year zero, at the start of the analysis period. You will also need to input the expected life beyond the analysis period. For example, if CPR has a design life of 10 years and is done on a pavement in year 19 of a 25-year analysis period, the pavement will be expected to have an acceptable level of serviceability for 4 years beyond the analysis period. This extended life information is used in calculating salvage value.

Table B-1

MATERIALS COST FOR MAINTENANCE ALTERNATIVES[a]

1.	Grinding PCC	$ 3.25 sq. yd.
2.	Grooving PCC	$ 9.00 sq. yd.
3.	Joint sealing	$ 1.25 ft.
4.	Milling AC	$ 0.60 sq. yd.
5.	Overlay without AC fabric: Plant mix	$ 30.00 ton
	NOTE: AC fabric cost is considered equivalent to the cost of a 1" overlay.	115 lb./sq. yd. in.
6.	Patching PCC: Full depth	$130.00 sq. yd.
7.	Patching PCC: Partial depth	$120.00 sq. yd.
8.	Single surface treatment	$ 0.40 sq. yd.
9.	Slurry seal	$ 0.65 sq. yd.
10.	Premix patching	$ 5.00 sq. yd.

[a]PCC = portland cement concrete; AC = asphalt concrete.

At this point, the program will ask you to choose the most appropriate detour model. Illustrations of these models are in Figure B-1. This is the method by which traffic is detoured through the work area while construction/maintenance is taking place. This choice determines the method of user cost calculation. In order to calculate these costs, it is necessary to input the number of hours the detour is in effect. If the road is reopened to normal traffic flow in the evening, do not include these hours. Include all hours during which traffic flow is disrupted during the whole activity.

Once you have entered all the required user cost inputs, the program will ask if additional maintenance beyond the original rehabilitation is required. If you respond with a "y" for "yes," the computer will ask for the year in which the maintenance is required. With this information entered, you must choose the appropriate maintenance activity from the list printed on the screen (Table B-2). The program will automatically calculate the cost of the maintenance and convert the cost to present value. If you choose alternative 13 (other), you must input the type of maintenance done as well as the cost per mile of this maintenance. This option is included to allow for more flexibility.

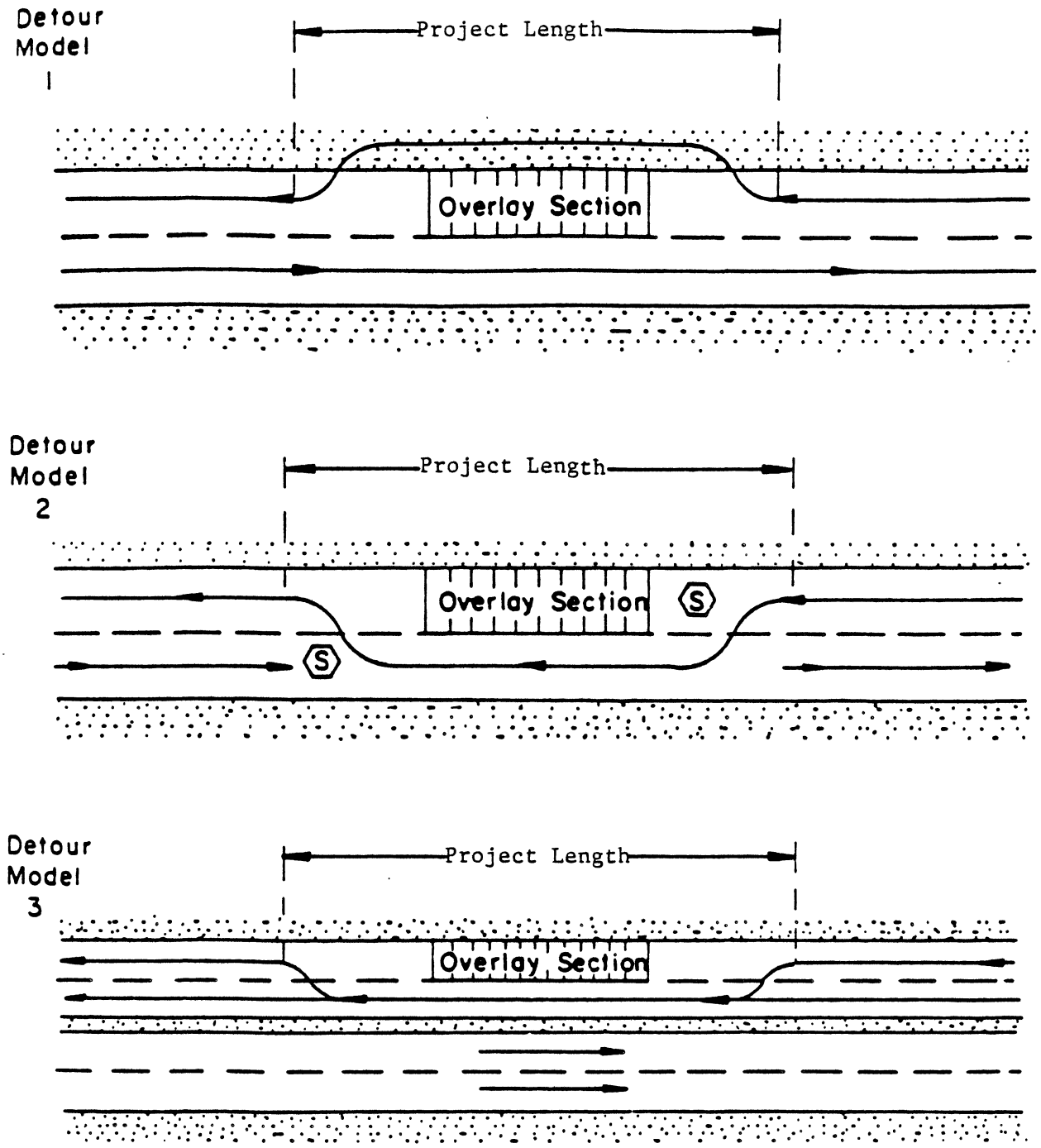


Figure B-1 Illustration of the detour models available in LCCA for use in estimating traffic delay cost. Source: Uddin, Waheed; Carmichael, R. F., III; and Hudson, W. R. 1985. Life cycle cost analysis for pavement management decision making: State of the art review. Report No. LCC/1. Austin: Texas Research and Development Foundation.

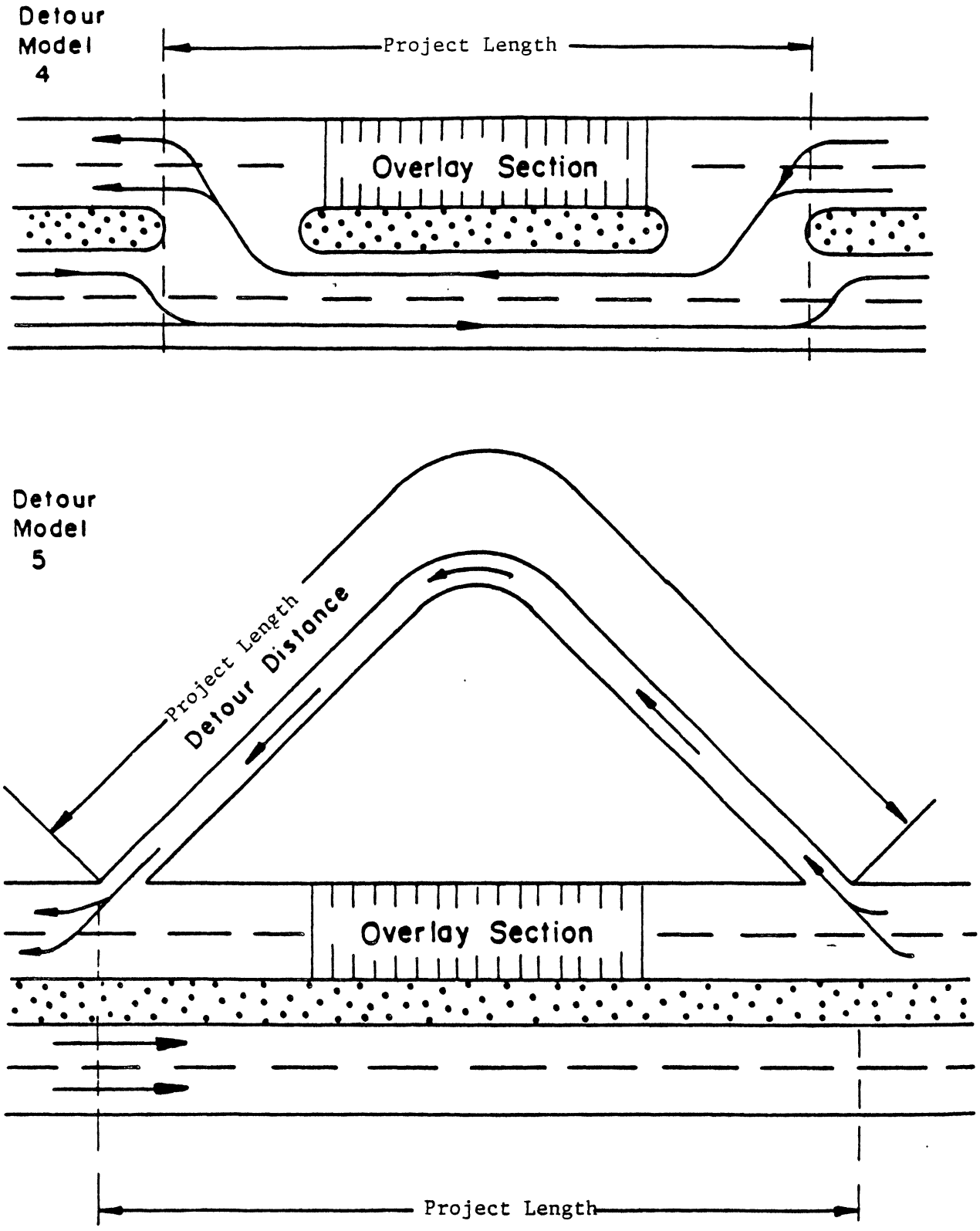


Figure B-1 (continued) Illustration of the detour models available in LCCA for use in estimating traffic delay cost. Source: Uddin, Waheed; Carmichael, R. F., III; and Hudson, W. R. 1985. Life cycle cost analysis for pavement management decision making: State of the art review. Report No. LCC/1. Austin: Texas Research and Development Foundation.

Table B-2

MAINTENANCE ALTERNATIVES[a]

1. Grinding PCC
2. Grooving PCC
3. Transverse joint sealing
4. Longitudinal joint sealing
5. Milling AC
6. Overlay with AC fabric
7. Overlay
8. Patching PCC: Full depth
9. Patching PCC: Partial depth
10. Single surface treatment
11. Slurry seal
12. Premix patching
13. Other

[a]PCC = portland cement concrete; AC = asphalt concrete.

If you answer "no" to the question "Is additional maintenance required?", the program will go on to the next alternative or begin printing the output, whichever is applicable.

Once you have entered the data for each of the specified number of alternatives, the computer will automatically begin printing the output. The printout includes a heading that identifies the project by county number, route number, direction, and beginning and ending mile posts. The average daily traffic, speed limit, analysis period, discount rate, and number of alternatives considered are also listed in the heading.

The alternatives are then printed in the same order in which they were entered, all in the following format: The initial reconstruction cost and traffic control cost along with the calculated user cost are printed first, followed by the type and cost of maintenance required in the specified years throughout the analysis period. The maintenance cost includes the costs of all maintenance activities plus the traffic control and user costs. After all maintenance activities have been listed, the total present value cost for the alternative will be printed.

The final items on the printout are the ranking of the alternatives on the basis of their initial and present value costs. Both the alternative number and the cost are printed with the smallest at the top

and the largest at the bottom. NOTE: This ranking is meant to be only a guide in the selection of the most appropriate alternative and should not be considered the sole criterion for selection.

APPENDIX C

SAMPLE PRINTOUT

VIRGINIA DEPARTMENT OF TRANSPORTATION

LIFE CYCLE COST ANALYSIS

COUNTY NUMBER- 2	AVERAGE DAILY TRAFFIC- 10000
ROUTE NUMBER- 3	SPEED LIMIT- 55 MPH
DIRECTION- 1	ANALYSIS PERIOD- 25 YEARS
BEGIN MP- 2	DISCOUNT RATE- 6 %
END MP- 3	NUMBER OF ALTERNATIVES- 3

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 1

INITIAL REHABILITATION COST	$300,000.00
TRAFFIC CONTROL COST	$30,000.00
USER COST	$6,518.44

MAINTENANCE REQUIRED IN YEAR 5
OVERLAY (NEW OR RECYCLED)(.75 in.)
COST OF REQUIRED MAINTENANCE $19,548.78

MAINTENANCE REQUIRED IN YEAR 12
MILLING(2 in.)
OVERLAY (NEW OR RECYCLED)(3 in.)
COST OF REQUIRED MAINTENANCE $97,101.24

MAINTENANCE REQUIRED IN YEAR 20
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $39,469.72

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 1 $402,985.20

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 2

INITIAL REHABILITATION COST	$320,000.00
TRAFFIC CONTROL COST	$30,000.00
USER COST	$6,518.44

MAINTENANCE REQUIRED IN YEAR 8
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $39,009.85

MAINTENANCE REQUIRED IN YEAR 15
PREMIX PATCHING(5 %)
OVERLAY (NEW OR RECYCLED)(2 in.)
COST OF REQUIRED MAINTENANCE $56,722.17

MAINTENANCE REQUIRED IN YEAR 23
OVERLAY (NEW OR RECYCLED)(1.5 in.)
COST OF REQUIRED MAINTENANCE $39,633.29

TOTAL PRESENT VALUE COST FOR ALTERNATIVE 2 $399,651.10

NOTE: ALL COSTS ARE GIVEN PER MILE

ALTERNATIVE 3
INITIAL REHABILITATION COST $280,000.00
TRAFFIC CONTROL COST $20,000.00
USER COST $6,518.44

MAINTENANCE REQUIRED IN YEAR 4
OVERLAY (NEW OR RECYCLED)(3 in.)
COST OF REQUIRED MAINTENANCE $76,814.78

MAINTENANCE REQUIRED IN YEAR 12
MILLING(3 in.)
OVERLAY (NEW OR RECYCLED)(4 in.)
COST OF REQUIRED MAINTENANCE $128,837.20

MAINTENANCE REQUIRED IN YEAR 19
OVERLAY (NEW OR RECYCLED)(2 in.)
COST OF REQUIRED MAINTENANCE $51,893.74

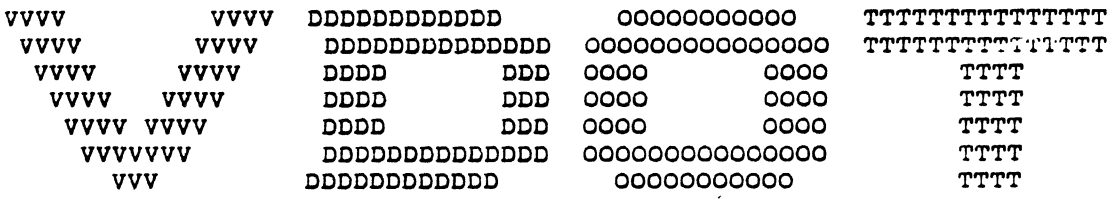
TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3 $448,542.80

INITIAL COSTS IN ASCENDING ORDER
ALTERNATIVE 3 $280,000.00
ALTERNATIVE 1 $300,000.00
ALTERNATIVE 2 $320,000.00

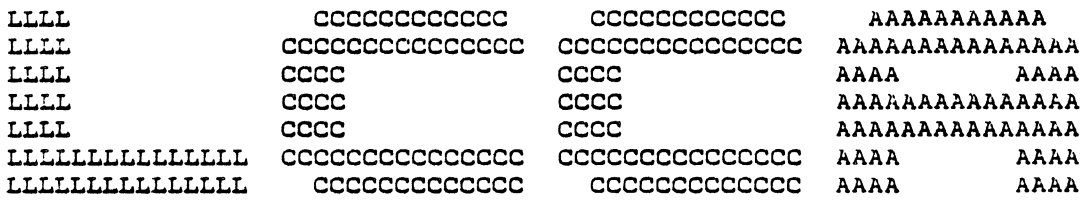
PRESENT VALUE COSTS IN ASCENDING ORDER
ALTERNATIVE 2 $399,651.10
ALTERNATIVE 1 $402,985.20
ALTERNATIVE 3 $448,542.80

APPENDIX D

SAMPLE PROGRAM SCREENS



VIRGINIA DEPARTMENT OF TRANSPORTATION



LIFE CYCLE COST ANALYSIS

VIRGINIA DEPARTMENT OF TRANSPORTATION
LIFE CYCLE COST ANALYSIS
10-27-1988

COUNTY NUMBER ? 2

ROUTE NUMBER ? 29

DIRECTION (1,2,3,4)? 1

BEGIN MP? 2

END MP? 3

AVERAGE DAILY TRAFFIC? 10000

SPEED LIMIT(MPH)-DEFAULT=55 MPH?

ANALYSIS PERIOD(YRS)-DEFAULT=25 YEARS?

DISCOUNT RATE(%)-DEFAULT=6%?

NUMBER OF ALTERNATIVES? 3

THE FOLLOWING TABLE LISTS THE UNIT COSTS USED IN THIS PROGRAM

GRINDING (sq.yd.),	$3.25
GROOVING (sq.yd.)	$9.00
TRANSVERSE JOINT SEALING (ft.)	$1.50
LONGITUDINAL JOINT SEALING (ft.)	$1.00
MILLING (sq.yd.)	$0.60
OVERLAY-PLANT MIX (ton)	$30.00
FULL DEPTH PATCHING (sq.yd.)	$130.00
PARTIAL DEPTH PATCHING (sq.yd.)	$120.00
SINGLE SURFACE TREATMENT (sq.yd.)	$0.40
SLURRY SEAL (sq.yd.)	$0.65
PREMIX PATCHING (sq. yd.)	$5.00

DO YOU WISH TO CHANGE ANY OF THESE COSTS (Y or N)? N

```
ALTERNATIVE  1

INITIAL REHABILITATION COST PER MILE ($) ? 300000

TRAFFIC CONTROL COST PER MILE ($) ? 30000

PREDICTED LIFE BEYOND ANALYSIS PERIOD(yrs)? 3

CHOOSE APPROPRIATE DETOUR MODEL FROM BELOW

SEE USER'S GUIDE FOR ILLUSTRATIONS

MODEL ONE IS A TWO LANE ROAD, ONE LANE IN EACH DIRECTION.
CONSTRUCTION IS IN ONE LANE AND TRAFFIC IS DIVERTED ON TO SHOULDER.

MODEL TWO IS A TWO LANE ROAD, ONE LANE IN EACH DIRECTION.
CONSTRUCTION IS IN ONE LANE AND TRAFFIC ALTERNATES THROUGH
THE REMAINING LANE.

MODEL THREE IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN ONE LANE.
TRAFFIC IS DETOURED INTO ADJACENT LANE.

MODEL FOUR IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN TWO
ADJACENT LANES. TRAFFIC IS DETOURED ACROSS MEDIAN, INTO ONE LANE
OF OPPOSITE DIRECTION.

MODEL FIVE IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN TWO
ADJACENT LANES. TRAFFIC IS DETOURED AROUND CONSTRUCTION ON ANOTHER ROAD.

APPROPRIATE DETOUR MODEL? 3

SPEED LIMIT THROUGH WORK ZONE? 35

LENGTH OF TYPICAL LANE CLOSURE (MILES)? 1

NUMBER OF HOURS DETOUR IS IN EFFECT (TOTAL)? 200

LAST MAINTENANCE WAS PERFORMED IN YEAR  0
IS ADDITIONAL MAINTENANCE REQUIRED (Y OR N) ? Y

YEAR MAINTENANCE REQUIRED? 5

NUMBER OF LANES BEING REPAIRED? 2
```

1200

```
CHOOSE APPROPRIATE MAINTENANCE ACTION FROM LIST BELOW (TABLE 1 OF USER'S GUIDE)

            MAINTENANCE ACTIONS

        CODE #          ACTION
        ------          ------
          1         GRINDING-PC
          2         GROOVING-PCC
          3         TRANSVERSE JOINT SEALING
          4         LONGITUDINAL JOINT SEALING
          5         MILLING-AC
          6         OVERLAY w/ AC FABRIC     \ NEW OR
          7         OVERLAY                  / RECYCLED
          8         PATCHING-PCC (FULL DEPTH)
          9         PATCHING-PCC (PARTIAL DEPTH)
         10         SINGLE SUFACE TREATMENT
         11         SLURRY SEAL
         12         PREMIX PATCHING
         13         OTHER

HOW MANY ACTIONS ARE NECESSARY? 1

ENTER APPROPRIATE CODE NUMBER(s).  HIT ENTER AFTER EACH.
? 7
OVERLAY (NEW OR RECYCLED)
DEPTH OF OVERLAY? .75

TRAFFIC CONTROL COST ($)? 2000
```

SEE USER'S GUIDE FOR ILLUSTRATIONS
MODEL ONE IS A TWO LANE ROAD, ONE LANE IN EACH DIRECTION.
CONSTRUCTION IS IN ONE LANE AND TRAFFIC IS DIVERTED ON TO SHOULDER.

MODEL TWO IS A TWO LANE ROAD, ONE LANE IN EACH DIRECTION.
CONSTRUCTION IS IN ONE LANE AND TRAFFIC ALTERNATES THROUGH
THE REMAINING LANE.

MODEL THREE IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN ONE LANE.
TRAFFIC IS DETOURED INTO ADJACENT LANE.

MODEL FOUR IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN TWO
ADJACENT LANES. TRAFFIC IS DETOURED ACROSS MEDIAN, INTO ONE LANE
OF OPPOSITE DIRECTION.

MODEL FIVE IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN TWO
ADJACENT LANES. TRAFFIC IS DETOURED AROUND CONSTRUCTION ON ANOTHER ROAD.

APPROPRIATE DETOUR MODEL? 3

INFORMATION FOR MAINTENANCE PERFORMED IN YEAR 5

SPEED LIMIT THROUGH WORK ZONE? 35

LENGTH OF TYPICAL LANE CLOSURE (MILES)? 1

NUMBER OF HOURS DETOUR IS IN EFFECT? 12

LAST MAINTENANCE WAS PERFORMED IN YEAR 5
IS ADDITIONAL MAINTENANCE REQUIRED (Y OR N) ? Y

YEAR MAINTENANCE REQUIRED? 12

NUMBER OF LANES BEING REPAIRED? 2

APPENDIX E

PROGRAM LISTING

```
10 'LIFE CYCLE COST ANALYSIS (LCCA.BAS)
20 CLS
30 CLOSE #1
40 COLOR 9
50 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
60 PRINT TAB(5)"VVVV"TAB(18)"VVVV"TAB(24)"DDDDDDDDDDD"TAB(43)
   "00000000000"TAB(58)"TTTTTTTTTTTTTTT"
70 PRINT TAB(6)"VVVV"TAB(17)"VVVV"TAB(25)"DDDDDDDDDDDDD"TAB(41)
   "000000000000000"TAB(58)"TTTTTTTTTTTTTTT"
80 PRINT TAB(7)"VVVV"TAB(16)"VVVV"TAB(25)"DDDD"TAB(36)"DDD"TAB(41)
   "0000"TAB(52)"0000"TAB(64)"TTTT"
90 PRINT TAB(8)"VVVV"TAB(15)"VVVV"TAB(25)"DDDD"TAB(36)"DDD"TAB(41)
   "0000"TAB(52)"0000"TAB(64)"TTTT"
100 PRINT TAB(9)"VVVV"TAB(14)"VVVV"TAB(25)"DDDD"TAB(36)"DDD"TAB(41)
    "0000"TAB(52)"0000"TAB(64)"TTTT"
110 PRINT TAB(10)"VVVVVVV"TAB(25)"DDDDDDDDDDDDD"TAB(41)"000000000000000"
    TAB(64)"TTTT"
120 PRINT TAB(12)"VVV"TAB(24)"DDDDDDDDDDD"TAB(43)"00000000000"TAB(64)
    "TTTT"
130 PRINT:PRINT
140 COLOR 14
150 PRINT TAB(20)"VIRGINIA DEPARTMENT OF TRANSPORTATION"
160 FOR GG=1 TO 2000
170 NEXT GG
180 CLS
190 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
200 COLOR 9
210 PRINT TAB(5)"LLLL"TAB(24)"CCCCCCCCCCCC"TAB(41)"CCCCCCCCCCCC"TAB(58)
    "AAAAAAAAAAA"
220 PRINT TAB(5)"LLLL"TAB(22)"CCCCCCCCCCCCCCC"TAB(39)"CCCCCCCCCCCCCCC"
    TAB(56)"AAAAAAAAAAAAAAA"
230 PRINT TAB(5)"LLLL"TAB(22)"CCCC"TAB(39)"CCCC"TAB(56)"AAAA"TAB(67)
    "AAAA"
240 PRINT TAB(5)"LLLL"TAB(22)"CCCC"TAB(39)"CCCC"TAB(56)"AAAAAAAAAAAAAAA"
250 PRINT TAB(5)"LLLL"TAB(22)"CCCC"TAB(39)"CCCC"TAB(56)"AAAAAAAAAAAAAAA"
260 PRINT TAB(5)"LLLLLLLLLLLLLLL"TAB(22)"CCCCCCCCCCCCCCC"TAB(39)
    "CCCCCCCCCCCCCCC"TAB(56)"AAAA"TAB(67)"AAAA"
270 PRINT TAB(5)"LLLLLLLLLLLLLLL"TAB(24)"CCCCCCCCCCCC"TAB(41)
    "CCCCCCCCCCCCC"TAB(56)"AAAA"TAB(67)"AAAA"
280 PRINT:PRINT
290 COLOR 14
300 PRINT TAB(26)"LIFE CYCLE COST ANALYSIS"
310 XX=1
320 FOR XX=1 TO 2000:NEXT XX
330 CLS
340 COLOR 13
350 OPTION BASE 1
360 CLOSE #1
```

```
370 DIM ICC(10,2),TCC(10),DM(10),UC(10),RCC(10),EL(10),DC(10),MY(10),
    MR(10,25),IDT(30),RS(25),MAC(10),MDS$(10,25,9),PPA(9),MM(10,25,9),
    APR(9)
380 DIM MT$(10,25,10),MC(10,25),MTC(10,25),AM(10,25),MUC(10,25),
    PV(10,25),SV(10),P(10,2),C(10,25),HIE(10),TLC(10),LBR(25),
    NA(10,25),BB(10),MSC(10),DTM(10),DOV(10),PAP(10),LCC(10),NHE(25)
390 CLS
400 COLOR 11
410 PRINT TAB(24)"VIRGINIA DEPARTMENT OF TRANSPORTATION"
420 PRINT TAB(30)"LIFE CYCLE COST ANALYSIS"
430 PRINT TAB(35)DATE$
440 PRINT:PRINT
450 COLOR 13
460 INPUT"COUNTY NUMBER ";CN
470 PRINT
480 INPUT "ROUTE NUMBER ";RN
490 PRINT
500 INPUT "DIRECTION (1,2,3,4)";D
510 PRINT
520 INPUT "BEGIN MP";BMP
530 IF BMP=0 THEN GOTO 520
540 PRINT
550 INPUT "END MP";EMP
560 IF EMP=0 THEN GOTO 550
570 SL=ABS(EMP-BMP)
580 PRINT
590 INPUT "AVERAGE DAILY TRAFFIC";ADT
600 IF ADT=0 THEN GOTO 590
610 PRINT
620 INPUT "SPEED LIMIT(MPH)-DEFAULT=55 MPH";SPL
630 IF SPL=0 THEN SPL=55
640 PRINT
650 INPUT "ANALYSIS PERIOD(YRS)-DEFAULT=25 YEARS";AP
660 IF AP=0 THEN AP=25
670 PRINT
680 INPUT "DISCOUNT RATE(%)-DEFAULT=6%";DR
690 IF DR=0 THEN DR=6
700 R=DR/100
710 PRINT
720 INPUT "NUMBER OF ALTERNATIVES";ALT
730 IF ALT=0 THEN GOTO 720
740  IDT(1)=ADT
750 PVT=0:K=0
760 AA=AP+1
770 FOR P=2 TO AA
780 RR=P-1
790  IDT(P)=IDT(RR)+(IDT(RR)*.05)
800  NEXT P
```

```
810 CLS
820 OPEN "COSTS" FOR INPUT AS #1
830 PRINT "THE FOLLOWING TABLE LISTS THE UNIT COSTS USED IN THIS PROGRAM"
840 PRINT
850 COLOR 11
860 INPUT #1,CGI,CGO,TJS,LJS,MIL,PM,PFD,PPD,SST,SLS,PMP
870 PRINT "GRINDING (sq.yd.)" TAB(35) USING"$$###.##";CGI
880 PRINT "GROOVING (sq.yd.)" TAB(35) USING"$$###.##";CGO
890 PRINT "TRANSVERSE JOINT SEALING (ft.)" TAB(35) USING"$$###.##";TJS
900 PRINT "LONGITUDINAL JOINT SEALING (ft.)" TAB(35) USING"$$###.##";LJS
910 PRINT "MILLING (sq.yd.)" TAB(35) USING"$$###.##";MIL
920 PRINT "OVERLAY-PLANT MIX (ton)" TAB(35) USING"$$###.##";PM
930 PRINT "FULL DEPTH PATCHING (sq.yd.)" TAB(35) USING"$$###.##";PFD
940 PRINT "PARTIAL DEPTH PATCHING (sq.yd.)" TAB(35) USING"$$###.##";PPD
950 PRINT "SINGLE SURFACE TREATMENT (sq.yd.)" TAB(35) USING"$$###.##";SST
960 PRINT "SLURRY SEAL (sq.yd.)" TAB(35) USING"$$###.##";SLS
970 PRINT "PREMIX PATCHING (sq. yd.)" TAB(35) USING "$$###.##";PMP
980 CLOSE #1
990 COLOR 13
1000 PRINT
1010 INPUT "DO YOU WISH TO CHANGE ANY OF THESE COSTS (Y or N)";CTC$
1020 IF CTC$="N" OR CTC$="n" THEN GOTO 1460
1030 OPEN "COSTS" FOR OUTPUT AS #1
1040 INPUT "HOW MANY COSTS WOULD YOU LIKE TO CHANGE(1-9)";CCC
1050 PRINT "ENTER CODE NUMBER(s) FOR EACH COST TO BE CHANGED. HIT ENTER
     AFTER EACH."
1060 IF CCC=1 THEN GOTO 1110
1070 FOR Z=1 TO CCC
1080 INPUT MAC(Z)
1090 NEXT Z
1100 GOTO 1130
1110 INPUT MAC(1)
1120 EE=1
1130 FOR EE=1 TO CCC
1140 IF MAC(EE)=1 GOTO 1240
1150 IF MAC(EE)=2 GOTO 1260
1160 IF MAC(EE)=3 GOTO 1280
1170 IF MAC(EE)=4 GOTO 1300
1180 IF MAC(EE)=5 GOTO 1320
1190 IF MAC(EE)=6 GOTO 1340
1200 IF MAC(EE)=7 GOTO 1360
1210 IF MAC(EE)=8 GOTO 1380
1220 IF MAC(EE)=9 GOTO 1400
1230 IF MAC(EE)=10 GOTO 1420
1240 INPUT "COST OF GRINDING (sq.yd.)";CGI
1250 GOTO 1430
1260 INPUT "COST OF GROOVING (sq.yd.)";CGO
1270 GOTO 1430
```

```
1280 INPUT "COST OF JOINT SEALING (ft.)";JS
1290 GOTO 1430
1300 INPUT "COST OF MILLING (sq.yd.)";MIL
1310 GOTO 1430
1320 INPUT "COST OF OVERLAY :PLANT MIX (ton)";PM
1330 GOTO 1430
1340 INPUT "COST OF FULL DEPTH PATCHING (sq.yd.)";PFD
1350 GOTO 1430
1360 INPUT "COST OF PARTIAL DEPTH PATCHING (sq.yd.)";PPD
1370 GOTO 1430
1380 INPUT "COST OF SINGLE SURFACE TREATMENT (sq.yd.)";SST
1390 GOTO 1430
1400 INPUT "COST OF SLURRY SEAL (sq.yd.)";SLS
1410 GOTO 1430
1420 INPUT "COST OF PREMIX PATCHING (sq. yd.)";PMP
1430 NEXT EE
1440 WRITE #1,CGI,CGO,TJS,LJS,MIL,PM,PFD,PPD,SST,SLS,PMP
1450 CLOSE #1
1460 OVL=PM*.0575
1470 FOR I=1 TO ALT
1480 PVT=0:K=1
1490 CLS
1500 PRINT "ALTERNATIVE "I
1510 PRINT
1520 INPUT "INITIAL REHABILITATION COST PER MILE ($) ";ICC(I,1)
1530 PRINT
1540 ICC(I,2)=I
1550 INPUT "TRAFFIC CONTROL COST PER MILE ($) ";TCC(I)
1560 RCC(I)=ICC(I,1)+TCC(I)
1570 PRINT
1580 INPUT "PREDICTED LIFE BEYOND ANALYSIS PERIOD(yrs)";EL(I)
1590 J=0
1600 CLS
1610 PRINT "CHOOSE APPROPRIATE DETOUR MODEL FROM BELOW"
1620 PRINT:PRINT"SEE USER'S GUIDE FOR ILLUSTRATIONS"
1630 FOR V=1 TO 1500:NEXT V
1640 PRINT "MODEL ONE IS A TWO LANE ROAD, ONE LANE IN EACH DIRECTION."
1650 PRINT "CONSTRUCTION IS IN ONE LANE AND TRAFFIC IS DIVERTED ON TO
     SHOULDER."
1660 PRINT:PRINT
1670 COLOR 11
1680 PRINT "MODEL TWO IS A TWO LANE ROAD, ONE LANE IN EACH DIRECTION."
1690 PRINT "CONSTRUCTION IS IN ONE LANE AND TRAFFIC ALTERNATES THROUGH"
1700 PRINT "THE REMAINING LANE."
1710 PRINT:PRINT
1720 COLOR 13
1730 PRINT "MODEL THREE IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN
     ONE LANE."
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1740 PRINT "TRAFFIC IS DETOURED INTO ADJACENT LANE."
1750 PRINT:PRINT
1760 COLOR 11
1770 PRINT "MODEL FOUR IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN
     TWO"
1780 PRINT "ADJACENT LANES. TRAFFIC IS DETOURED ACROSS MEDIAN, INTO ONE
     LANE"
1790 PRINT "OF OPPOSITE DIRECTION."
1800 PRINT:PRINT
1810 COLOR 13
1820 PRINT "MODEL FIVE IS A FOUR LANE DIVIDED ROAD WITH CONSTRUCTION IN
     TWO"
1830 PRINT "ADJACENT LANES. TRAFFIC IS DETOURED AROUND CONSTRUCTION ON
     ANOTHER ROAD."
1840 IF J=1 THEN 3590
1850 PRINT:PRINT:PRINT
1860 COLOR 11
1870 INPUT "APPROPRIATE DETOUR MODEL";DM(I)
1880 COLOR 13
1890 CLS
1900 INPUT "SPEED LIMIT THROUGH WORK ZONE";RSL(I)
1910 PRINT
1920 INPUT "LENGTH OF TYPICAL LANE CLOSURE (MILES)";TLC(I)
1930 PRINT
1940 INPUT "NUMBER OF HOURS DETOUR IS IN EFFECT (TOTAL)";HIE(I)
1950 IF DM(I)=1 THEN 2000
1960 IF DM(I)=2 THEN 2020
1970 IF DM(I)=3 THEN 2040
1980 IF DM(I)=4 THEN 2060
1990 IF DM(I)=5 THEN 2080
2000 UC(I)=((ADT)*.3137*TLC(I)*((1/RSL(I))-(1/SPL))*HIE(I))/SL
2010 GOTO 2100
2020 UC(I)=((ADT)*.6273*TLC(I)*((1/RSL(I))-(1/SPL))*HIE(I))/SL
2030 GOTO 2100
2040 UC(I)=((ADT)*.3137*TLC(I)*((1/RSL(I))-(1/SPL))*HIE(I))/SL
2050 GOTO 2100
2060 UC(I)=((ADT)*.6273*TLC(I)*((1/RSL(I))-(1/SPL))*HIE(I))/SL
2070 GOTO 2100
2080 INPUT "LENGTH OF DETOUR";DD
2090 UC(I)=(ADT*.3137*((DD/RSL(I))-(SL/SPL))*HIE(I))/SL
2100 CLS
2110 Q=0
2120 PRINT:PRINT
2125 PRINT "LAST MAINTENANCE WAS PERFORMED IN YEAR "MR(I,K)
2130 INPUT "IS ADDITIONAL MAINTENANCE REQUIRED (Y OR N) ";Q$
2140 IF Q$="N" OR Q$="n" THEN 3860
2150 PRINT:PRINT:PRINT
2160 K=K+1
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2170 INPUT "YEAR MAINTENANCE REQUIRED";MR(I,K)
2180  T=MR(I,K)+1
2190 PRINT
2200 INPUT "NUMBER OF LANES BEING REPAIRED";LBR(K)
2210 PRINT:PRINT
2220 OPEN "COSTS" FOR INPUT AS #1
2230 INPUT #1,CGI,CGO,TJS,LJS,MIL,PM,PFD,PPD,SST,SLS,PMP
2240 PRINT "CHOOSE APPROPRIATE MAINTENANCE ACTION FROM LIST BELOW (TABLE
     1 OF USER'S GUIDE)
2250 PRINT:PRINT
2255 COLOR 11
2260 PRINT TAB(15) "MAINTENANCE ACTIONS"
2270 PRINT
2280 PRINT TAB(10) "CODE #" TAB(25)"ACTION"
2285 PRINT TAB(10) "------"TAB(25)"------"
2290 PRINT TAB(10) "  1" TAB(20)"GRINDING-PC"
2300 PRINT TAB(10) "  2" TAB(20)"GROOVING-PCC"
2310 PRINT TAB(10) "  3" TAB(20)"TRANSVERSE JOINT SEALING"
2320 PRINT TAB(10) "  4" TAB(20)"LONGITUDINAL JOINT SEALING"
2330 PRINT TAB(10) "  5" TAB(20)"MILLING-AC"
2340 PRINT TAB(10) "  6" TAB(20)"OVERLAY w/ AC FABRIC"TAB(44)"\ NEW OR"
2350 PRINT TAB(10) "  7" TAB(20)"OVERLAY" TAB(44) "/ RECYCLED"
2360 PRINT TAB(10) "  8" TAB(20)"PATCHING-PCC (FULL DEPTH)"
2370 PRINT TAB(10) "  9" TAB(20)"PATCHING-PCC (PARTIAL DEPTH)"
2380 PRINT TAB(10) " 10" TAB(20)"SINGLE SUFACE TREATMENT"
2390 PRINT TAB(10) " 11" TAB(20)"SLURRY SEAL"
2400 PRINT TAB(10) " 12" TAB(20)"PREMIX PATCHING"
2410 PRINT TAB(10) " 13" TAB(20)"OTHER"
2415 COLOR 13
2420 PRINT
2430 INPUT "HOW MANY ACTIONS ARE NECESSARY";NA(I,K)
2440 PRINT
2450 PRINT "ENTER APPROPRIATE CODE NUMBER(s).  HIT ENTER AFTER EACH."
2460 IF NA(I,K)=1 THEN GOTO 2510
2470 FOR AA=1 TO NA(I,K)
2480 INPUT BB(AA)
2490 NEXT AA
2500 GOTO 2540
2510 INPUT BB(1)
2520 CC=1
2530 GOTO 2550
2540 FOR CC=1 TO NA(I,K)
2550 IF BB(CC)=1 THEN GOTO 2680
2560 IF BB(CC)=2 THEN GOTO 2730
2570 IF BB(CC)=3 THEN GOTO 2780
2580 IF BB(CC)=4 THEN GOTO 2850
2590 IF BB(CC)=5 THEN GOTO 2920
2600 IF BB(CC)=6 THEN GOTO 2990
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2610 IF BB(CC)=7 THEN GOTO 3060
2620 IF BB(CC)=8 THEN GOTO 3130
2630 IF BB(CC)=9 THEN GOTO 3200
2640 IF BB(CC)=10 THEN GOTO 3270
2650 IF BB(CC)=11 THEN GOTO 3320
2660 IF BB(CC)=12 THEN GOTO 3370
2670 IF BB(CC)=13 THEN GOTO 3440
2680 MT$(I,K,CC)="GRINDING"
2690 MM(I,K,CC)=0
2700 PRINT MT$(I,K,CC)
2710 MSC(CC)=((LBR(K)*12*5280)/9)*CGI
2720 GOTO 3470
2730 MT$(I,K,CC)="GROOVING"
2740 MM(I,K,CC)=0
2750 PRINT MT$(I,K,CC)
2760 MSC(CC)=((LBR(K)*12*5280)/9)*CGO
2770 GOTO 3470
2780 MT$(I,K,CC)="TRANSVERSE JOINT SEALING"
2785 MM(I,K,CC)=1
2790 PRINT MT$(I,K,CC)
2800 INPUT "LINEAR FEET PER MILE TO BE SEALED";SLF
2810 MM(I,K,CC)=SLF
2820 MDS$(I,K,CC)="ft."
2830 MSC(CC)=TJS*SLF
2840 GOTO 3470
2850 MT$(I,K,CC)="LONGITUDINAL JOINT SEALING"
2855 MM(I,K,CC)=1
2860 PRINT MT$(I,K,CC)
2870 INPUT "LINEAR FEET PER MILE TO BE SEALED";LFS
2880 MM(I,K,CC)=LFS
2890 MDS$(I,K,CC)="ft."
2900 MSC(CC)=LFS*LJS
2910 GOTO 3470
2920 MT$(I,K,CC)="MILLING"
2925 MM(I,K,CC)=1
2930 PRINT MT$(I,K,CC)
2940 INPUT "DEPTH TO BE MILLED (INCHES)";DTM(CC)
2950 MM(I,K,CC)=DTM(CC)
2960 MDS$(I,K,CC)="in."
2970 MSC(CC)=((LBR(K)*12*5280)/9)*MIL*DTM(CC)
2980 GOTO 3470
2990 MT$(I,K,CC)="OVERLAY WITH AC FABRIC"
2995 MM(I,K,CC)=1
3000 PRINT MT$(I,K,CC)
3010 INPUT "DEPTH OF OVERLAY";DOV(CC)
3020 MM(I,K,CC)=DOV(CC)
3030 MDS$(I,K,CC)="in."
3040 MSC(CC)=((LBR(K)*12*5280)/9)*(OVL+DOV(CC)*OVL)
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3050 GOTO 3470
3060 MT$(I,K,CC)="OVERLAY (NEW OR RECYCLED)"
3065 MM(I,K,CC)=1
3070 PRINT MT$(I,K,CC)
3080 INPUT "DEPTH OF OVERLAY";DOV(CC)
3090 MM(I,K,CC)=DOV(CC)
3100 MDS$(I,K,CC)="in."
3110 MSC(CC)=((LBR(K)*12*5280)/9)*DOV(CC)*OVL
3120 GOTO 3470
3130 MT$(I,K,CC)="FULL DEPTH PATCHING"
3135 MM(I,K,CC)=1
3140 PRINT MT$(I,K,CC)
3150 INPUT "PERCENTAGE OF TOTAL AREA REQUIRING PATCHING";PAP(CC)
3160 MM(I,K,CC)=PAP(CC)
3170 MDS$(I,K,CC)="%"
3180 MSC(CC)=((LBR(K)*12*5280)/9)*(PAP(CC)/100)*PFD
3190 GOTO 3470
3200 MT$(I,K,CC)="PARTIAL DEPTH PATCHING"
3205 MM(I,K,CC)=1
3210 PRINT MT$(I,K,CC)
3220 INPUT "PERCENTAGE OF TOTAL AREA REQUIRING PATCHING";PPA(CC)
3230 MM(I,K,CC)=PPA(CC)
3240 MDS$(I,K,CC)="%"
3250 MSC(CC)=((LBR(K)*12*5280)/9)*(PPA(CC)/100)*PPD
3260 GOTO 3470
3270 MT$(I,K,CC)="SINGLE SURFACE TREATMENT"
3280 MM(I,K,CC)=0
3290 PRINT MT$(I,K,CC)
3300 MSC(CC)=((LBR(K)*12*5280)/9)*SST
3310 GOTO 3470
3320 MT$(I,K,CC)="SLURRY SEAL"
3330 MM(I,K,CC)=0
3340 PRINT MT$(I,K,CC)
3350 MSC(CC)=((LBR(K)*12*5280)/9)*SLS
3360 GOTO 3470
3370 MT$(I,K,CC)="PREMIX PATCHING"
3375 MM(I,K,CC)=1
3380 PRINT MT$(I,K,CC)
3390 INPUT "PERCENTAGE OF TOTAL AREA REQUIRING PATCHING";APR(CC)
3400 MM(I,K,CC)=APR(CC)
3410 MDS$(I,K,CC)="%"
3420 MSC(CC)=((LBR(K)*12*5280)/9)*(APR(CC)/100)*PMP
3430 GOTO 3470
3440 INPUT "MAINTENANCE ACTIVITY";MT$(I,K,CC)
3450 MM(I,K,CC)=0
3460 INPUT "COST OF MAINTENANCE ACTIVITY (PER MILE)";MSC(CC)
3470 IF NA(I,K)=1 THEN GOTO 3530
3480 NEXT CC
```

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3490 FOR DD=1 TO NA(I,K)
3500 MC(I,K)=MC(I,K)+MSC(DD)
3510 NEXT DD
3520 GOTO 3540
3530 MC(I,K)=MSC(CC)
3540 PRINT
3550 CLOSE #1
3560 INPUT "TRAFFIC CONTROL COST ($)";MTC(I,K)
3570 J=1
3580 GOTO 1610
3590 PRINT
3600 INPUT "APPROPRIATE DETOUR MODEL";AM(I,K)
3610 CLS
3615 PRINT "INFORMATION FOR MAINTENANCE PERFORMED IN YEAR "MR(I,K)
3616 PRINT:PRINT
3620 INPUT "SPEED LIMIT THROUGH WORK ZONE";RS(K)
3630 PRINT
3640 INPUT "LENGTH OF TYPICAL LANE CLOSURE (MILES)";LCC(K)
3650 PRINT
3660 INPUT "NUMBER OF HOURS DETOUR IS IN EFFECT";NHE(K)
3670 IF AM(I,K)=1 THEN 3720
3680 IF AM(I,K)=2 THEN 3740
3690 IF AM(I,K)=3 THEN 3760
3700 IF AM(I,K)=4 THEN 3780
3710 IF AM(I,K)=5 THEN 3800
3720 C(I,K)=(IDT(T)*.3137*LCC(K)*((1/RS(K))-(1/SPL))*NHE(K))/SL
3730 GOTO 3820
3740 C(I,K)=(IDT(T)*.6273*LCC(K)*((1/RS(K))-(1/SPL))*NHE(K))/SL
3750 GOTO 3820
3760 C(I,K)=(IDT(T)*.3137*LCC(K)*((1/RS(K))-(1/SPL))*NHE(K))/SL
3770 GOTO 3820
3780 C(I,K)=(IDT(T)*.6273*LCC(K)*((1/RS(K))-(1/SPL))*NHE(K))/SL
3790 GOTO 3820
3800 INPUT "LENGTH OF DETOUR";DD
3810 C(I,K)=(IDT(T)*.3137*(DD/RS(K)-SL/SPL)*NHE(K))/SL
3820 TMC(I,K)=C(I,K)+MTC(I,K)+MC(I,K)
3830 PV(I,K)=TMC(I,K)*(1/(1+R)^MR(I,K))
3840 PVT=PVT+PV(I,K)
3850 GOTO 2120
3860 SV(I)=(((EL(I)/AP)*RCC(I))*(1/(1+R)^(AP+1)))/SL
3870 P(I,1)=PVT+ICC(I,1)+TCC(I)+UC(I)-SV(I)
3880 P(I,2)=I
3890 A(I)=K
3900 NEXT I
3910 CLS
3920 LPRINT TAB(24)"VIRGINIA DEPARTMENT OF TRANSPORTATION"
3930 LPRINT:LPRINT TAB(30)"LIFE CYCLE COST ANALYSIS"
3940 LPRINT:LPRINT:LPRINT
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3950 LPRINT "COUNTY NUMBER-"CN TAB(30) "AVERAGE DAILY TRAFFIC-"ADT
3960 LPRINT "ROUTE NUMBER-"RN TAB(30) "SPEED LIMIT-"SPL" MPH"
3970 LPRINT "DIRECTION-"D TAB(30) "ANALYSIS PERIOD-"AP" YEARS"
3980 LPRINT "BEGIN MP-"BMP TAB(30) "DISCOUNT RATE-"DR"%"
3990 LPRINT "END MP-"EMP TAB(30) "NUMBER OF ALTERNATIVES-"ALT
4000 FOR I=1 TO ALT
4010 LPRINT:LPRINT
4020 LPRINT"***NOTE: ALL COSTS ARE GIVEN PER MILE***"
4030 LPRINT
4040 LPRINT "ALTERNATIVE "I
4050 LPRINT "INITIAL REHABILITATION COST" TAB(30) USING "$$##########,
     .##";ICC(I,1)
4060 LPRINT "TRAFFIC CONTROL COST" TAB(30) USING "$$##########,.##";TCC(I)
4070 LPRINT "USER COST" TAB(30) USING "$$##########,.##";UC(I)
4080 FOR K=2 TO A(I)
4090 LPRINT
4100 LPRINT "MAINTENANCE REQUIRED IN YEAR "MR(I,K)
4110 IF NA(I,K)=1 THEN GOTO 4190
4120 FOR XX=1 TO NA(I,K)
4130 IF MM(I,K,XX)=0 GOTO 4160
4140 LPRINT MT$(I,K,XX) "("MM(I,K,XX) MDS$(I,K,XX)")"
4150 GOTO 4170
4160 LPRINT MT$(I,K,XX)
4170 NEXT XX
4180 GOTO 4230
4190 IF MM(I,K,1)=0 GOTO 4220
4200 LPRINT MT$(I,K,1) "("MM(I,K,1) MDS$(I,K,1)")"
4210 GOTO 4230
4220 LPRINT MT$(I,K,1)
4230 LPRINT "COST OF REQUIRED MAINTENANCE    ";
4240 LPRINT USING "$$##########,.##";TMC(I,K)
4250 NEXT K
4260 LPRINT:LPRINT
4270 LPRINT "TOTAL PRESENT VALUE COST FOR ALTERNATIVE "I "    ";
4280 LPRINT USING "$$##########,.##";P(I,1)
4290 NEXT I
4300 LPRINT:LPRINT
4310 X=ALT-1
4320 U=0:B=0
4330 FOR I=1 TO X
4340 B=I
4350 B=B+1
4360 IF ICC(I,1)<ICC(B,1) THEN 4440
4370 U=1
4380 T1=ICC(B,1)
4390 T2=ICC(B,2)
4400 ICC(B,1)=ICC(I,1)
4410 ICC(B,2)=ICC(I,2)
```

```
4420 ICC(I,1)=T1
4430 ICC(I,2)=T2
4440 IF B<ALT THEN NEXT I
4450 IF U<>0 THEN 4320
4460 LPRINT "INITIAL COSTS IN ASCENDING ORDER"
4470 FOR I=1 TO ALT
4480 LPRINT "ALTERNATIVE ";ICC(I,2)"     ";
4490 LPRINT USING "$$##########,.##";ICC(I,1)
4500 NEXT I
4510 LPRINT:LPRINT
4520 X=ALT-1
4530 U=0:B=0
4540 FOR I=1 TO X
4550 B=I
4560 B=B+1
4570 IF P(I,1)<P(B,1) THEN 4650
4580 U=1
4590 T1=P(B,1)
4600 T2=P(B,2)
4610 P(B,1)=P(I,1)
4620 P(B,2)=P(I,2)
4630 P(I,1)=T1
4640 P(I,2)=T2
4650 IF B<ALT THEN NEXT I
4660 IF U<>0 THEN 4530
4670 LPRINT "PRESENT VALUE COSTS IN ASCENDING ORDER"
4680 FOR I=1 TO ALT
4690 LPRINT "ALTERNATIVE ";P(I,2)"      ";
4700 LPRINT USING "$$##########,.##";P(I,1)
4710 NEXT I
4720 END
```