MINNESOTA DEPARTMENT OF TRANSPORTATION

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A CRITICAL REVIEW OF
THE PAVEMENT SELECTION PROCESS

MINNESOTA DEPARTMENT OF TRANSPORTATION

Technical Support Services Division

Office of Materials, Research & Standards

A CRITICAL REVIEW OF THE PAVEMENT SELECTION PROCESS

Prepared

by the

Research and Standards Section

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PURPOSE

Ideally, the type of pavement chosen for highway construction projects is the product of an analysis resulting in the most favorable combination of economic and engineering factors expressed in terms of the lowest annual cost per mile of road. Circumstances make the analysis somewhat less than ideal because inherent in the procedure is the need to make assumptions about future maintenance and costs in order to compare alternatives over equal periods of time. This report is a critical review of the pavement selection process as practiced by the Minnesota Department of Transportation. The study was conducted by the Research and Standards Section in response to an assignment made on June 23, 1975 by the Director of Materials, Research and Standards Office who also serves as chairman of the Pavement Selection Committee. The report presents a resume' of current practice together with analysis and recommendations for improvements in the process.

BACKGROUND

The Department has used a formal pavement selection procedure since 1959. The policy and procedures applied are described in the Department Directives Manual, Directive 2-013, the latest revision dated October, 1977 appended as Exhibit I. Briefly, the procedure involves six progressive steps with the offices involved identified corresponding to the Mn/DOT organizational structure:

- A request by the district director together with supporting project data covering location, description, traffic, soils and material sources. (See Exhibit II)

- Design recommendations for alternate pavement types from the Materials Engineering Section.

- Detailed cost estimates for alternate pavement types by the Estimating Unit, Design Section, Office of Design Services.

- Computation of comparative annual road costs by the Estimating Unit and checked by the Research and Standards Section.

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- Computation of comparative annual road costs by the Estimating Unit and checked by the Research and Standards Section.

- A pavement-type determination made by the Pavement Selection Committee.

- Final approval of the selection by the Assistant Commissioner for Technical Support Services, Assistant Commissioner for Field Operations and the Deputy Commissioner of Operations.

Since its inception, the procedure has applied only to new construction projects of 9-ton axle load design, comparing, among other factors, the annual cost per mile of structurally-equivalent rigid and flexible pavement designs inclusive of the base, surfacing and shoulder components. (The term "structurally-equivalent" is a convenience term indicating comparable design for traffic loading rather than reflecting the structural behavior of the two types, which is dissimilar.) Originally, comparative analysis was limited to two alternate standard designs: concrete and bituminous with aggregate base. When full-depth bituminous pavement was accepted as a standard in 1970, it became an alternative for flexible design and was included in the pavement selection procedure. Thus, each project analysis involves a computation of annual road cost per mile for one rigid type and two flexible types of pavement. Other changes in policy have been minor, affecting only the length of time a decision remains valid, as necessitated by recent materials cost fluctuations and the stringency of the final design schedule. Most recently the increase to 10-ton legal load limits for parts of the trunk highway system has necessitated a corresponding increase in pavement design loadings. In addition to the cost study, the policy directive allows for the consideration of judgmental factors other than economic that could influence the final result. At the time that a pavement selection request is received from the district director, associations of the pavement industry are notified of the pending analysis and are invited to provide supplemental information about the relative availability of suitable materials.

ANNUAL ROAD COST MODEL

The formula used in computing annual road cost was developed by C.B. Breed (1) and published by the Highway Research Board in 1934. This relationship, with minor modifications, was adopted by the Department as its basis for computing annual costs and is similar to other formulas applied by highway departments in analyzing the project-by-project construction and performance economics of alternate pavement types. The annual road cost model as used by the Department is expressed by the equation:

$$C = \frac{A-S}{n} + \left(\frac{A+S}{2}\right)r + B + \frac{E}{n}$$

Where:

C = annual road cost

A = original capital investment or first cost

S = salvage value of pavement at end of n years

n = years of service life

r = rate of interest

B = annual routine surface maintenance cost

E = cost of special surface maintenance

Some of the foregoing factors, as applied, have carried certain fixed values since adoption of the annual road cost formula. The salvage value, S, after "n" years of service life has been assumed at 40% of the first cost for both rigid and flexible types of pavement. The interest rate, r, has been assumed at 2.5%. Both types of pavement were estimated to have a service life, n, of 35 years with the exception of intervening overlays required for the flexible design as expressed in the "E" factor. Values for "B", routine maintenance costs, were developed by monitoring costs of 27 selected highway projects with the intent of maintaining a 10-year moving average. The "E" factor includes special maintenance activities performed periodically as necessary to keep the pavement surface and shoulders serviceable for the service life period. This includes the estimated cost of resurfacing flexible pavements at the 12-year and 24-year age points using 3/4-inch, high-type bituminous overlays. Using the foregoing criteria, a typical example of a completed pavement selection package is appended as Exhibit III.

COST ANALYSIS INPUT FACTORS

A valid road cost comparison should attempt to relate all increments of cost for alternate designs, assuming equal traffic service and service life. Somewhat oversimplified, this would basically include purchase of rights of way, initial construction cost, maintenance expense, future supplemental work, engineering and overhead required to keep the road serviceable for a given number of years.

For purposes of comparison, the unit of measurement adopted for road life economic studies by those who have treated the subject is the average annual road cost per mile. As defined by Agg(2), "The annual cost of a road . . . may be expressed as the total yearly expenditure that will construct, replace, and maintain in perpetuity in standard serviceable condition any existing road under existing traffic and climatic conditions."

Also, for simplification, it has become the practice in pavement selection procedure to consider only those costs associated with the base, surfacing and shoulder elements. Right of way costs, grading, and appurtenances are considered non-influencing as far as the pavement selection procedure is concerned. Some may contend with justification that grading is an influencing cost factor for at least two reasons, one being the strategic management of subgrade materials which could influence the thickness of base and surface courses and the other being a subgrade elevation differential to accommodate base and surface courses, particularly the differential between aggregate base and bituminous base. For the latter the designer has the freedom to adjust the balance of materials and possibly negate any undue influence, but the former poses an influence with a great deal of variability and one which cannot be adequately evaluated at a time during project development when a pavement-type selection must be made. Thus, it has become practice to neglect any influence of grading characteristics in the cost comparison study.

Baldock (3) lists the following factors as necessary inputs to the annual-cost-of-highways problem:

- First cost
- Maintenance cost
- Operation cost
- Administration and overhead
- Resurfacing cost
- Salvage value
- Interest rate
- Analysis life or period

With the exception of operation cost and administration and overhead, the above factors have been used with some modification in the Department's pavement selection procedure. Baldock has made the list all-inclusive to serve purposes in addition to pavement selection. Because of the importance of the input factors to the analysis and the need for some justification and rationalization as to their inclusion and application, they are treated separately under headings in the paragraphs that follow.

First Cost

For reasons already stated, the Department's practice for considering initial costs in pavement selection is limited to the base, surfacing and shoulder elements. Important to the analysis, however, is that these elements be expressed in standard designs officially adopted by the Department. Because of tentative technological advancements and experimentation, design changes are often made for one type of pavement or the other in the interest of seeking improvement in performance. Such changes, prior to full acceptance and adoption as standard, should not be considered in pavement selection analysis. If any additional initial costs are incurred for such experimentation, they should be chargeable to research and development. First costs should be predicated on the basis of adequate design data, design recommendations and detailed cost estimates as current as feasible with respect to final design constraints and project letting schedules.

Maintenance Cost

The average annual routine surface maintenance cost per mile of road should reflect actual cost experience with the two major types of pavement. Unfortunately, maintenance cost records are not all that detailed, and values that can be fully substantiated are rare. A survey of practices in other states (Exhibit IV) indicates an average routine surface maintenance cost of $352 per mile for 2-lane rural roads of rigid design and $594 per mile for flexible. Values from nine states ranged between $108 and $566 for rigid to between $200 and $900 for flexible, the latter averaged for eight states. These costs are not completely current and therefore not fully reflective of probable present costs, considering inflationary effects.

Minnesota has some limited average annual surface maintenance costs data, inclusive of shoulders, which was collected during the 10-year period prior to 1973. For rigid pavements these costs averaged $64 per mile for 2-lane, $298 per mile for 4-lane-divided. Comparable costs for flexible pavements were $168 and $223 respectively.

A study by Moyer and Lampe (4) cites average annual routine surface maintenance costs of 2-lane pavements in California as $320 per mile for rigid and $450 for flexible based on comparable 26-year analysis periods. Again, these data are well outdated and do not reflect current costs.

For lack of more specific data, the best that can be surmised from the foregoing information is that routine surface maintenance costs are somewhat greater for flexible pavements than for rigid. Minnesota data while showing an advantage for 2-lane rigid indicates a lower cost for 4-lane flexible, the latter being a departure from data furnished by other states.

Differential surface maintenance costs appear to be small factors in the computation of annual road costs compared to first costs and, therefore, have a small corresponding effect on the end result. The limited data on the relative surface maintenance costs is inconclusive except that the records cited seem to indicate a somewhat higher annual maintenance for flexible pavements. Mn/DOT is currently developing a computerized cost-accounting system. Until such time as cost-accounting data are available, it seems more prudent to ignore routine maintenance costs in the economic analysis process. Thus, pending availability of actual cost data, routine surface maintenance cost would not be an input factor in the annual cost relationship for pavement selection.

Operation Costs

Operation costs cover the cost of services to the road user, such services being traffic controls in the form of signs, signals and markings, snow and ice control, policing, etc. While these costs are important in the context of determining overall annual road costs, they are not thought to be sufficiently different for each type of pavement to have an influencing effect on an economic analysis for pavement selection. In any event, records are not available in a form in which differences could be distinquished. Therefore, for the purpose of pavement-type selection operation costs are ignored.

Administration and Overhead

The term "administration and overhead" as conceived by Baldock includes engineering which is normally a direct cost that can be charged to design and construction technical activites. Administration and overhead, exclusive of engineering, are indirect costs associated with the detailed support activities required to process projects from inception to completion. Likewise, continuous maintenance incurs costs chargeable to administration and overhead, all of which reflect on annual road costs.

The indirect costs for project support activities, other than engineering, are normally expressed as a fixed percentage derived from gross operational experience. Likewise, engineering costs can be similarly established as an overall percentage. Yet such percentages are generally not applicable to individual project analysis where alternate designs are being compared. This is because administration and overhead, inclusive of engineering and expressed as a percentage, tends to vary inversely with project costs. For instance, five rigid pavement projects examined ranged in first cost from 1.8 to 5.1 million dollars while engineering cost ranged correspondingly from 7.3 to 1.9 percent. Similarily, three flexible pavement projects, though smaller, varied from 0.68 to 0.98 million dollars in construction cost and 8.1 to 6.8 percent in engineering cost. This information tallies, at least trend-wise, with guidance curves used in establishing consulting engineer fees for public works projects where the rate decreases as the cost increases.

If engineering costs were to be included in a comparative pavement selection analysis, the data should be carefully documented for a series of projects that could define the inverse curve relationship for a full range of project construction costs. This would mean cost accounting monitoring of projects through the design and construction phases to secure the necessary data. With time the Financial Information Resources Management System (FIRMS) now under development by Mn/DOT should fulfill this need. Meanwhile, even though administration and overhead constitute a valid increment of annual road cost, it is fairer to conclude, until more specific information is available, that such costs in comparing pavement alternatives are essentially offsetting and can be ignored. A similar rational might be reasoned for omitting administration and overhead from the cost of future resurfacing work as covered in the ensuing paragraphs.

Resurfacing Cost

Resurfacing cost constitutes those expenditures, other than routine surface maintenance, for extending service life to comparable periods for the two basic types of pavements. Assuming the service life of rigid pavement to be fixed, resurfacing applies to flexible pavement as a means of equalizing service life periods. The design of concrete pavements in Minnesota is based on a traffic projection for the 20th year of service using the tractor-semitrailer component of the estimated heavy commercial traffic. Experience has shown that on the average in Minnesota rigid pavements designed to this traffic loading have a service life of 35 years. Flexible pavements are designed on the basis of a summation of equivalent 18,000-lb. axle load repetitions projected for a 20-year design period. Thus, by the 20th year, assuming traffic developed as predicted, serviceability of the road would have deteriorated to a point where resurfacing would be required to extend the service life an additional 15 years.

Resurfacing costs are incurred also with the rigid pavement alternate for the replacement of flexible shoulders. Experience shows that on the average shoulder surfacing flanking rigid pavement deteriorates and has to be replaced at about the halfway service-life point, or at 17.5 years. This, then, constitutes an interim cost to be considered in the annual road cost for the rigid alternate. The halfway point of 17.5 years is admittedly a convenience point and is inconsistent with the 20-year design life of flexible pavement; however, shoulders are built to a weaker structure and are not subjected to the beneficial kneading effect of constant traffic.

Resurfacing, then, is an interim construction cost that must be expended at a future time to resurface bituminous pavement and shoulders and to replace shoulder surfacing along concrete pavements.

Salvage Value

Salvage value refers to the residual value of the road after it has served its useful service life. Within the context of this study, it would represent the value of the materials remaining in the base, surfacing and shoulder structure. Minnesota practice has been to assign an arbitrary residual value amounting to 40% of the initial cost. Whether a value remains at all is problematical depending upon whether the road is abandoned, obliterated or reconstructed. Today there is much emphasis on reconstruction and re-use of old roadbed materials so that in most cases a salvage value would exist after a full service life. Yet to assign values for materials which may or may not be used 35 years distant in time is, at best, conjectural. Complete amortization of the original investment over a 35-year span would seem more prudent, considering that the salvage value remaining would be reflected in a reduced cost for a subsequent reconstruction project.

Interest Rate

The validity of applying interest as an inherent increment of annual road cost has often been debated, partly because it reflects adversely on the pavement type with the higher initial cost. Interest is normally defined as money paid for the use of money borrowed. Most highway projects are financed from funds currently available; hence the concept that since funds are not borrowed, interest is not a valid charge in annual cost studies. Yet an investment of public funds is rightly expected to produce a return to the public whether in terms of tangible or intangible benefits. The least the public would expect from tax revenues spent on public works is a return equal to that available to the taxpayer had he the freedom to invest his tax monies himself. In highway public works this return can be expressed in road user benefits.

Ogelsby (5) with respect to the use of interest in highway economic studies cites the following:

> "In the past in the public-works field some have argued that interest should be charged only where borrowing will finance the proposed project. This viewpoint has now largely disappeared as two concepts have been accepted. These are (a) that capital can and should be productive and (b) that interest is a reward or incentive for deferred consumption, as is the case when money is invested in highways because of anticipated future benefits."

As to what the interest charge should be, Oglesby refers to two practices: (1) that "interest should be charged at the current rate at which a particular highway agency can borrow money" or (2) "... a rate representing the minimum attractive return." The latter would be somewhat higher than the former recognizing the risk in predicting future events, i.e. where the prediction of benefits would be more uncertain. The first view was supported by the AASHO Planning and Design Policies Committee report entitled, Road User Benefit Analysis for Highway Improvement, 1960. The second concept would indicate a family of rates from which a choice could be made for economic studies of public works projects based on the anticipated return. The situation today is one where highway funds are insufficient and the likelihood of investment in low-return projects is remote. Thus, a fair rate for annual road cost studies would seem to be one at which the Department could borrow funds under existing economic conditions.

The Department has had no recent experience in selling highway bonds, and for its current bonded indebtedness is paying less than 5% interest. The bonding authority granted to the Commissioner by Article XVI of the State Constitution limits interest to 5%. This rate may be too low for the current economy since the Department had to seek legislative authorization in 1976 to finance its bridge replacement and rehabilitation program through initial proceeds from the sale of $25 million in State of Minnesota general obligation bonds. General obligation bonds have been sold at interest bearing rates ranging from 4.4% to 5.7% over the past 5 years, averaging about 5%. There is reason to believe as of October, 1977 that bonds can be sold at slightly less than 5%. With the prospect that the rate may increase somewhat as the economy continues to inflate a 5-year moving average would seem a fair means of establishing an interest rate for pavement selection studies, subject to annual redetermination. A rate in the range so determined is supported by the survey of other states tabulated in Exhibit IV which shows, for those states using interest as a factor in computing annual road costs, a range of 2.5% to 7.0% with Minnesota using the 2.5% and most of the other applying 5% or more.

Analysis Period

The "analysis period" refers to the length of time in years for which comparable economic analyses are made for alternate pavement types. It corresponds to "service life" as previously discussed and indicates a span of years for which, on the average, the initially, longer-lasting alternate serves traffic without major interim expenditures for rehabilitation. Minnesota, as indicated in its annual road cost model, has used a service life span of n = 35 years. When comparative economic analysis was first adopted as a guidance tool in pavement selection, 35 years appeared reasonable on the basis of concrete pavement performance up to that time. With the ensuing years of experience, it is appropriate to re-examine the basis for mean service life and determine whether a 35-year average is still valid.

One measure of pavement performance is that expressed by condition ratings established for trunk highways throughout the State. The condition rating, CR, is the composite value obtained by averaging the sum of the present serviceability rating, PSR, and the structural rating, SR, the former relating to riding comfort and the latter to traffic loading reactions. The CR ranges in value from 5 to 0 on a descending scale of quality. A rating falling within the 2.8 to 2.5 range represents a condition at which resurfacing is strongly advised to forestall more rapid deterioration.

To check the validity of n = 35 years for rigid pavement and the probable resurfacing requirement point for flexible pavement, a computer run of condition ratings was plotted relating years of service to CR. Out of 151 rigid pavement projects averaging 8.9 miles in length the trend line at age 35 years appears to be at or slightly above the 2.8 - 2.5 CR resurfacing criterion. Likewise, a similar plot for 59 flexible pavement projects seems to define a resurfacing point near 20 years. These data are shown graphically in Exhibits V and VI.

Obviously, many factors, environmental and other, affect roadway deterioration, but perhaps some of the chief influences are the differences that can occur between predicted traffic as used for design and the actual traffic experienced. If the latter greatly exceeds the former, obviously the deterioration is more rapid and vice versa. Lacking more specific methods of assessment, it would appear for rural highways, at least, that a 35-year service life for rigid pavement is reasonable and that resurfacing of flexible pavement is indicated by the 20th year.

DISCUSSION

The foregoing descriptions of cost analysis input factors involves some rationalization as to their relative importance in contributing to a reasoned result and to their validity for inclusion or exclusion in an economic cost model. It appears logical to eliminate those factors which either exert a near-equal influence on alternate pavement types or are of small influence and/or not well supported by adequate documentation. Thus, such a modified economic model would not produce true road cost values but would represent relative differences in the overall annual road cost for alternate designs. Prior rationalization has already identified those road cost factors that might be deleted from an annual road cost model while still retaining an equitable basis for comparing relative costs of alternate pavement types. These specifically are maintenance costs and administration and overhead, (unless substantiated by adequate records), operation costs and salvage value. For the purpose of comparison, salvage value may be considered zero at the end of the service life period. Administration and overhead as a cost varies inversely with the initial construction cost, and there is no documentation available indicating that it is substantially different for one type of pavement than another. Likewise, a fixed administration and overhead factor for interim resurfacing costs is difficult to defend without a backing of supporting data. The viable factors remaining, then, are first cost, resurfacing cost, interest rate and service life. The same factors would apply for both the rigid and flexible types of pavements except that the "resurfacing" cost for concrete pavement would apply only to the shoulders, while for bituminous pavements it would include resurfacing of the travel lanes as well as the shoulders.

The present method (Breed) of annual cost used by the Department fails to fully recognize the time value of money, using simple interest instead of compound interest in application to the initial capital investment and failing to convert interim improvement expenditures (resurfacing) to "present worth" as part of the capital cost. Present worth is merely a means for converting a future cost to current dollars on the basis that money set aside today plus interest earnings would provide the money for the future expenditure. Present worth evaluations in economic studies involving incremental future expenditures are valid in a stable economy; in an inflationary economy, however, inflation tends to offset the earning power of interest depending on relative rates for each. Inflation is likely to be an influencing factor in the economy for many years in the future and should realistically be taken into account in comparative cost analysis studies involving interim capital investments and present worth conversions.

Since alternative pavement types require different resurfacing treatments at different points along the project life time scale to keep them serviceable, the incremental costs for each must be accumulated in a way that keeps the annual costs truly comparable. The method which best accomplishes this is that presented by Baldock (3) in which the annual cost of the initial investment is combined with the present worth of future expenditures but modified, including an adjustment for inflation, to fit Minnesota concepts and assumptions.

Thus:

$$C = CRF_n [A + (E_b \text{ or } E_c) \; PWF_{n_b \text{ or } n_c}]$$

Where:

C	=	comparative annual cost per mile
CRF	=	capital recovery factor = $\dfrac{r(1+r)^n}{(1+r)^n - 1}$
r	=	interest rate
n	=	analysis period in years
A	=	construction cost per mile
E_b	=	bituminous pavement and shoulder resurfacing cost per mile
E_c	=	concrete pavement shoulder resurfacing cost per mile
n_b	=	years to resurfacing, bituminous pavement
n_c	=	years to shoulder surface replacement, concrete pavement
$*PWF$	=	present worth factor = $\dfrac{1}{(1+r')^{n_b \text{ or } n_c}}$
r'	=	difference between interest rate and inflation rate

*Capital recovery and present worth tables for various compound interest rates are found in many texts dealing with business finance and engineering economics.

The factors of greatest concern in the foregoing relationship are the interest rates r and r'. Current values for these can be established using the 5-year-moving-average approach with data from the Department of Finance on the sale of general obligation bonds and Mn/DOT on the Minnesota Highway Construction Cost Index. To establish a current interest rate, r, in this manner, the following data apply:

Sale of 20-year Bonds

Date		Interest Rate
3/72		4.5%
9/72		4.4
8/73		5.0
1/75		5.7
12/75		5.6
7/76		5.1
	Mean	5.05%

Similarly, the inflation rate from the construction cost index may be developed as follows:

Inflation Rate Computation

Year	Min Hwy. Cost Index	Annual Diff	% Change
1971	127.1		
		+3.4	
1972	130.5		+2.7
		+6.0	
1973	136.5		+4.6
		+35.9	
1974	172.4		+26.3
		+4.5	
1975	176.9		+2.6
		−8.2	
1976	168.7		−4.6
		Mean	+6.32

$r' = 5.05 - 6.32 = -1.27\%$

It is apparent from the foregoing derivation that r' can be a negative value where the inflation rate is greater than the interest rate. This tends to give the present worth factor a value greater than unity, and the "present worth" of resurfacing and reshouldering costs greater than current cost estimates. This is not to be unanticipated since the objective of applying the present-worth principle is to determine in terms of today's dollars an amount adequate to meet a future expenditure, considering interest earnings in the interim and, in this case, the purchasing power loss through inflation.

The other factors in the formula can be obtained from prior rationalization or as direct inputs. For instance, the analysis period, n, of 35 years corresponding to the average service life of rural concrete pavement appears basic. Likewise, the n_b value of 20 years for the resurfacing of bituminous pavement is consistent with design theory, and the n_c value of 17.5 years for replacement of bituminous shoulder along concrete pavement is consistent with experience for one shoulder replacement during the mean 35-year service life for concrete pavements. The first cost, A, should be based on the best design data available at the time of the analysis and applied to the estimated construction cost of base, surfacing and shoulders conforming to comparable established design standards for the alternate choices. The flexible pavement alternate would include consideration of both gravel base and full-depth bituminous design. Engineering and other overhead would be neglected pending development of more supporting data pertaining to such costs and their influence on results. Resurfacing cost, E_b, would be based on the estimated need for a leveling course and bituminous overlay of the traffic lanes and shoulders at the 20th year as proposed in Exhibit VII. The bituminous surfaced shoulders adjacent to concrete pavement would be estimated as a replacement cost, E_c, at 17.5 years.

The following two hypothetical examples illustrate the use of the formula for each of the two principal pavement types:

Example 1

Given: A concrete pavement project where

$A = \$150{,}000/\text{mi.}, E_c = \$20{,}000/\text{mi.},$

$r = 5.05\%, r' = -1.27\%, n = 35$ years.,

$n_c = 17.5$ yrs.

$$\text{Also } CRF_n = \frac{r(1+r)^n}{(1+r)^n - 1} = \frac{0.0505\,(1+0.0505)^{35}}{(1+0.0505)^{35} - 1} = 0.0615$$

$$PWF_{n_c} = \frac{1}{(1+r')^{n_c}} = \frac{1}{(1-.0127)^{17.5}} = \frac{1}{(.9873)^{17.5}} = 1.25$$

Substituting in the equation $C = CRF_n\,[A + E_c\,PWF_{n_c}]$

$$C = 0.0615\,(150{,}000 + 20{,}000 \times 1.25)$$

$C = \$10{,}762/\text{mi.}$ annual road cost

Example 2

Given: A bituminous pavement project where

$A = \$130{,}000/\text{mi.}, E_b = \$35{,}000/\text{mi.},$

$r = 5.05\%, r' = -1.27\%, n = 35 \text{ yrs.},$

$n_b = 20 \text{ yrs.}$

Also $CRF_n = 0.0615$ (From Example 1)

$$PWF_{n_b} = \frac{1}{(1-.0127)^{20}} = \frac{1}{(.9873)^{20}} = 1.29$$

$$C = CRF_n\,[A + E_b\,PWF_{n_b}]$$

$$C = 0.0615\,(130{,}000 + 35{,}000 \times 1.29)$$

$$C = \$10{,}772/\text{mi. annual road cost}$$

CONCLUSIONS AND RECOMMENDATIONS

This examination of the pavement selection process leads to the conclusion that the current method is obsolete and logically indefensible. It is deficient in the following ways, inclusive of practices that have evolved in its use:

- It fails to apply the principle of investment amortization, or capital recovery, by using simple interest instead of compound interest.
- The interest rate does not reflect current rates.
- It applies arbitrary salvage value at the end of the pavement service life period when such value can neither be reasonably predicted nor proportionately determined for alternate pavement choices.
- It fails to convert interim capital expenditures for resurfacing and/or shoulders to present worth and to include such anticipated expenditures in the amortization analysis.
- It fails to consider the effects of inflation on interim capital expenditures.

- Average annual routine maintenance costs are included without adequate documentation of such costs.

The aforementioned deficiencies can be largely eliminated by adopting the relationship $C = CRF_n \, [A + (E_b \text{ or } E_c) \, PWF_{n_b \text{ or } n_c}]$ where the PWF is modified to reflect a trend rate for inflation. This is not a true road cost model in that it is limited in application only to those elements of roadway structure consisting of base, surfacing and shoulders. While it still deals with the average performance of pavements and cost estimates that are subject to the vagaries of the marketplace, the relationship is basically consistent with recommended practice for comparing the economic attributes of various alternatives. It can also be "added to" as more factual data are derived for inputs, such as routine surface maintenance and administration and overhead. Its use, however, should be tempered by specific policy guidelines. Therefore, it is recommended that the procedure be adopted by the Minnesota Department of Transportation subject to the following policy guidelines:

1. The initial or first cost per mile, A, will be based on established design standards as modified by design analysis using current unit prices.

2. First costs will include only the base, surfacing and shoulders for one mile of two-way, undivided roadway or the one-way roadway of divided highways, exclusive of engineering and administrative overhead.

3. The interest rate, r, will be the 5-year moving average rate for State of Minnesota general obligation bonds as determined annually.

4. The inflation rate will be the 5-year moving average rate as determined annually from the Minnesota Highway Construction Cost Index.

5. The service life period, n, will be 35 years.

6. Salvage value will not be considered.

7. The rigid pavement alternate will include the cost of shoulder surface replacement, E_c, at 17.5 years.

8. The flexible pavement alternates will include the cost of resurfacing, E_b, at 20 years.

9. The resurfacing costs represented by E_b and E_c will be estimated at current prices exclusive of engineering and administrative overhead.

10. The relative costs of routine surface maintenance will not be considered until such time as cost-accouting can provide sufficient data to justify such costs in the annual road cost model.

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7. Lee, Robert R. and Grant, E. L., Inflation and Highway Economy Studies, HRB Record 100, pp. 20-35.

GENERAL INFORMATION (2-000)

Pavement Selection Policies and Procedures (2-013)

2-013.1 PURPOSE

The purpose of this directive is to establish the policies and procedures used by the Minnesota Department of Transportation in the selection of the type of pavement for projects designed for unrestricted traffic within legal load limits.

2-013.2 POLICY

I. It is the policy of the Minnesota Department of Transportation to pre-determine the type of pavement to be used for each surfacing project for unrestricted traffic within legal load limits; alternate bidding will not be considered. This policy is based on the principle that no two designs are clearly equal and that design engineers, as trained professionals, are best qualified to consider those factors which bear on the most appropriate choice. To this end alternatives for each project will be critically studied by considering engineering and cost factors. Comparative annual road costs will be developed for each alternative by using an economic model expressed as a mathematical relationship. A final determination will be based on the aforementioned procedure together with the following listed factors which were originally identified by the AASHO (now AASHTO) Special Committee on Project Procedures:

1. Traffic
2. Soils and Characteristics
3. Weather
4. Performance of similar pavements in the area
5. Economics or cost comparison
6. Adjacent existing pavements
7. Stage construction
8. Depressed, surface, or elevated design
9. Highway system
10. Conservation of materials
11. Stimulation of competition
12. Construction considerations
13. Municipal preference or recognition of local industry
14. Traffic safety
15. Availability of and adaptations of local materials or of local commerically produced paving mixes.

Items numbered 1, 2, 4, 5, 6, 10 and 12 shall be considered to be principal factors, however, major consideration shall be given to Item 5.

EXHIBIT I

II. There is a hereby continued a pavement selection committee to review and evaluate comparative designs, an engineering study and a cost analysis, and to recommend to the Assistant Commissioner for Technical Support Services, Assistant Commissioner-Field Operations, Division and the Deputy Commissioner of Operations the pavement type appropriate for the project.

A. The pavement selection committee shall consist of the following members:

Office Director, Materials Research and Standards (Chairman)
Office Director, Design Services
District Director (for the subject project)

At the request of the committee chairman, appropriate staff personnel may be requested to provide special information desired by the committee or to attend a meeting.

B. The Technical Services Engineer, Research and Standards Section, shall act as secretary to the committee. He shall prepare pertinent data for the projects under consideration, present same to the committee and maintain a file of all documents.

2-013.3 PROCEDURE AND RESPONSIBILITIES

I. It shall be the responsibility of the district director to request a surface-type determination. The request shall be directed to the Chairman, Office Director for Materials, Research and Standards, using Form 24213 with copies to the Office Director for Design Services and the secretary of the pavement selection committee. It shall also be the responsibility of the district director to present all available information pertinent to the project. This information shall include at the minimum:

1. A small scale map and profile showing the project, with intermittent key points indicating stationing.

2. Traffic data, including ADT, TST and Sigma N-18 projections.

3. A description of the project in terms of termini, total mileage, number of lanes, use if any of the inplace pavement, exceptions if any.

4. A preliminary soils report which will:

   a. delineate the major soil areas and potential borrow sites by texture, by AASHTO soil type and by "R" value.

   b. list any significant topographic features such as swamps, deep cuts, etc.

   c. list aggregrate production sites, including commercial sources, in the area.

The complete information package shall be sent to the secretary, pavement selection committee.

The request shall show which method is to be used in developing the study.

Use of Method 1 (normal procedure) requires the development of a detailed and complete engineering and cost study. Comparative designs for rigid and flexible types will be developed by the Materials Engineering Section for the conditions of traffic, soils and availability of aggregates. The investigation for aggregates will include a solicitation of information from the paving organizations sponsoring rigid and flexible types of pavement. The Subgrade & Base Design Engineer shall act as coordinator and expeditor for the Materials Engineering Section. Quantities, first costs and annual road costs will be developed by the Estimates Engineer.

Method 2 (short procedure, for limited use only) is for very short projects, normally less than one mile, or projects where only one type of surface logically fits an unusual condition of design, construction, soils, traffic, etc. The main objective of this method is to provide a much simplified means of developing a pavement type study for such minor projects. The district director's request shall include comparative designs and estimated costs developed by the district for both rigid and flexible types. A simplified cost estimate based on average unit cost for similar work on projects recently constructed in the same general area is acceptable. Where the district director recommends a specified type of surface for use, he shall support his reasoning with a complete explanation. The designs will be reviewed by the Materials Engineering Section with comments sent to the secretary, pavement selection committee. Likewise the estimates will be reviewed by the Estimates Engineer with comments forwarded to the secretary.

Under "Remarks" and with the necessary attachments the district director shall provide any additional information pertinent to the project and all other special features of design recommended for use such as an explanation of the need for the improvement, condition of the existing roadway and type of existing surface. Unusual problems in handling traffic or providing detours is required for developing comparative designs and costs.

II. The secretary for the pavement selection committee shall be responsible for requesting and expediting the development of informational data pertaining to aggregate sources, comparative designs, estimated first costs and annual road costs. He is authorized to request the necessary services from the Bureau of Policy and Planning, Materials Engineering Section, Design Section and the Research and Standards Section for development of the above data. He shall be responsible to coordinate with personnel in the Maintenance Section to develop a continuing study of surface maintenance costs from actual field records. He shall prepare a documentary file for each project, present same to the committee, and request approval of the committee recommendation by the Assistant Commissioner for Technical Support Services, Assistant Commissioner-Field Operations Division and the Deputy Commissioner of Operations. He shall maintain special files for all project documents.

III. Meetings of the pavement selection committee may be called by the chairman for the review and action on completed data for one or more projects or for the consideration of policy, design or other related matters.

IV. A recommendation for a type of surface may be made on a two-thirds majority vote of the three-member committee. Any dissenting opinions by committee members shall be noted. A project may be tabled for the development of additional data, investigation and review on the request of one member.

V. In presenting its recommendations to the Assistant Commissioner for Technical Support Services and Assistant Commissioner-Field Operations, Division, the pavement selection committee shall include a complete analysis of the project including the formula, criteria and other factors upon which the recommendations are based.

VI. Each pavement type selection must have the final approval of the Deputy Commissioner of Operations.

VII. All of the above proceedings shall be recorded by the committee secretary and become a part of the official project record.

VIII. All past decisions made prior to March 25, 1974 on projects for which final design has not commenced are subject to review by the pavement selection committee. The district director shall be responsible for requesting such review through the committee secretary. Henceforth, all surface-type determinations may be reviewed by the committee for any of the following reasons:

A. A time lapse of more than two years between the determination date and the commencement of final design.

B. Notwithstanding VIII.A above, a change in economic conditions and/or technical changes having a marked effect on pavement construction costs.

C. A change in project location, project limits or major design change.

Jim Harrington

Jim Harrington, Commissioner
Minnesota Department of Transportation

Form No. 24213
12-69

REQUEST FOR SURFACE TYPE DETERMINATION AND PRESENTATION OF PRELIMINARY INFORMATION

TO: ______________________________

Assistant Commissioner - Research and Standards
Chairman of Pavement Selection Committee

Date ______________

FROM: ______________________ District Engineer District No.______________

RE: TH ______________. Length ______________ Miles

SP__________, AJ __________, County ______________, Miles ________

SP__________, AJ __________, County ______________, Miles ________

SP__________, AJ __________, County ______________, Miles ________

Located ____

____

Proposed letting date ____

A surface type determination is requested for the subject project. It is recommended the determination be based on the Method indicated below.

☐ METHOD 1 (Normal Procedure)
Requires the development of a detailed and complete engineering and cost study. Comparative designs for rigid and flexible types will be developed by the Office of Materials for the conditions of traffic, soils and availability of aggregates. The investigation for aggregates will include a solicitation of information from the paving organizations sponsoring rigid and flexible types of pavement. Quantities, first costs and annual road costs will be developed by the Estimates Engineer.

☐ METHOD 2 (Short Procedure, for limited use only)
For very short projects, normally less than one mile, or projects where only one type of surface logically fits a very unusual condition of design, construction, soils, traffic etc. The main objective of this method is to provide a much simplified means of developing a pavement type study for such minor projects. The District Engineer's request shall include comparative designs and estimated costs for both rigid and flexible types. A simplified cost estimate based on average unit costs, for similar work, on projects recently constructed in the same general area is acceptable. Where the District Engineer recommends a specified type of surface for use he shall support his reasoning with a complete explanation.

REMARKS:
The District Engineer shall provide, under REMARKS, and with necessary attachments a full description of all information pertinent to the project. Show the number of lanes to be constructed, project and lane termini, special features of design recommended, type of shoulder surface, the use to be made of the existing facility, preliminary data on soils, granular materials, traffic etc. For further instructions refer to HIGHWAY DEPARTMENT DIRECTIVE, Pavement Selection Policies and Procedures, 2-013, dated December, 1969.

cc: Assistant Commissioner- Design and Right of Way
Cost Analysis Engineer

Standards: Form 21305 Request No. ________
Rev. 2-72

REQUEST FOR DATA FOR PRELIMINARY ESTIMATE

TO: ☐ B. F. Himmelman, Materials Engineer, Rm. 137 DATE ________
☐ L. L. Hansen, Director of System Planning, Rm. 814

Please furnish data for use in developing a preliminary cost estimate on the following project:

T.H. ________ LENGTH ________ MILES, DISTRICT NO. ________

S.P. ________ ________ CO. AJ ________ ________ MILES

S.P. ________ ________ CO. AJ ________ ________ MILES

S.P. ________ ________ CO. AJ ________ ________ MILES

NO. LANES ________ DESIGN LOADING ________ TON

LOCATED ________

____

TO BE ESTIMATED: ________ MILES OF _________ ROADWAY

DATA NEEDED: ________ SPAR NO. ________

MAIN LINE TRAFFIC (Total of both directions) FOR YEAR ________, TAS NO. ________

HIGH: ________ ADT ________ HCADT ________ DHV SEGMENT NO. ________

HIGH: ________ ADT ________ HCADT ________ DHV SEGMENT NO. ________

LOW : ________ ADT ________ HCADT ________ DHV SEGMENT NO. ________

LOW : ________ ADT ________ HCADT ________ DHV SEGMENT NO. ________

ESTIMATED BASED ON PRELIMINARY DESIGN OF:

LAYOUT NO. ________, FILE NO. ________ DATED ________ BY ________

PROFILE NO. ________, FILE NO. ________ DATED ________ BY ________

REMARKS ________

____

____

____

SURFACE TYPE DETERMINATION
REQUESTED BY ________ TITLE ________
DATE SURFACE TYPE
IS DESIRED ________

cc: ☐ W. N. Yoerg, Rm. 131 ☐ G. R. Cochran, Rm. 130 ☐ M. Gildemeister, Rm. 807
☐ L. P. Warren, Rm. 132 ☐ A. J. Phelps, Rm. 706 ☐
☐ P. C. Hughes, Rm. 135 ☐ D. P. Manley, Rm. 320 ☐

This request initiated by: D.P.Manley, Analysis Engineer, Room 320, Ext. 3073

EXHIBIT III

From : Office of Materials [signature]

Subject : Data for Preliminary Estimates

Surface Type: Rigid ☒ Flexible (Grav. Base) ☐ Flexible (Bit. Base) ☐

Lanes: ______

S.P.	T.H.	Location	Miles	Traffic & Design Load	Sta.-Sta.	% Soil Factor	Tentative Sections	Tons
			0.9	9 Ton one way ADT = 3006, one way TST = 103 (1995)	917- 963	R=30	8" Non-reinforced Concrete 5" Aggregate Base Cl. 5* (*Use only 1" stabilizing aggregate in granular area Station 1000-1026.) 10' Shoulders	
			4.8		963-1242 except 1000-1026	R=15	1 1/2" Bit. Shoulder Surface, 2331 3" Aggregate Shouldering, Cl. 5 Variable Aggregate Shouldering, Cl. 3	
			0.5		1000-1026	R=70		
			3.3		1242-1414	R=25	3' Shoulder Same as above or 8" Non-reinforced Concrete 5" Aggregate Base (Cl. 5)	

General Soils: Station 917-963 - S.L. 963-1000, S.L. with L.S. & Silt Area. Station 1000-1026, S. & G. Station 1026-1140 S.L. with Silt Area. Station 1140-1242, Loam with Silt areas. Station 1242-1415 S.L. The project is predominantly A-4 type soils.

Total Mileage 9.5

Page 1 of 1

NOTE: See attached correspondence from Estimates Section for total quantities and haul distances.

EXHIBIT II

To : Assistant Commissioner

From : Office of Materials

Subject : Data for Preliminary Estimates

Date:

Form 2471

Surface Type: Rigid ☐ Flexible (Grav. Base) ☒ Flexible (Bit. Base) ☐

Lanes:

S.P.	T.H.	Location	Miles	Traffic & Design Load	Sta.-Sta.	% Soil Factor	Tentative Sections	Tons
			0.9	9 ton, one way ADT = 3006 EN18 = 925,000 (1998)	917- 963	R=30	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 2" 2331 Bit. Base 6" Cl. 6 Base 8 1/2" Cl. 4 Base 10' Shoulder 1 1/2" Bit Shoulder 2331 3" Agg. Shouldering Cl. 5 Variable Agg. Shouldering Cl. 3	
			4.8	9 ton, one way ADT = 3006 EN18 = 925,000 (1998)	963-1242 except 1000-1026	R=15	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 2" 2331 Bit. Base 6" Cl. 6 Base 6" Cl. 4 Base 12" Cl. 3 Base 10' Shoulder 1 1/2" Bit. Shoulder 3" Agg. Shouldering Cl. 5 Variable Agg. Shouldering Cl. 3	

General Soils: Station 917-963, Sandy Loam. Station 963-1000, Sandy Loam with Loamy Sand ans Silt Areas. Station 1000-1026, Sand and Gravel. Station 1026-1140, Sandy Loam with Silt Areas. Station 1140-1242, Loam with Silty Cla[y] Areas.

Total Mileage 9.5

Page 1 of 2

EXHIBIT III

To : [illegible] Assistant Commissioner

From : Office of Materials [illegible]

Subject : Data for Preliminary Estimates

Date: [illegible]

Form 247

Surface Type: Rigid ☐ Flexible (Grav. Base) ☒ Flexible (Bit. Base) ☐

Lanes:

S.P.	T.H.	Location	Miles	Traffic & Design Load	Sta.-Sta.	% Soil Factor	Tentative Sections	Ton
			0.5	9 Ton, one way ADT = 3006 EN18 = 925,000 (1998)	1000-1026	R=70	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 2" 2331 Bit. Base 6 1/2" Cl. 6 Base 10' Shoulder 1 1/2" Bit. Shoulder 2331 3" Aggr. Shouldering Cl. 5 Variable Agg. Shouldering Cl. 3	
			3.3	9 ton, one way ADT = 3006 EN18 = 925,000 (1998)	1242-1415	R-25	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 2" 2331 Bit. Base 6" Cl. 6 Base 6" Cl. 4 Base 6" Cl. 3 Base 10' Shoulder 1 1/2" Bit. Shoulder 3" Agg. Shouldering Cl. 5 Variable Agg. Shouldering Cl. 3	

General Soils: Station 1242-1415, Sandy Loam. Entire area predominately A-4 soils.

Total Mileage 9.5

Page 2 of 2

EXHIBIT III

To : [illegible] Assistant Commissioner

From : Office of Materials [illegible signature]

Subject : Data for Preliminary Estimates

Date: March 15, 1976

Form 247

Surface Type: Rigid ☐ Flexible (Grav. Base) ☐ Flexible (Bit. Base) ☒

Lanes: ______

S.P.	T.H.	Location	Miles	Traffic & Design Load	Sta.-Sta.	% Soil Factor	Tentative Sections	Ton
			8.9	9 Ton one way ADT = 3006 EN18 = 925,000 (1998)	917- 963	R=30	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 8 1/2" 2331 Bit. Base 10' Shoulders Variable Depth 2331 Bit. Shoulder Surface (1 1/2" Min.) 3" Agg. Shouldering Cl. 5 Variable Aggr. Shouldering Cl. 3	
			4.8	9 ton one way ADT = 3006 EN18 = 925,000 (1998)	963-1242 except 1000-1026	R=15	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 12" 2331 Bit. Base 10' Shoulders Variable Depth 2331 Bit. Shoulder Surface (1 1/2" Min.) 3" Agg. Shouldering Cl. 5 Variable Aggr. Shouldering Cl. 3	
			0.5	9 ton one way ADT = 3006 EN18 = 925,000 (1998)	1000-1026	R=70	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 5 1/2" 2331 Bit. Base 10' Shoulder Variable Depth 2331 Bit. Shoulder Surface (1 1/2" Min.) Variable Agg. Shouldering Cl. 5	
			3.3	9 ton one way ADT = 3006 EN18 = 925,000 (1998)	1242-1415	R=25	3/4" 2361 Bit. Wear 1 1/2" 2331 Bit. Binder 9 1/2" 2331 Bit.BBase 10' Shoulder Variable Depth 2331 Bit. Shoulder Surface (1 1/2" Min.) Variable Agg. Shouldering Cl. 5	

General Soils: See Flexible (gravel base).

Total Mileage 9.

Page 1 of 1

EXHIBIT III

STATE OF MINNESOTA

Office Memorandum

DEPARTMENT Highway, Materials Office, Rm 134
Extension 3111

TO : G. R. Cochran, Subgrade & Base Design Engineer
Office of Materials Engineering

DATE: February 4, 1976

In reply refer to:
350

FROM : L. P. Warren, Chief of Concrete Engineering
Office of Materials Engineering

SUBJECT:

A request has been received for the rigid surface design for the above referenced project.

The data indicates a K of 150 and a oneway TST of 103 should be used for design purposes.

Therefore, I recommend that 8 inch non-reinforced concrete pavement be used.

Leo P Warren

L. P. Warren
Chief of Concrete Engineering

cc:
D. E. Durgin - K. J. Wasnie
D. P. Manley

Use above rec for 1998 Traffic
LPW

EXHIBIT III

ADMIN 1000

DEPARTMENT Highway, Materials Office, Rm 135

STATE OF MINNESOTA

Office Memorandum

TO : G. R. Cochran, Subgrade & Base Design Engineer
Office of Materials Engineering, Room 132

DATE: March 16, 1976

In reply refer to:
350

FROM : P. C. Hughes, Bituminous Engineer
Office of Materials Engineering

PHONE: 3196

SUBJECT:
Data for Preliminary Estimates
(Bituminous Surfacing)

Thickness		Specification Number	Course	Estimated Percent Bituminous
I. Rigid:				
A. Shoulder				
1. Sta. 917-Sta. 1415	1 1/2"	2331	Bituminous Shoulder Wear	6.0
II. Flexible (Gravel Base):				
A. Mainline				
1. Sta. 917-Sta. 1415	3/4"	2361	Bituminous Wear	6.5
	1 1/2"	2331	Bituminous Binder	4.5
	2"	2331	Bituminous Base	4.5
B. Shoulder				
1. Sta. 917-Sta. 1415	1 1/2"	2331	Bituminous Shoulder Wear	6.0
III. Flexible (Bituminous Base):				
A. Mainline				
1. Sta. 917-Sta. 963	3/4"	2361	Bituminous Wear	6.5
	1 1/2"	2331	Bituminous Binder	4.5
	8 1/2"	2331	Bituminous Base	4.5
2. Sta. 963-Sta. 1242	3/4"	2361	Bituminous Wear	6.5
(except 1000-1026)	1 1/2"	2331	Bituminous Binder	4.5
	12"	2331	Bituminous Base	4.5
3. Sta. 1000-Sta. 1026	3/4"	2361	Bituminous Wear	6.5
	1 1/2"	2331	Bituminous Binder	4.5
	5 1/2"	2331	Bituminous Base	4.5
4. Sta. 1242-Sta. 1415	3/4"	2361	Bituminous Wear	6.5
	1 1/2"	2331	Bituminous Binder	4.5
	9 1/2"	2331	Bituminous Base	4.5
B. Shoulder				
1. Sta. 917-Sta. 1415	Var. Depth (1 1/2" min.)	2331	Bituminous Shoulder Wear	6.0

P. C. Hughes

P. C. Hughes
Bituminous Engineer

cc: J. R. McConaha

To : F.W.Thorstenson Assistant Commissioner

From : Office of Materials J R McCormick

Subject : Aggregate Sources

Date: January 27, 1976

Form 2471b

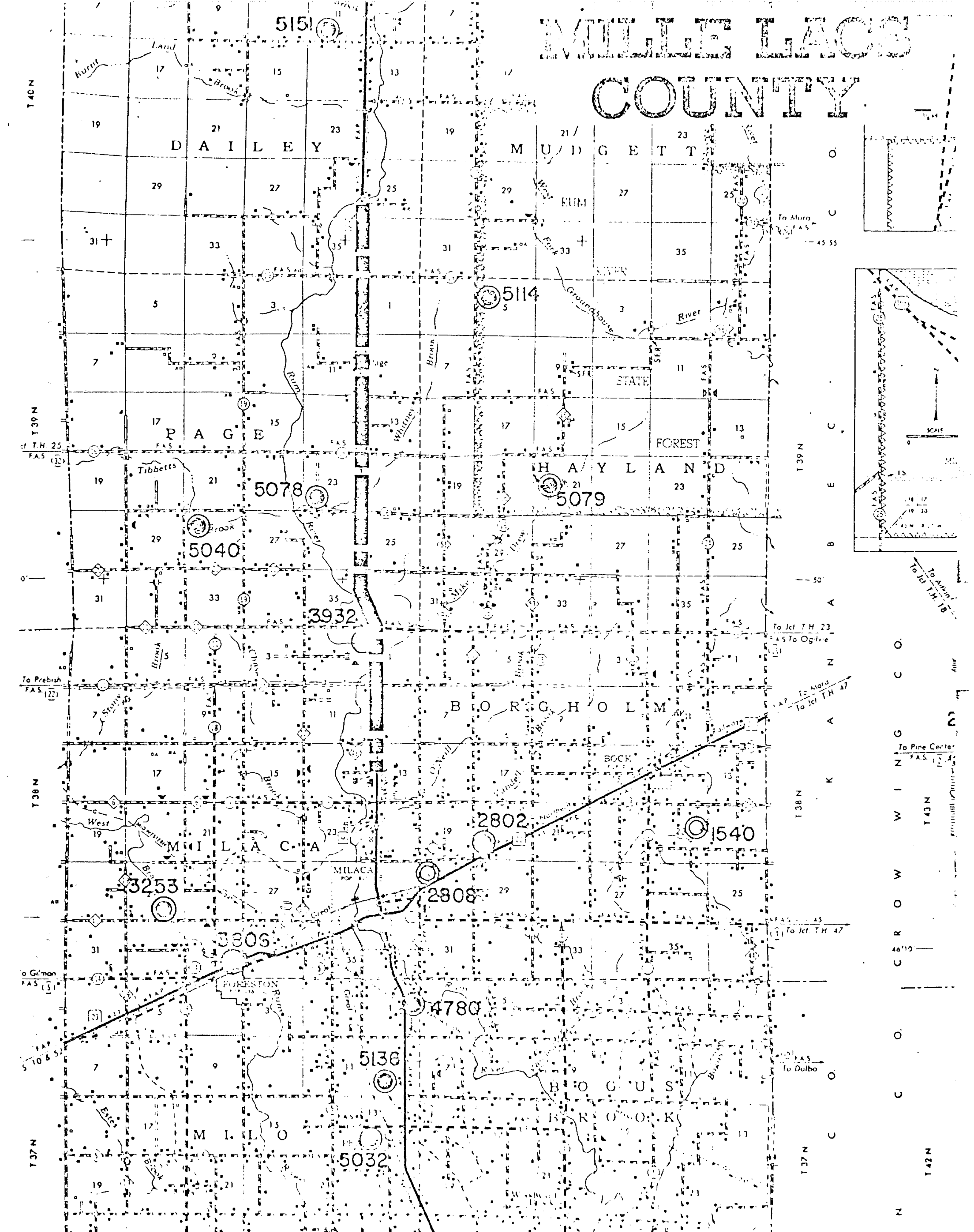
S.P. ______ T.H. ______

Location ______

Pit	County	Cond't Survey	Location	Class	Quantity (Cu. Yds.)	% Strip.	% Shale	% Spall	% Crushing 2"	1"	3/4	% Passing 4	10	40	200
2802	Mille Lacs	8/68	20-38-26	Cl. 6	22,000	16	-	1.1			23	58	49	21	5.5
3253	Mille Lacs	2/47	29-38-27	Cl. 6	26,000	20	0	0		19	24	62	55	19	2.2
3306	Mille Lacs	3/71	33-38-27	Cl. 6	110,000	23	0.1	0.1			33	47	39	20	6.3
5032	Mille Lacs	10/71	13-37-27	Cl. 5, BA-2	18,500	55	0	0			12	70	61	34	7.7
5078	Mille Lacs	8/69	23-39-27	Cl. 6	37,000	4	T	T			17	50	33	8	1.8
5136B	Mille Lacs	1/75	12-37-27	Cl. 5, BA-2	19,000	31	T	0.1	0	3	6	76	63	25	5.3
5151	Mille Lacs	6/70	11-40-27	Cl. 6	17,700	46	T	T			13	64	48	16	2.6
5076	Mille Lacs	12/74	12-41-27	Cl. 6	120,000	33	T	0.2		22	27	54	44	19	4.4
3932	Milli Lacs	7/69	1 & 2-38-37	Too coarse to drill, but is a potential source of BA-1											

Commercial aggregates are available from Ille Lacs Aggregate and Concrete, Inc., Millaca.

EXHIBIT III


MILLE LACS
COUNTY
T 40 N
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DAILEY
MUDGETT
PAGE
HAYLAND
BORGHOLM
MILACA
MILO
BOGUS BROOK
KANABEC CO
CROW WING CO
5151
5114
5078
5079
5040
3932
2802
1540
2808
3253
3306
4780
5136
5032
Burnt Land Brook
West Fork Rum River
Groundhouse River
Rum River
Whitney Brook
Tibbetts Brook
Mike Drew Brook
Stony Brook
West Branch
Great Northern
STATE FOREST
BOCK
MILACA
FORESTON
To Mora
To Jct. T.H. 23
F.A.S. To Ogilvie
To Prebish
To Jct. T.H. 47
To Pine Center
To Gilman
To Dalbo
To Aitkin
To Jct. T.H. 18
Jct. T.H. 25
F.A.S.
F.A.P.
SCALE

EXHIBIT III

Form #21182 (Rev. 4-69) File No. ____________

REQUEST FOR PRELIMINARY COST ESTIMATE

TO: A. J. Phelps, Estimates Engineer, Room 706. DATE: ____________

Please prepare the following described preliminary cost estimate.

T.H. ____________ LENGTH ____________ MILES, DISTRICT NO. ______

S.P. ____________ ____________ CO. AJ ____________ ____________ MILES

S.P. ____________ ____________ CO. AJ ____________ ____________ MILES

S.P. ____________ ____________ CO. AJ ____________ ____________ MILES

LOCATED ____

TYPE OF ESTIMATE REQUIRED

- [ ] Cost comparison of flexible and rigid pavements
- [ ] Cost of right-of-way
- [ ] Cost of complete construction (grading, surfacing, misc. structures, etc.)
- [ ] Cost of utility rearrangement
- [ ] Cost of bridges
- [ ] Cost of -

DATA TRANSMITTED (attached hereto)

______ Copies, Layout No. ________ File No. ______ Prepared by ____________

______ Copies, Profile No. ________ File No. ______ Prepared by ____________

______ Copies, Layout No. ________ File No. ______ Prepared by ____________

______ Copies, Profile No. ________ File No. ______ Prepared by ____________

______ Copies of design recommendations by Materials and Research Section, ______ Sheets

______ Copies ________________________________, ______ Sheets

______ Copies ________________________________, ______ Sheets

ESTIMATES REQUESTED BY ____________ TITLE ____________

MAIN LINE AVERAGE DAILY TRAFFIC (Total of both directions) FOR YEAR ________

	ALL VEHICLES	HEAVY COMM	TST	DHV
HIGH				
LOW				

REMARKS:

NOTE: Transmit _____ copies of estimate to: D.I. Manley, Cost Analysis Engineer - Room 320

cc: D. P. Manley

EXHIBIT III

Form No. 21815
(5-66)

ANNUAL ROAD COSTS
Computation Sheet
Model ________

S.P. ______________________
T.H. __________ __________ Mi.

Location ______________________

Type of Roadway Surface

	RIGID	FLEXIBLE
(n) Life Expectancy (years)	35	35 BIT. BASE
(s) Salvage Value (%)	40	40
(r) Interest Rate (%)	2.5	2.5
(i) Economic Increase (% per yr.)		

		RIGID		FLEXIBLE
ANNUAL INVESTMENT				
(A)	1. First Cost per mile	140 713	1.	119 022
(S)	2. Salvage (Item 1 x 0.40)	56 285	2.	47 209
(A-S)	3. Depreciation (Item 1 x 0.60)	84 428	3.	70 813
$\frac{A-S}{n}$	4. Annual Depreciation (Item 3/35 or Item 1 x 0.017143)	2 412	4.	2 023
ANNUAL INTEREST				
$\frac{(A+S)r}{2}$	5. Annual Interest on investment (Item 1 x 0.0175)	2 462	5.	2 065
ANNUAL MAINTENANCE COSTS				
(B)	6. Routine Surface Maintenance (a)	64	(a)	168
(E)	7. Special Surface Maintenance (b,c,d & e)		(b)	704
			(c)	194
		23	(d)	23
		50	(e)	—
ANNUAL ROAD COSTS				
	8. Total Annual Road Costs per mile Items 4, 5, 6, 7 (b, c, d, e)	5 011		5 177

HIGHWAY RESEARCH BOARD METHOD

Formula: $C = \frac{A-S}{n} + \frac{(A+S)r}{2} + B + E$

C=Annual Road Costs
A=First Costs
S=Salvage value of Surface Structure at end of (n) years.
B=Annual costs of Routine Surface Maint.
E=Annual costs of Special Surface Maint.
n=Life Expectancy in years.
r=Rate of Interest

BASIC DATA

No. of lanes ☐
Divided roadway ☐ Undivided roadway ☐
½ of divided roadway ☐
Interstate ☐ Regular T.H. ☐
A.D.T. ☐
H.C.A.D.T. ☐
Shoulders: Bituminous ☐
Gravel ☐
Shoulder reseal: Light ☐ Heavy ☐
Traffic lane reseal: Light ☐ Heavy ☐

DESCRIPTION OF ITEMS 6 & 7

RIGID

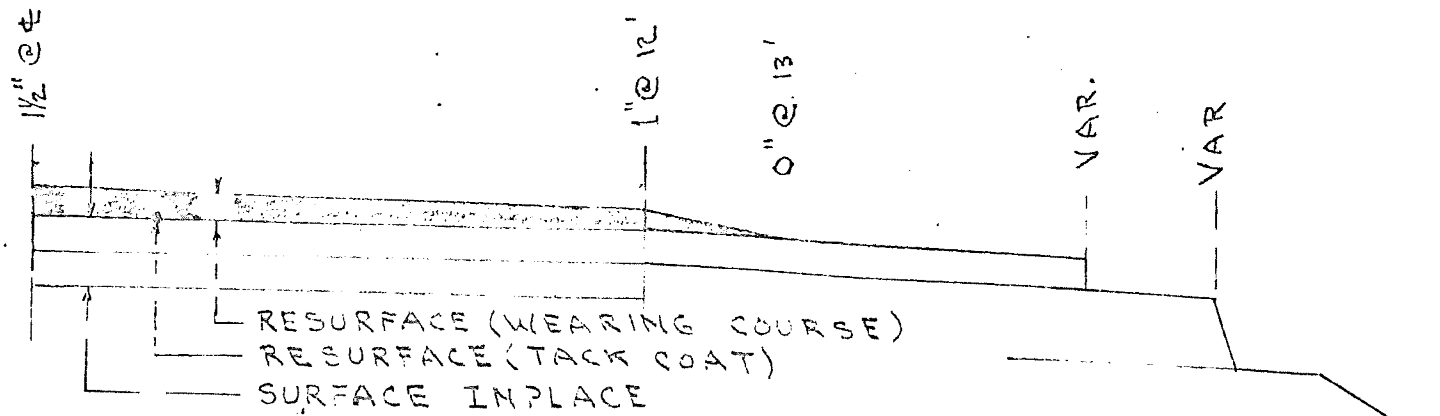
(a) Routine maintenance of traffic lanes and shoulders.
(b) Resurfacing traffic lanes and shoulders.
(c) Reseal bituminous surfaced traffic lanes.
(d) Reseal bituminous shoulders at years 6,12,18,24 & 30.
(e) Joint and crack renovation.

FLEXIBLE

(a) Routine maintenance of traffic lanes and shoulders.
(b) Resurfacing traffic lanes and shoulders.
(c) Reseal bituminous surfaced traffic lanes at years 6,12,24 & 30.
(d) Reseal bituminous shoulders at years 6,12,18,24 & 30.
(e) Joint and crack renovation.

EXHIBIT III

RESURFACE FLEXIBLE
MODEL "A"



VALUES FOR ONE ROADWAY (2-12' lanes, 2 shoulders)

MODEL "A" END AREA $= \frac{1.5\text{" to } 1\text{"}}{℄ \text{ to } 12'} + \frac{1\text{" to } 0\text{"}}{12' \text{ to } 13'}$

Traffic Lanes

Lanes - $1\frac{1}{4}$" x 24' x 5280' = 13,200.4 CF

Shoulders - 2 x $\frac{1\text{" + } 0\text{"}}{2}$ x 5280' = 440.0 CF

Total 13,640.4 CF per mile

Wearing Courses	Lbs. per S.Y. 1" Depth	Lbs. per C.F.	1¼" Average Thickness Tons of Mixture Per C.F.	Per Mile
2361	112 ½ #	150	0.075	1023.03
2351 A	116 2/3#	155.556	0.077778	1060.92
2351 B	115#	153.333	0.076667	1045.77
2341	110#	146.67	0.073333	1000.29
2331	100#	133.33	0.066667	909.36

Tack Coat 14' +14' = 28' x 5280 x 0.025 GSY = 411 gal. per mile

Resurface at years 12 9 & 24 with 2361 mixture, no seal coat required.
Based on 3/4" depth for 24' width plus 1.0' taper on 2 sides.

	Including Tapers	Lbs per S.Y.	Lbs per C.F.	Tons per C.F.	Tons of Mix per Mile incl. tapers
2361	3/4" - 8,250 CF/M	84.375	150	0.075	618.75
2361	5/8" - 6,875 CF/M	70.31	150	0.075	515.63

Years in study period

	0	6	12	18	24	30	35
Year to resurface			X		X		

SUMMARY OF PAVEMENT SELECTION PROCEDURES, 47 STATES

State	Describe the organization for pavement selection	How many years is used for total service life (Rigid, Flexible)	Which of the following costs are considered: Construction, Resurfacing, maintenance or all of the above.	What is the interest rate on the investment.	Is any salvage value used at the end of the total service life (rigid, flexible)	What amount is used in the cost for resurfacing and when is it done during the service life (rigid, flexible)	What amount is used in the cost study for maintenance during the service life (rigid, flexible)	Is consideration given to road user costs and benefits.
Alabama	No description furnished	Same number of years as the design life which is not listed.	Construction, (resurfacing and maintenance not listed but may be used)	Not stated	Not stated	Not stated	Not stated	Not stated
Arizona	Materials Division	30 years	All. If the cost difference is within 15% the State may use either. If greater than 15%, the least expensive is used.	Interest rate is used but no figure was given.	Not listed	Maintenance costs are used but no figures were given.	No amount was given but it is done to bring flexible to a 30 year life, also no time was given when the resurfacing is done.	Not stated
Georgia	A committee reviews all selections of 1000 VPD (future traffic) and any other it is requested to review.	Appears to be the design life (20 years)	All. (The AASHO "An Informational Guide on Project Procedures" is used.)	Not stated	Not stated	Not stated	Not stated	Not stated
Montana	Has a pavement Selection Committee that selects a type.	39 years	All	None used	No	Assumed to be equal but it is considered	Flexible (overlay at 13 and 26 years, seal coat at 7, 20, 33 years) Rigid (seal coat shoulders 7, 13 and 20 seal coat full width 33 years) overlay 26 years. No cost given.	No
Maine	Use primarily bit. surface. With only roads carrying heavy truck traffic being made of concrete.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
California	Not stated.	20 years or more	All	5%	Only the unused portion of the resurfacing.	Not stated	Not stated	No
Nevada	No formal policy on pavement selection but uses economics to determine type. Maintenance and resurfacing do not appear to play a part in the selection process.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Massachusetts	No formal selection process but consults with design section and materials section. Uses almost entirely bit. for the following 1. low initial cost 2. adaptability to stage construction 3. availability of materials 4. good performance with little maintenance 5. they experienced difficulty with concrete prior to 1950	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Ohio	No formal committee. Cost and selection is made by design personnel and then submitted for approval.	21 years	All costs	5%	Not stated but doesn't appear to be used.	2 lanes (rigid $217 per mile, flexible $264 per mile.)	Flexible annual resurfacing costs = 3" @ 7 years $29,300, 1-1/2" @ 14 years $14,650 Rigid annual resurfacing = 3" @ 14 years = 29,300 after 14 years it is assumed both types will have to be resurfaced every 7 years.	Not given
North Carolina	Committee on pavement designs makes recommendations to planning board.	Apparently design life (20 years)	Initial cost	None	None listed	Not stated	Not stated	Not stated
South Carolina	A pavement design committee evaluates the 15 factors listed in AASHO "An Informational Guide on Project Procedures". However flexible pavement is generally used with only interstate or heavy truck traffic pavements being made of concrete.	Cost based on 20 year life	All	None stated.	No	Not stated	Not stated	Yes, if the initial costs are close Concrete is used because it offers less inconvience to the user.
Pennsylvania	The recommended type is issued to the Bureau of Design for review and approval.	40 years	All	5%	Not stated	$230/lane mile/year for rigid, 260/lane mile/year for flexible, and 210/lane mile/year for modified flexible.	Not given, rigid is resurfaced with 3" after 20 years flexible 2-1/2" at 8 years and modified flexible 2-1/2" at 10 years.	Not stated
Tennessee	A committee selects the type very similar to the procedure used in Minnesota.	Not stated	All	Not stated	Not stated	Not stated	Not stated	Not stated
Wyoming	The Materials Division selects the pavement based on an economic analysis of both types	20 years	It appears that only construction costs are compared.	None	Not stated	Not stated	Not stated	Not stated
Wisconsin	No formal policy. The design is done in the districts with final approval being made by the Central Office.	50 years	All	None	Each type is given credit for the number of years of the resurfacing not used.	Rigid, $230/year/mile until the first resurfacing (26.5 years) and thereafter $450/year/mile, Flexible, $450/year/mile for its life.	23,232/lane mile of 1-1/2" overlay for all types of pavement. Rigid is resurfaced at 26.5 year and thereafter every 10 years. Flexible is resurfaced every 10 years.	No
Vermont	No formal pavement selection process. Except for some test sections, 100% bituminous construction is used.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Washington	Has a pavement committee similar to Minnesota.	25 years	All	None	None	Rigid $70/year/lane, Flexible $100/year/lane	Not stated	No
Virginia	Does not have a committee. Design is sent to various staff members for their approval.	Not stated	All	None	Not stated	Not stated	Not stated	No
Texas	Design is done in the district using the 15 factors listed in AASHO "An Informational Guide on Project Procedures".	Not stated	Not known	Not known	Not stated	Not stated	Not stated	Not stated

EXHIBIT IV

SUMMARY OF PAVEMENT SELECTION PROCEDURES, 47 STATES

State	Describe the organization for pavement selection	How many years is used for total service life (Rigid, Flexible)	Which of the following costs are considered: Construction, Resurfacing, maintenance or all of the above.	What is the interest rate on the investment	Is any salvage value used at the end of the total service life (rigid, flexible)	What amount is used in the cost study for maintenance during the service life (rigid, flexible)	What amount is used in the cost for resurfacing and when is it done during the service life (rigid, flexible)	Is consideration given to road user costs and benefits.
Utah	Has a committee similar to Minnesota.	40 years	All	None	No	Rigid $125/lane mile/year, Flexible $300/lane mile/year	Rigid is sealed once and resurfaced once with 5" bituminous. Flexible is sealed 7 times and resurfaced 3 times with 2-1/2" bituminous.	No
South Dakota	Committee similar to Minnesota is used. In addition they have a pre-selection committee that analyzes the request to determine whether a formal selection process is needed.	50, however they are thinking about using 35 or 40	All	None	No	Varies depending on the soil base and whether reinforced concrete is used or non-reinforced. Rigid varies from $635/2 lane mile/year to $195/2 lane mile/year. Flexible varies from $530/2 lane mile/year to $410/2 lane mile/year.	Overlay flexible @ 8 years and 18 years with 1" and 29 years with 1-1/2". Whereas rigid is not overlaid.	No
Oregon	No formal selection committee	25 years	All	5%	None	Not stated	No value is given but one overlay is required for flexible at 12 years.	No
North Dakota	Uses a pavement selection committee.	40 years	All	None	No	CRCP $54/roadway/mile, PCC $54 roadway/mile full depth asphalt $269/roadway/mile	CRCP and PCC $20,000 @ 30 years. Full depth asphalt $20,000 @ 18 and 36 years. Credit is given to all types for the unused life of the resurfacing based on a 18 year resurfacing life.	No
New York State	Not stated whether a selection committee is used.	Not given	All	None	No, both considered equal	None, both are considered equal	Rigid is resurfaced with a 2-1/2" bituminous layer at 15 years and flexible is resurfaced at 7 years with 1-1/2" and at 15 years with 2-1/2".	No
New Mexico*	No formal pavement selection committee. They use the 15 factors listed in AASHO "An Informational Guide on Project Procedures.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
New Jersey	No formal policy. AASHO "An Informational Guide on Project Procedures" is used with economics getting prime consideration. Flexible is resurfaced at 15 years and rigid at 30.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Nebraska	No formal pavement selection committee.	40 years	Construction and resurfacing. Maintenance is not used.	6%	Some salvage value is used for rigid. None for flexible.	None	Not stated	No
Oklahoma	The surface type is determined by a pavement selection committee.	Don't have a fixed number of years. 20 years is a minimum.	Construction and resurfacing costs are used. Maintenance costs are used only when there is a difference in the two types.	5%	No	None if they are the same.	2-1/2" for flexible at 14 years.	Traffic delays are estimated and included in the resurfacing costs.
Alaska	Does not have a pavement selection policy or committee. Uses almost entirely bituminous.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Arkansas	Does not have a formal policy but does make an economic analysis of the types.	35 years	All	None	Not stated	Not stated	Not stated	Not stated
Colorado	No formal pavement selection policy	35 years	All	None	No	Rigid = $575/year/24' roadway. Flexible = $800/year/24' roadway.	Concrete is resurfaced with 3" at 25 years and flexible is resurfaced with 2" at 20 and 30 years.	No
Connecticut	No formal pavement selection policy	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Delaware	No formal pavement selection policy	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Florida	Is presently developing a pavement selection policy. An economic analysis adopted by their local FHWA office is used.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Hawaii	AASHO "An Informational Guide on Project Procedures" is used.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Idaho	Has a pavement determination committee	40 years	Only construction and resurfacing. Unless determined otherwise, the maintenance costs are considered equal.	None	Not stated	No	Rigid is resurfaced at 25 years and flexible at 18 and 32 years.	No
Indiana	AASHO "An Informational Guide on Project Procedures" is used.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Iowa	No formal pavement selection committee	30 years	All	5%	No	Rigid $512/2 lane mile, Flexible $729/2 lane mile	Not stated	No
Kansas	Has a pavement selection committee and considers the same 15 factors that Minnesota does.	Not known	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Kentucky	Has no formal pavement selection process but uses the same 15 factors that Minnesota does.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated

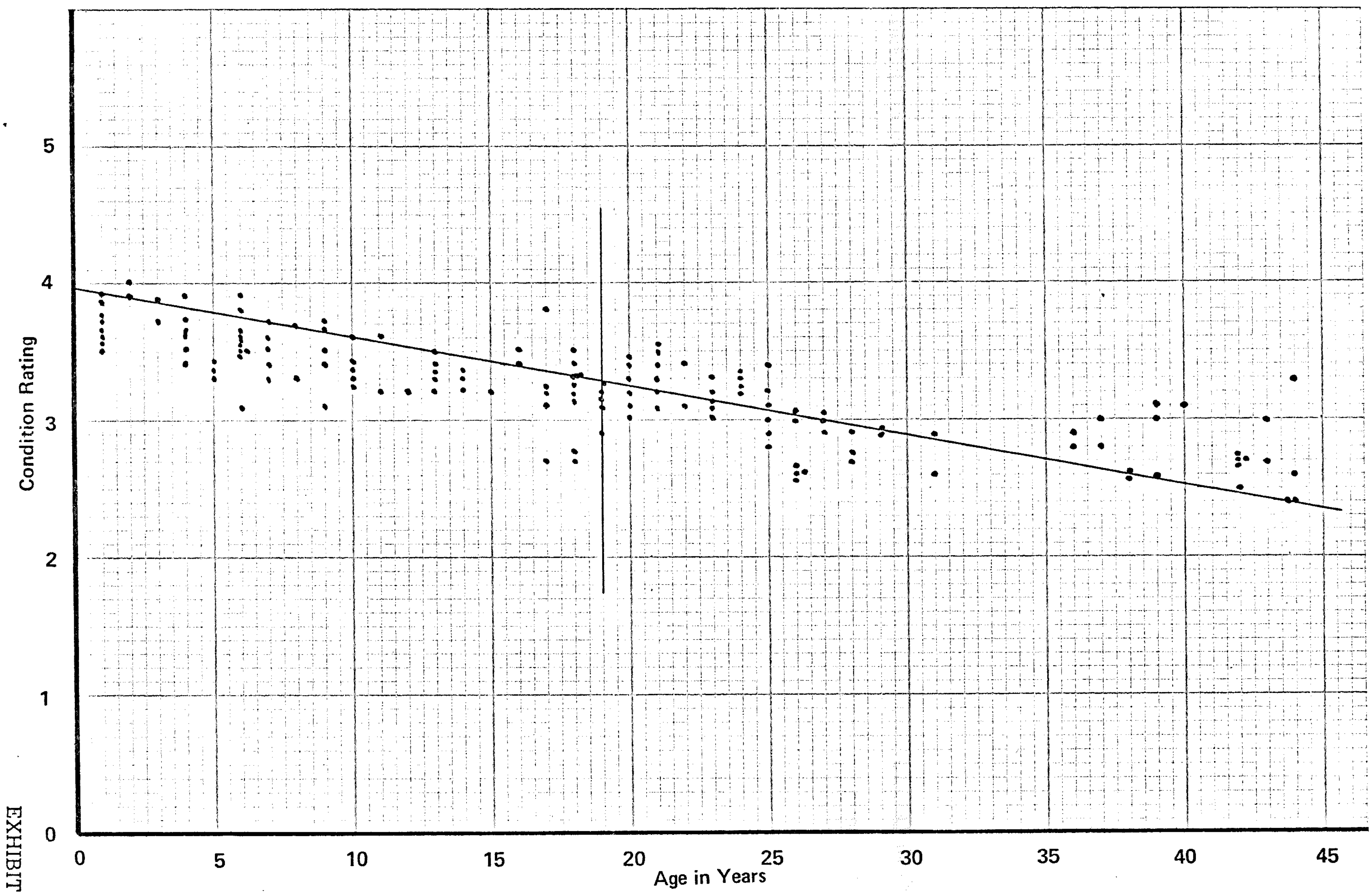
EXHIBIT IV

SUMMARY OF PAVEMENT SELECTION PROCEDURES, 47 STATES

State	Describe the organization for pavement selection	How many years is used for total service life (Rigid, Flexible)	Which of the following costs are considered: Construction, Resurfacing, maintenance or all of the above.	What is the interest rate on the investment.	Is any salvage value used at the end of the total service life (rigid, flexible)	What amount is used in the cost study for mainenance during the service life (rigid, flexible)	What amount is used in the cost for resurfacing and when is it done during the service life (rigid, flexible)	Is consideration given to road user costs and benefits.
Louisiana	AASHO "An Informational Guide on Project Procedures" is used.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Maryland	Has a pavement selection committee.	30 years	All	5%	All	Varies	Flexible at 10 and rigid at 20 years	Not stated
Michigan	Has a pavement selection committee that compares costs of various design types.	Not stated	Not stated	Not stated	Not stateu	Not stated	Not stated	Not stated
Missouri	Did not respond. Considered the information in-house.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
West Virginia	No formal committee.	40 years	All	4.5%	No	Both assumed equal.	Rigid $26,390 @ 20 years for 3" and $13,195 at 30 years for 1.5", Flexible $13,195 for 1.5" every 10 years.	No
Minnesota	Pavement selection committee recommends a type.	35 years	All	2.5%	Yes 40% of construction costs for both.	Rigid: 2 lane $53, 4 lane $268 Flexible: 2 lane $160, 4 lane $211	Varies with individual projects	No
Ontario, Canada	Not stated who recommends pavement type.	30 years	All	7%	Only the unused portion of a resurfacing.	Varies	Rigid is resurfaced at 14 years using 3" Flexible full dpeth is resurfaced at 10 and 21 years using 3".	Yes, both traffic delay costs and extra service costs due to deterioration of the roadway.

EXHIBIT IV

EXHIBIT V

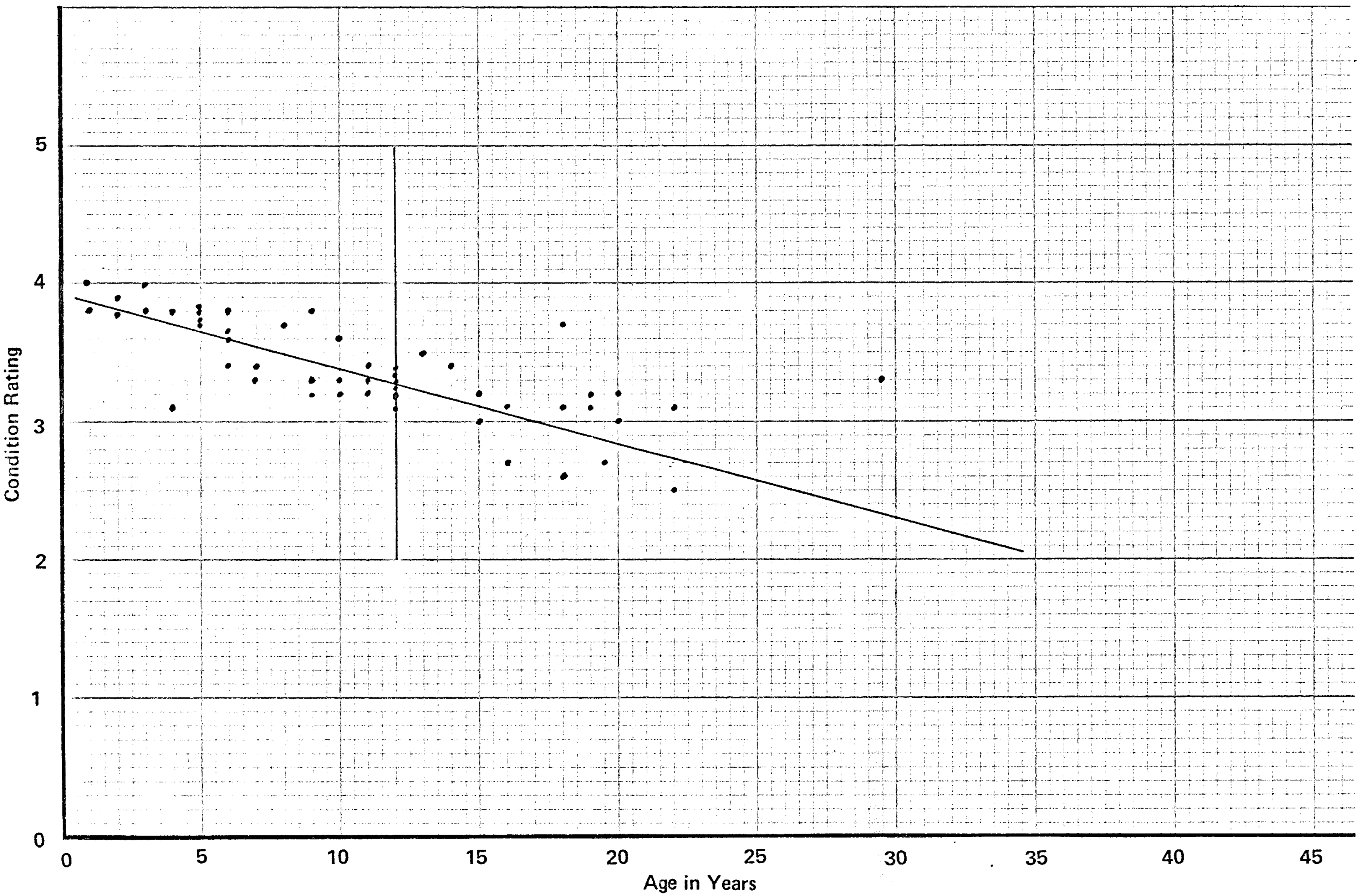


CONCRETE PAVEMENT CONDITION RATING

(151 Typical Sections)*

*Computer Print Out

EXHIBIT VI



BITUMINOUS PAVEMENT CONDITION RATING

(54 Typical 2331 & 2341 Sections)*

*Computer Print Out

ADMIN 1000

STATE OF MINNESOTA

Office Memorandum

DEPARTMENT Highway, Materials Office, Rm 135

TO : F. W. Thorstenson, Division Director
Materials, Research and Standards, Rm 408

DATE: July 15, 1976

In reply refer to:
350

PHONE: 3196

FROM : P. C. Hughes, Bituminous Engineer
Office of Materials Engineering

SUBJECT: Resurfacing of Bituminous Pavements and Bituminous Shoulders

The original structure of a bituminous pavement should, on the average last 20 years before an overlay is required. This is based on the results of Investigation 183. To achieve a total design life of 35 years (to enable a cost comparison with concrete pavement) it is estimated that one overlay would have to be placed. This estimate of one overlay is based on data collected by the Bituminous Engineering Section from soils reports, construction log books, and the condition rating system. A summary of the collected data is shown in graphical form on the attached graph. The data (149 sets) indicate that on the average a bituminous overlay of a bituminous pavement will reach a condition rating of 2.5 at about 19 years. Normally a 2.5 condition rating is the point at which another overlay would be required. As the average overlay life is shown to be 19 years it is reasonable, from a historical performance standpoint and for ease of computations, to set the service life of an overlay at 15 years to achieve the overall 35 year design life.

The next area to be considered is the thickness and type of overlay which will be placed after 20 years. Based on information collected from soils reports on overlay projects designed and completed during the last four years it can be generally stated that a one inch leveling course and a wearing course will be placed. The wearing course thickness would depend on the type of mix used but would either be 3/4 inch or 1 1/2 inches. This total thickness should be sufficient to restore the pavement to its original rideability and surface condition. Shown in Table I, attached, is the type and thickness of bituminous overlay to be placed after 20 years based on the original wearing course surface.

Also shown in Table I is the shoulder construction required at the time of overlay. As shown this depends on the original shoulder type.

For bituminous shoulders next to rigid pavement the question of whether or not resurfacing or reconstruction will be required depends on the R-value of the inplace soils and the ΣN-18. Using our present typical section for bituminous shoulders and going through the flexible pavement design procedure (assuming some percentage of the design lane ΣN-18 will be on the bituminous shoulder) it can be seen that in many cases the first foot at least of the bituminous shoulder is grossly underdesigned. The deterioration of the first foot will play a large part in the determination of whether or not a resurfacing or reconstruction is required. A variable service life for bituminous shoulders could be determined depending on the R-value and expected traffic (probably varying anywhere from two years up to over 35 years) but for simplicity and in general the following type of maintenance could be expected. At five to seven years after the original construction a bituminous wedge will be placed next to the rigid pavement. At 17.5 years the entire inplace bituminous shoulder will be removed and a new bituminous shoulder will be placed (Specification 2331).

If the department sees fit sometime in the future to increase the width of the rigid pavement so that a portion of it would be used as the shoulder a totally different type of maintenance could be expected. In this case the first foot of the bituminous shoulder (second, third, or fourth foot of the bituminous shoulder in our present design depending on the width of the concrete pavement) would not be underdesigned. If this were the case it could be expected that FA-2 sand seals placed at 12 and 24 years would enable the bituminous shoulder to have a service life equal to the design life of 35 years.

If you have any questions or comments on the above please contact me.

P. C. Hughes

P. C. Hughes
Bituminous Engineer

Attachments:
Table 1
Graph

cc:
W. N. Yoerg
G. R. Cochran

Table I

Type and Thickness of Bituminous Overlay to be Placed After 20 Years.

Original Wearing Course	2361	2341		2331
Original Shoulder Type	Bituminous	Bituminous	Gravel	Gravel
Resurfacing Wearing Course	3/4" - 2361	1 1/2" - 2341	1 1/2" - 2341	1 1/2" - 2331
Resurfacing Leveling Course	1" - 2331	1" - 2331	1" - 2331	1" - 2331
Resurfacing Shoulder Course	1 3/4" taper to 1 1/2"	2 1/2" taper to 1 1/2"	2 1/2" taper to 1 1/2"	2 1/2" taper to 1 1/2"

EXHIBIT VII

2-23-76

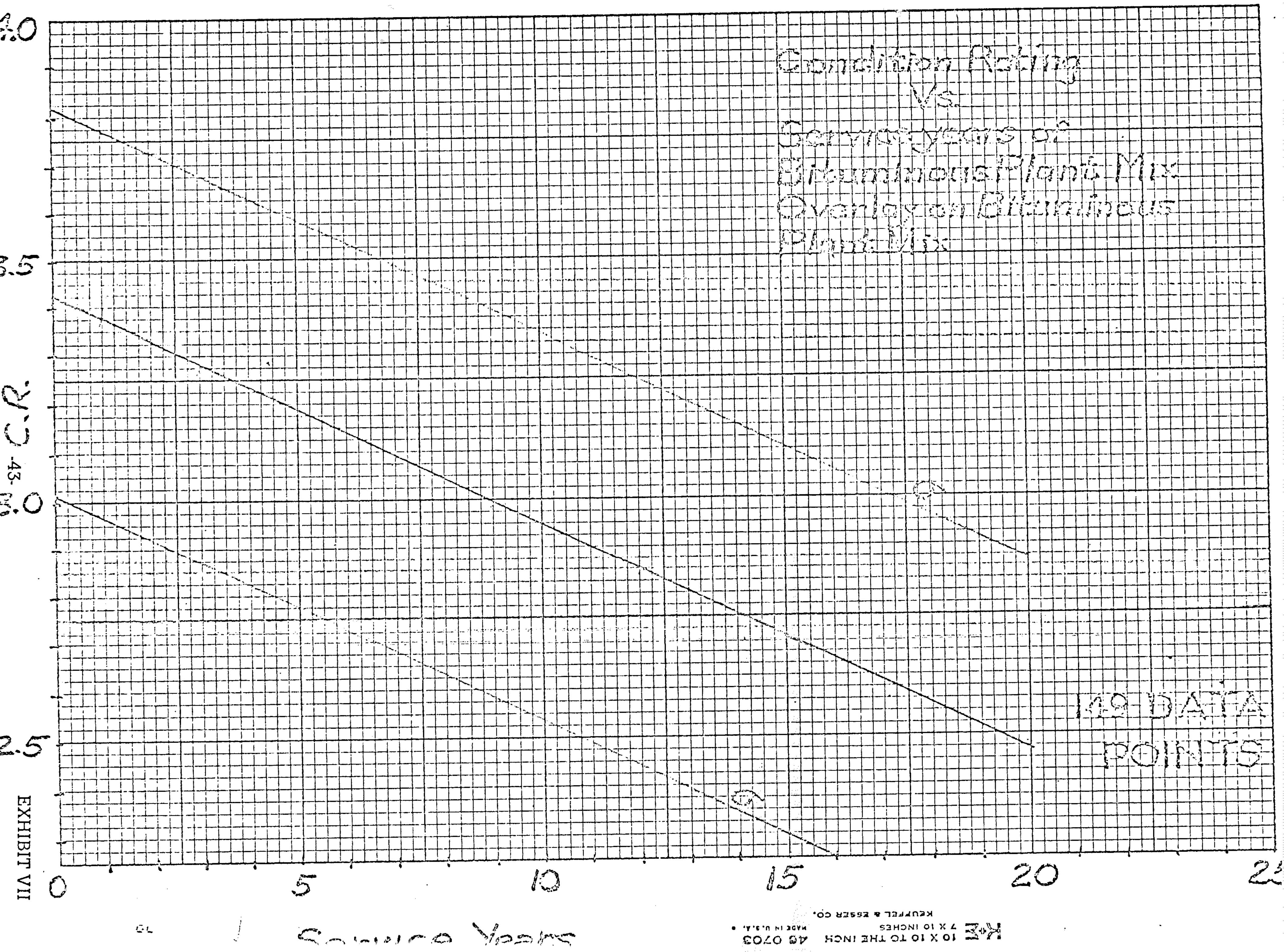


EXHIBIT VII