Highway Pavement Maintenance Costs and Pavement Type Selection

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MEMO TO: J. R. Harbison  
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SUBJECT: Research Report No. 413, "Highway Pavement Maintenance Costs and Pavement Type Selection"; KYHPR-64-11; HPR-I(9), Part II  

The report submitted herewith constitutes the final, and only, report on Study KYHPR-64-11. It presents long-term (1958-1971) analyses of pavement maintenance costs. It does not include analyses of construction costs or resurfacing costs. More than 40 tapes were processed to obtain the maintenance costs and construction records; pavement maintenance transactions alone filled one tape. The study was intended to answer long-standing questions concerning the significance of maintenance costs in selecting the type of pavements to be specified on various highway construction projects. Many unforeseen difficulties and uncertainties arose from a 1968 analysis; the report was withheld -- awaiting additional data and verifications. The analysis then yielded a gross or combined average of $313 per mile per year; and, from that standpoint, the results were comparable to those which had been reported by others. However, the costs according to type of pavement seemed untrustworthy because of apparent mismatches between charge codes and pavement type. In the final analysis, charges were compiled only for projects and sections which could be discretely identified according to pavement type. This reduced the sample sizes severely; and, in analyzing costs according to age and type of pavement, an unexpected bias in the sample of PCC pavements was discovered. A large portion of the BC sample was between 1 and 20 years old. This disparity tends to nullify the differences shown in Figure 5 in the report. The apparent differences in early ages, shown in Figure 6, may therefore be due to sample limitations. The interstate and parkway systems had been isolated beforehand and analyzed as a group. The effect of sample size in that group shows up strongly after an age of 8 years (see Figure 3).

I am fairly persuaded that the results of this study are significant only from the standpoint of providing insights into the order of magnitude of pavement maintenance costs and that differences according to type are very intangible and perhaps not significant. In order to be more definitive, we would have to group or "cell" pavement projects according to age, traffic, and structural capacity and would have to know the nature of the defect associated with each maintenance charge.

At this stage, I would recommend adaptive adoption of the so-called systems approach to pavement management and further uses of design strategies.

Respectfully submitted,

Jas. H. Havens  
Director of Research
A long-term analysis of pavement maintenance cost has been performed. The analysis does not include construction or resurfacing costs. The sample of pavement sections investigated were chosen to best represent the entire state. These sections were classified by pavement type; either bituminous concrete, portland cement concrete, or composite. The cost per lane mile (kilometer) per year was calculated for each pavement type by year and by age of pavement. Apparent differences in pavement maintenance costs between the two basic types of pavements were adjudged insignificant from the standpoint of determining pavement type. Because of poor or erroneous cost reporting, actual maintenance costs shown should be interpreted to be accurate in order of magnitude only.
HIGHWAY PAVEMENT MAINTENANCE COSTS AND PAVEMENT TYPE SELECTION

KYHPR 64-11, HPR-1(9), Part II
Final Report

by

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Kentucky Bureau of Highways. This report does not constitute a standard, specification, or regulation.

December 1974
INTRODUCTION

This study originated in 1964 at the request of the State Highway Engineer. Compelling questions concerning pavement type selection and comparative costs date much further into the past. Earlier studies of “road life” and “costs” were generally controversial and not very definitive. Road life, in years, was a very confusing factor; the so-called “resurfacing cycle” was equally as elusive as “road life.” Service life, in terms of accumulated equivalent loadings and structural capabilities, has been used to evaluate pavement structural design criteria and in incremental cost studies but not in evaluating total costs for the purpose of selecting the type of pavement; indeed, equality in design criteria would preclude differences in service life.

The guiding policies or principles of pavement type selection were formulated through AASHO in 1960 (1). Five principal factors and ten secondary factors were outlined; they are included in APPENDIX I for convenient reference.

It had been the policy in Kentucky prior to 1957 to specify presumably equivalent designs of bituminous and portland cement concrete pavements and to select the lowest and best bid.* Later, with the approval of federal officials, a provisional policy of selecting the pavement type on the basis of engineering, comparative estimates of construction costs, and other considerations, was established. The imperative provision was that eventually the comparative costs would be based on estimated total costs—i.e., construction costs plus maintenance costs less residual or salvage values. Otherwise, the AASHO guide has been respected as the prevailing policy in the interim.

Meanwhile, others determined or adjudged maintenance costs to be comparatively insignificant and(or) well within the limits of accuracy of the engineer’s estimate of construction costs. Results reported (2, 3, 4, 5, 6) have generally been in the order of $200 to $600 per mile (1.6 kilometers) per year. In 1955, R. D. Medley (7, 8) estimated the cost of all types of maintenance in Kentucky to be $969 per mile (1.6 kilometers) for roads having less than 500 AADT and $1562 for roads having AADT’s of 3000 or more.

A study of pavement life was also made in 1955 (9). Some early, off-hand estimates for the total maintenance of interstate highways were $4000 to $6000 per mile (1.6 kilometers) per year. The 1972, national average for all types of state roads was $2,420 per mile (1.6 kilometers); expenditures in Kentucky were slightly under the national average (10). References 11, 12, and 13 provide additional background information.

Only traffic lane pavement maintenance costs, together with residual or salvage value considerations, if feasible and valid, enter into the pavement-type-selection process. Residual or salvage value depends on the particular circumstances. If a pavement is to be abandoned and the land reclaimed, it is a liability; and the cost of disposal would be accounted in the project. The residual value of the pavement would be a technical loss. If an existing pavement is to be incorporated into a new but equivalent structure, the estimated cost of a totally new structure minus the estimated cost of reinforcing the existing structure is the esimated salvage value of the existing pavement. Existing pavement layer thicknesses multiplied by estimated, fractional structural worth factors yields an estimated, equivalent like-new thickness contribution to the new structural design. The structural worth factors, treated as (100-percent deterioration)/100, multiplied by the current cost per square yard per inch of thickness of the material in place yields a salvage value more directly. Certain pretreatments or preconditioning may be necessary to render an existing pavement usable in a reinforced (overlaid) structure; the cost of preconditioning would add to the cost of utilizing the old pavement and has the effect of diminishing its residual value. A portion of the salvage value estimated at the first extension of service life extends successively into the second, third, etc.; and, therefore, the value compounds in some yet undefined way. Nevertheless, the value at any point in time is probably best and most conveniently estimated by the current cost of the material in place multiplied by the residual structural worth factor. Continual assessments of pavement conditions are, indeed, important factors in guiding decisions to defer or intensify maintenance, to overlay, or reconstruct—whether based on situational analysis or systems

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*Since 1942, KRS 176.070 (2) has stated: "...the department may determine the type of improvement desired, and may advertise and receive bids for only the types determined." Presumably, this context applies to pavement type or types but not exclusively so. It may also protect the Department against counterclaims.

Section 4356t-6 (enacted in 1920) required that "...bids will be received for three or more distinct types of highways for which specifications have been adopted." This requirement was repealed by Section 4356t-17-2b.
management theory. The residual values of interstate
downway pavements and others designed to
comparable standards are expected to be very high at
the end of their designed service life. Additional
thicknesses required in redesigning and extension of
service life actually may not greatly exceed overlay
thicknesses required to rehabilitate lesser pavement
structures. If the renewal or extension of service life
is deferred or delayed too long, structural deterioration
accelerates. In reality because of competing priorities for
funding, each pavement project generates its own unique
history. Collection of all pertinent data needed for
statistical sampling and analyses of interacting variables
has preceded, thus far, gross comparisons or regressional
analyses of residual values of the two major types of
pavements. Consequently, it seems improper to
superimpose residual or salvage values on estimates of
initial construction costs, in the pavement type selection
process, until such values are duly quantified and
validated. To disregard salvage values has the effect in
the selection process of adjudging them to be equal and
nullifying.

"Lumping" annual maintenance costs by types of
pavements and obtaining averages seemed more
permissible. For instance, assuming sufficient data to be
available, "compiling and averaging" tests the question:
Are there unique attributes of either type of pavement
which collectively cause one type to require significantly
greater maintenance expenditures than the other type?
To obtain additional information requires sorting by
attributes or classes of attributes. For example,
interstates and parkways are most easily identified and
isolated as a class.

In 1968, a "lumping" analysis of magnetic tape
records of maintenance transactions covering 9 years
(1958 through July 1, 1966) was undertaken but was
not reported then. It was suspected that charge codes
and project identifications were not altogether "pure".
At that time, interstate and parkway records covered a
relatively short term. Further analysis was deferred
until additional data became available. The data finally
analyzed extended from 1959 through 1971. The
remainder of this report is concerned with the analysis
of those records.

METHODOLOGY

A sample of pavement sections distributed over the
state consisted of bituminous concrete and portland
cement concrete roadways. An effort was made to select
sections which were representative of the state (Figure
1). The sample contained 184 sections; of these, 118
were bituminous concrete and 66 were portland cement
concrete. The entire interstate and parkway systems in
Kentucky, completed through 1971, was part of the
sample; thus, recent heavy designs were included in the
analysis. The sample size in 1971 was 1669 miles (2686
km) of pavement. This involved 5271 lane-miles (8483
lane-km) or 3.2 lanes per mile (1.6 kilometers).

Historical information and identification data were
obtained for a 20-year period or greater. Cost data were
for a period of 13 years, from 1959 through 1971. This
period for costs was used because the account coding
systems made the data more readily identifiable and
retrievable.

Bureau of Highway files contain information on
maintenance sections identified by a seven-digit number
with letters added to identify subsections. An example
is 034-0124-W. Each of the 120 counties in the state
is assigned a number, 034 being Fayette County. Each
highway within a county is given a number of four digits
or less; 0124 is US 27 south of Lexington towards the
Jessamine County line. The letter W identifies a portion
or subsection of this section. The numbers remain
constant once assigned. The letter changes when a
reconstruction, major maintenance operation, or other
changes occur. Bureau files contain pavement structural
data recorded on the basis of two layers or components.
Extraction of the complete history of a subsection
proved invaluable for identification of structural
components that were considered base under the
two-component system. The identity of the pavement
type was recovered, even though multiple paving
operations may have taken place. Historical data thus
obtained was used to graphically reconstruct the
pavement section showing components. These graphs
were extremely helpful to relate components, where
applicable, with costs for analysis. Finally, pavement
structural data available were added to complete the
historical and identification data file (see APPENDIX
II for data attributes contained in the historical and
identification data file developed for this study).

A list of sections and subsections for the study
sample was submitted to the Division of Data Processing
for retrieval of cost data stored on magnetic tapes. At
this point, it was found that cost data were readily
available only for the previous 13-year period (1959
- 1971). Cost data for years prior to 1959 had been stored
manually. The 1959 - 71 data were considered
sufficiently valid for the selected spectrum of roads and
highways.

A second data file developed for this study
contained descriptions of the subsection termini
(APPENDIX III). This file enabled the location of the
limits of the subsections as prescribed by construction
contracts. The subsection could then be located with
some accuracy on a map.
The third and final data file (APPENDIX IV) compiled contained lengths, cross-section descriptions, and route identification by subsection number. This data file was invaluable in determining the cross section of the pavement.

The three data files, which complement each other, gave all identification and history required to relate the cost data. There are, of course, more data within the separate files than was used in this study.

The system of accounting for maintenance costs in Kentucky uses subledger numbers. This system assigns specific numbers to components of the roadway and maintenance operations related to these components. To retrieve maintenance costs, subledger codes were used. One difficulty in retrieving cost data was related to a change in subledger code designations on July 1, 1966. Examples of these subledger codes for maintenance operations are indicated below:

Post 1966 Codes:

206 - Bituminous Concrete Surface
207 - Portland Cement Concrete Surface

Note: These two codes are for routine maintenance operations such as repairing potholes, cracks, or joints; sweeping or grading by hand or equipment; and removal of excess material such as trash, gravel, or chips.

216 - Bituminous Concrete Surface
217 - Portland Cement Concrete Surface

Note: These two codes are for "special" maintenance operations such as surface treatments of all types, including bituminous concrete. Costs are charged against these codes if the operation adds less than 3/4 inch (19 mm) to the surface thickness, or if 3/4 inch (19 mm) or more is added to the pavement thickness over 10 percent or less of the surface area in any one mile (km).

200 - Shoulder and Side Approaches
302 - Right-of-Way Mowing
306 - Litter Cleaning
340 - Snow and Ice Removal

1958 - 1966 Codes:

80 - Bituminous Concrete Surface on Non-rigid Base (Surface 3/4 inch (19 mm) and greater)
90 - Portland Cement Concrete Surface

Note: These codes are for comparable routine maintenance operations listed above.

180 - Bituminous Concrete Surface on Non-rigid Base (Surface 3/4 inch (19 mm) and greater)
190 - Portland Cement Concrete Surface

Note: These codes are for comparable "special" operations listed above. The four 1959 - 1966 codes listed above are examples from a series of 99 subledger numbers for routine maintenance and 99 subledger numbers for special maintenance for various surface types and thicknesses and base types.

Costs of operations performed, identified by subledger codes, were charged to respective sections or subsections; however, it was necessary in the analyses to spread the charges throughout the length in the section regardless of how concentrated the actual work might have been. Also, whereas the charge codes recognize only portland cement concrete (PCC) and bituminous concrete (BC) surface types, it was known that charges to BC sections included not only maintenance on bituminous pavement structures but also portland cement concrete overlaid with bituminous concrete. In the analyses, overlaid concrete sections were identified from the historical file and classified as a composite type of pavement (COM). COM pavements were treated as a third type; their age was counted from the time of original construction. It should be noted, however, that the change in classification from PCC to COM diminishes the sample of PCC pavements and increases the sample of COM-type pavements.

The analyses merely attempt to isolate "pure" pavement maintenance costs. At first, full reliance was given to subledger codes 80, 180, 206, and 216 for screening purposes. Later, it was discovered that many of those charges were against pavement sections classed as PCC. Consequently, it was inferred that successive or repeated bituminous patching or leveling, such as at bridge approaches, joints, other settlements, and fill-slips, were actually charged as maintenance of a bituminous concrete surface after the first instance regardless of the length of road treated in the section. In other words, the length of road receiving the treatment was not sufficient to change its classification to BC or to identify a COM-type pavement for purposes of these analyses. Nevertheless, the charge was recorded as maintenance on BC surfaces. This had the effect of steadily increasing the annual lane-mile (lane-kilometer) cost for BC pavements and diminishing the cost for PCC pavements.
It finally became apparent that the as-built classifications, together with identifications of COM pavements as previously described, were more reliable than subledger coding. In the final analyses, all pavement maintenance costs, regardless of coding, were sorted and summed for each type of pavement for each year. These sums divided by the respective lane miles (lane kilometers) in the qualifying sample produced an average cost per lane mile (lane kilometer) for that year. Actually, a 3-year running average was completed; and those are the costs reported here.

The interstate and parkway systems provided a grand sample of modern highways worthy of analysis as an independent set. All other projects were lumped into another set and analyzed in the same way. In each of the two cases, only those sections which could be identified as being "pure in type" throughout the entire length of the section were used in these analyses. There were no COM pavements in the interstate and parkway sample set; therefore, the sample set represents almost the total systems. Only two-thirds or less of the remaining sample set qualified.

RESULTS

Interstate and Parkway System

Undoubtedly, the interstate and parkway systems provided the purest set of maintenance cost records. Although the first section of interstate was completed in 1959, significant mileage was opened to traffic by 1962. Mileage increased steadily during the period covered by this analysis. The Kentucky Turnpike, built in 1955, was the only project included in the sample which pre-dated the study period. Nevertheless, the remaining parkways provided a sampling about equal to and contemporary with the interstate system. No cross-comparison was made: instead, they were lumped together; and the 3-year running-average maintenance costs per lane per year are shown graphically in Figure 2. Naturally, the costs at the beginning of the period were nearly zero. They mounted gradually to approximately $150 per lane-mile ($93 per lane-kilometer) per year in 1970. These costs were then adjusted to the 1967 base year according to the Federal Highway Administration’s maintenance cost index (10). Costs of maintenance for BC and COM pavements merge and remerge. This may be due to surges in overlay programs and lapses in the maintenance burden which follow resurfacing. Figure 6 shows average annual costs according to age of pavements. These costs were adjusted to the 1967 base year. Here again, mileage effects superimpose. Mileages by ages of pavements in the sample during the study period are shown in Figure 7. The mileage distributions are not as was expected. Mileage of COM pavements rose in the 12th through 16th year. Mileage of PCC pavements in the sample was expected to diminish after about the 20th year; instead, it rose through the 32nd year. Some very old PCC pavements have been preserved without overlays and entered the sample through areal selection. Therefore, the costs at given ages are not directly comparable.

Referring again to Figure 6, the average annual cost for all "mature" pavements appears to be about $350 per lane mile ($218 per lane kilometer) per year. This appears to be the cost of maintenance near the end of and beyond the design period. The cost during the design period are not statistically comparable.

Statewide Maintenance Costs

As a general test of the sample set and the aforementioned analyses, all pavement maintenance costs for each year from 1967 through 1971 were summed and divided by the total mileage of paved highways in the state system in each year (10). These yearly averages are shown in the upper-right portion of Figure 8. These costs are based on the subledger codes adopted in 1967. For comparison, the average per-mile(kilometer)-pen-year costs for the sample set was determined for all years of data and are also shown. In the comparative years, the annual costs per mile (kilometer) for the sample set are approximately equal to the statewide averages. Greater differences were expected because of the greater influence of interstate and parkway mileage in the sample set than in the statewide system. Perhaps the differences expected were nullified by the greater number of lane-miles (lane-kilometers) contributed to the sample set. Because of data-processing difficulties, the statewide costs were not computed for the years prior to 1967. Presumably, any differences would diminish toward the beginning of the study period.
Figure 2. Three-Year Running Average Costs of Pavement Maintenance for the Interstate and Parkway Systems (Does Not Include Maintenance of Shoulders).

Figure 3. Thirteen-Year Average Costs Per Lane-Mile (Lane-Kilometer) Per Year of PC and BC Pavement Maintenance on the Interstate and Parkway Systems (Shown According to Ages of Pavements).
Figure 4. Number of Lane-Miles (Lane-Kilometers) on Interstate and Parkway Systems Used in Computing Pavement Maintenance Costs.

Figure 5. Three-Year Running Average Costs of Maintenance on PCC, BC, and COM Pavements Per Lane-Mile (Lane-Kilometer) Per Year; Based on Sample Set Excluding the Interstate and Parkway Systems (Only Those Sections Clearly Identified By Type of Pavement Were Used In This Analysis).
Figure 6. Thirteen-Year Average Costs Per Lane-Mile (Lane-Kilometer) Per Year of PCC, BC, and COM Pavement Maintenance; Based on Sample Set Excluding Interstate and Parkway Systems Shown According to Ages of Pavements (Only Sections Clearly Identified By Type of Pavement Were Used in this Analysis).

Figure 7. Sample Length Excluding the Interstate and Parkway Systems in Sections Identified By Type of Pavement Corresponding to Figures 5 and 6 (Distribution of PCC Pavements Prevents Direct Comparison of Costs By Types of Pavements).
SUMMARY AND RECOMMENDATIONS

Summarily, apparent differences in pavement maintenance costs between the two basic types of pavements, as found in this study, are probably not significant from the standpoint of determining pavement type. Moreover, the specificity of maintenance cost coding, from the standpoint of quantifying pure and true pavement maintenance, remains in doubt. If it were possible, which it is not because of the limited detail identified by the charge codes, to eliminate from the record those costs charged as pavement maintenance and which involved patching necessitated by settlement at bridge approaches, settlement in embankments and fill-slips, leveling dips etc.; the apparent costs of pavement maintenance found in this study might have been diminished considerably. In view of these probable uncertainties in cost identification, addition of maintenance costs factors in the pavement type determination process is not recommended. To adjudge these costs to be indiscernible or the apparent differences to be insignificant for the intended purposes has the effect of having implemented the maintenance cost consideration in the AASHO Informational Guide . . . in the very beginning. However, seemingly imminent needs for deslicking treatments and for releveling wear- and load-induced ruts may emerge as significant factors affecting maintenance of high-volume roads. Further uses of design strategies, together with insights and foresights toward future trends and needs of the times, may forestall otherwise surprising rises in maintenance expenditures.
DISCUSSIONS

Effects of Studded Tires

Although others (14) have estimated the impact of studded tires on pavement maintenance costs, the estimates are in terms of additional per-year costs for the miles needing additional maintenance and are based on the expected number of additional overlays needed in a 25-year period. These estimates are in the order of $4000 to $5000 per mile (1.6 kilometers) per year. As many as 10 overlays have been predicted during a 25-year period where traffic volumes are high and the percentage of studded tires is also high. Wear equations have been formulated (15).

Overlying and Resurfacing Programs

Until recently, overlaying or resurfacing, although budgeted as maintenance, has been mostly for the purpose of restructuring pavements for extended life, load-carrying capacity, and riding quality. Overlays for purposes of deslicking, smoothing ruts caused by studded tires, improving surface drainage, etc., bring forth new types of maintenance and additional costs. Present cost coding is not sufficient to identify these specific costs in future analyses of maintenance records.

Maintenance-Free Design Concepts

Ideally, pavements designed for high volumes of traffic should be maintenance free, or nearly so, during their designed service life. Some years ago, some engineers held the opinion that a pavement which does not develop some structural failures during its service life was overdesigned and that "no-defect" designs would not spread highway revenues to the maximum. Now, because of the perils associated with making pavement repairs on high-speed high-traffic-volume highways, the "no-defect" maintenance-free notions are most appealing. In other words, a low level of maintenance costs could be associated with a structural design criterion which provides a high level of confidence and certainty in the performance of pavements. Kentucky design criteria (16) have been derived on the basis of high confidence interval principles and therefore exceed the designs provided by the 1972 AASHO Interim Guide... (17) which is based on best-fit regression rather than on statistical limits.

Design Strategies

Planned restructuring of pavements coincident with anticipated needs for surface renewal would tend to further minimize pavement maintenance and perhaps offset the costs of surface renewals. First-stage designs would likely be for considerably less than 20 years, but the ultimate might be for considerably more than 20 years. Also, the impracticality of designing all first-stage pavements for very low volume roads to last 20 years is apparent. Optimum design strategies ultimately involve many economic considerations beyond initial construction costs. Whereas some economic factors must be quantified through historical derivation, others must be anticipated. Further implementation of design strategies would likely require a designer's commentary and plan for each project or class of highway.

Economic Modeling and Pavement Management Systems

Several economic models or equations have evolved (18, 19, 20, 21, 22, and 23) through the years. A resume of them is included here as APPENDIX V. Some are more directly applicable to specific highways or projects than to highway systems. Annual maintenance cost is common to all the models, and the period of years considered is required in most of them; however, the outputs are as specific or general as the input values.

The most recent development is the concept of pavement management systems - in which pavement structural criteria become a subsystem modeled by mathematical equation(s) and translated for computer use (24). Separate subsystems are modeled for construction costs, maintenance costs, resurfacing costs, traffic, costs to traveling public for delays during maintenance and reconstruction work, pavement conditions histories, salvage values, environmental impacts, and decision-making routines and alternatives. Continual input and feedback make the system ongoing; consequences of "do-nothing" decisions or deferment of action become apparent. The ultimate benefit of such a system could be a form of dynamic programming of funds -- that is, scheduling of work where it is needed most or where the benefits are highest. For instance, the so-called resurfacing program in Kentucky could be fully computerized and balanced for budgeting. The system would, of course, contain a complete inventory of pavements, condition, history, traffic, investments, planned obsolescence, etc. This concept merges nicely with the total highway inventory, project identifications, and information retrieval programs currently under consideration and now being partially implemented.

It would be possible, by further extension of the concept, to analyze incremental costs in terms of geometric requirements in roadway design and in terms of loads imposed by various types and classes of vehicles (including overloads). This could be extended to determine user taxing and licensing levels.
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APPENDIX I

PAVING TYPE DETERMINATION
AND DOCUMENTATION

(From Reference 1)

AMERICAN ASSOCIATION OF
STATE HIGHWAY OFFICIALS

PAVING TYPE DETERMINATION AND DOCUMENTATION

The highway engineer or administrator does not have at his disposal generally acceptable theoretical or rational methods that give an absolute and indisputable comparison of the competitive pavement types for set conditions.

Prerequisites for such an evaluation procedure would, of course, with other things, involve the development of improved scientific structural design methods for both rigid and flexible pavement structures to render comparable service under similar traffic and weather conditions.

It would also involve the availability of reliable cost accounting data on the maintenance costs of the two pavement types for those comparable conditions. Here again factual information in complete desirable form is not presently available. Even though information is being developed through research it will not be wholly applicable on a national basis without modifications to adjust for the various soil and climatic conditions encountered.

Past, current and proposed major research undertakings such as the Maryland Road Test, the WASHO Road Test and the current AASHO Road Test research project, and its proposed satellite projects, together with road life and maintenance studies underway in the several State highway departments all contribute to fill in, gradually, some of the gaps.

The AASHO Committee on Design is currently in the process of converting the basic scientific relationships of pavement performance and applied loads, as developed on the AASHO Road Test, into improved rational design methods for pavements.

Pending the development of better tools, the State highway departments must rely on those that are available. Certain assumptions must be made and an empirical approach used, based on the best professional highway engineering judgement and experience available.

In other words there is no magic formula, where certain figures can be inserted and a definite answer as to pavement type required will result.

Governing Factors

To avoid criticism, if that is possible, any decision as to paving type to be used should be firmly based. Judicious and prudent consideration and evaluation of the governing factors will result in a firm base for a decision on paving type.

A list of such factors comprises the following items:

1. Traffic
2. Soils 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 aggregates
11. Stimulation of competition
12. Construction considerations
13. Municipal preference and recognition of local industry
14. Traffic Safety
15. Availability of and adaptations of local materials or of local commercially produced paving mixes

In the following pages, these factors are discussed and grouped, one group including all those which may be considered to have major influence, and the second, those which have lesser, or only occasional influence. The order of magnitude of influence is to be considered interchangeable within the groups and between the groups, as no single order is held to apply in all cases.

PRINCIPLE FACTORS

1. Traffic

The volume of passenger cars generally affects only the geometric or lane requirement. The percentage of commercial traffic and frequency of heavy load application generally has the major direct effect on the structural design of the pavement. Existing heavy-duty highways constitute sufficient evidence that both flexible and rigid pavement designs can meet requirements under given conditions.

If a cost comparison between competitive paving types is to be of value, it is imperative that the structural designs compared have equal capacity to carry loads. Since the matter is one of basic economics, the cost comparison must also include not only the cost of original construction, but that of needed periodic repairs and routine maintenance over the service life of the pavement, and an estimate as to what its probable useable salvage value will be at the end of that time.

It must be conceded that in these important areas, some assumption still must be made pending the results of current and further research developments not already available in guide form. When such assumptions are made, they must be made by the best qualified personnel available.

Present legal load limits are, to all intents and purposes, frozen by the Federal-Aid Highway Act of 1956, and will remain until certain studies are presented to the Congress for its consideration and further action.

Even accepting this restriction, it is reasonable and proper to make allowances in the structural designs of pavements for possible future modest legal load increases as well as the occasional overloads, whether moving by special permit or illegally, that are likely to use the pavement.

Currently, the AASHO Transport Committee is preparing new proposed vehicle weights and size regulations for consideration of the various States from data received from the AASHO Road Test and other appropriate sources. The Transport Committee assignment is to develop recommended size and weights to give an optimum balance between the best highway use and maximum highway life, for roads and bridges that can be furnished with the funds available for highway purposes.

In the projection of the density and weight of future traffic that will likely use the pavement during its lifetime, it is essential that not only normal increases be anticipated, but that consideration be given to the possibility of additional traffic being generated by potential industrial development or changes in land use for the area served.

The construction of a modern highway may also divert large amounts of heavy traffic, from other routes in the same broad traffic corridor, that should be considered by the designer.
II. Soils Characteristics

Of paramount importance is the ability of a native soil, which forms the subgrade for the pavement structure in cuts and on embankments, to withstand applied loads. Even in given limited areas the inherent qualities of such native soils are far from uniform, and they are further subjected to variations by the influence of weather.

The characteristics of native soil not only directly affect the pavement structure design, but may, in certain cases, dictate the type of pavement economically justified for a given location.

The evaluation of the characteristics of soils is, axiomatically, a requirement for each individual pavement structure design.

III. Weather

Weather affects subgrade as well as pavement wearing course. The amount of rainfall, snow and ice, and frost penetration will seasonally influence the bearing capacity of subgrade materials. Moisture, freezing and thawing, and winter clearing operations will affect pavement wearing surfaces as to maintenance costs, etc. These surfaces, in turn, will have some effect on the ease of winter clearing operations due to differences in thermal absorption or to the ability of the pavement to resist damage from snow and ice control equipment or materials.

In drawing upon performance record of pavements elsewhere, it is most important to take into consideration the conditions pertaining in the particular climatic belt.

IV. Performance of Similar Pavements in the Area

To a large degree, the experience and judgment of the highway engineer is based on the performance of pavements in the immediate area of his jurisdiction. Past performance is a valuable guide, provided there is good correlation between conditions and service requirements between the reference pavements and the designs under study. This factor should not be allowed to develop into blind prejudice. Caution must be urged against reliance on short-term performance records, and on those long-term records of pavements which may have been subjected to much lighter loadings for a large portion of their present life. The need for periodic reanalysis is apparent.

V. Cost Comparison

In any cost comparison of paving types, the matter of availability of local or commercially produced materials, and the existence and proximity of manufacturing or processing plants will be of significant importance.

Unavoidably, there will be instances where the financial circumstances are such as to make first cost the dominant factor in paving type selection even though greater maintenance costs may be involved later. Where circumstances permit, a better and more realistic measure would be the cost on the basis of service life or service rendered by a pavement structure. Such cost computation should reflect original investment, anticipated life, maintenance expenditures, and salvage value.

Original cost can be fairly accurately estimated. Doubt as to validity arises in the case where on type of pavement has been given monopoly status by the long-term exclusion of a competitive type.
The highly desirable determination of cost on a service life basis is presently adversely affected by some incomplete areas in needed factual information. One such area is the life expectancy of different paving types, a second, the matter of maintenance costs, and a third, the salvage value of pavements.

With our present state of limited knowledge as to the effect of frequency of heavy load applications, it is difficult to conceive of anything but an empirical approach to the determination of life expectancy of a pavement. The Bureau of Public Roads report "Lives of Highway Surfaces-Half Century Trends" shows a difference in the probable life for rigid and flexible pavements. It is not known if these trends hold for the pavements currently being constructed for the modern heavier traffic loadings, such as will be involved for the National System of Interstate and Defense Highways. The experience of the individual states as to assignment of probable life expectancy of different paving types, under the pertaining conditions, must for the present be accepted.

Assigned maintenance costs will seriously affect the cost comparison. If these costs are to be considered wholly valid, they must be based on accurately kept, long-term maintenance records reflecting an established maintenance standard adhered to in practice. Since traffic and structural standards in the past have been such variables, it is difficult to accurately evaluate maintenance costs. This has not been a dereliction of the highway official.

It is urged that the individual states take the necessary steps to develop factual information from Interstate System of highways, which will be valuable in the years ahead. These highways are built to modern standards. Establishment of, and adherence to, a maintenance standard, supplemented by accurate cost recording, will produce for the future more reliable data on maintenance cost and life expectancy.

Salvage value to be ascribed to pavements is somewhat open to conjecture. As it were, a large proportion of highway reconstruction involves changes in alignment or gradient which negate the salvage value. Each project actually must be considered individually.

SECONDARY FACTORS

I. Adjacent Existing Pavements

Provided there is no radical change in conditions, the choice of paving type on a highway may be influenced by existing sections thereof which have given adequate service. This will result in a desirable continuity of pavement and consequent simplification of maintenance operations.

II. Stage Construction

Where financial circumstances dictate stage construction of the type of pavement, where a thinner wearing course is later brought up to design requirements by an additional course or courses of wearing course material, flexible design becomes mandatory.

III. Depressed, Surface, or Elevated Design

Depressed and surface design may involve a high water table which will influence the choice of paving type. Elevated design, as in the case of approaches to long bridges or viaducts with concrete decks, may influence the decision in
favor of rigid pavement to preserve a desirable continuity of pavement surface. A depressed design, presenting some periodic possible drainage problems, may also indicate the use of one type of pavement over another.

IV. Highway System

It is not considered good practice to let a system designation influence the choice of paving type. Merits of the individual case and economics should prevail.

V. Conservation of Aggregates

This consideration may well have influence in choosing a paving type which will involve, in the total pavement structure, less of the scarce critical material than might be required by another type.

VI. Stimulation of Competition

It is desirable that monopoly situations be avoided, and that improvement in products and methods be encouraged through continued and healthy competition among industries involved in the production of paving materials.

VII. Construction Consideration

Such considerations as speed of construction, reduction of traffic maintenance during construction, ease of replacement, anticipated future widening, need for minimum of surface maintenance in highly congested locations, seasons of the year when construction must be accomplished, and perhaps others may have a strong influence on paving type selections in specific cases.

VIII. Municipal Preference, Participating Local Government Preference and Recognition of Local Industry

While these considerations seem outside of the realm of the highway engineer, they cannot always be ignored by the highway administrator, especially if all other factors involved are indecisive as to the pavement type to select.

IX. Traffic Safety

The particular characteristics of a wearing course surface, the need for delineation through pavement and shoulder contrast, reflectivity under highway lighting, and the maintenance of a non-skid surface as affected by the available materials may each influence the paving type selection in specific locations.

X. Availability of and Adaptation of Local Materials or of Local Commercially Produced Paving Mixes

The prevalence of adaptability of local materials may influence, or the availability of commercial produced mixes particularly on small projects, may influence the selection of pavement type.
Conclusion...

In the foregoing, there have been listed and discussed those factors and considerations which influence, to various degree, the determination of paving types. This has brought to the fore the need, in certain areas, for the development of basic information that is not available at present. It has also served to point out that, in general, conditions are so variable, and influences sufficiently different from locality to locality, to necessitate a study of individual projects in most instances.

The public, although a critical judge, cannot be expected to be aware of the variety of considerations which influence the decisions of a highway administrator.

Consequently, whatever factors control the selection of the pavement type should be made part of the project file and should carry the identity of the person or persons involved in the entire process of making recommendations and in making the final decisions. It is very important that the reasons for reaching the decision be fully documented in the project file.

The judgment of the decision may be disputed at some subsequent time, but if the reasons are fully outlined and documented, the matter becomes only a difference of opinion and the reasons of the person or persons, who are responsible for the decision, are a matter of record for any future review or investigation.
## APPENDIX II

### HISTORICAL DATA ATTRIBUTES

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### ABBREVIATIONS FOR SURFACE AND BASE TYPES

- **COM**: Composite
- **PCC**: Portland Cement Concrete
- **BSFC**: Bituminous Surface
- **TBM**: Traffic Bound Macadam
- **TBL**: Traffic Bound Limestone
- **GR**: Grade
- **DR**: Drain
- **GV**: Gravel
- **RA**: Rock Asphalt
- **WBM**: Water Bound Macadam
- **DGA**: Dense Graded Aggregate
- **CCB**: Calcium Chloride Stabilized
- **BSB**: Bitumen Stabilized Base
- **CLI**: Bituminous Concrete Class I
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STA 289600
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MEADE CO LINE
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JCT KY 55
NEAR CAMPBELLSBURG
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NEAR CAMPBELLSBURG
NEAR CAMPBELLSBURG
JCT KY 37
JCT KY 37
JCT KY 37
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JCT KY 138 NEAR ECL OF SLAUGHTERS
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SCL OF HANSON
SCL OF HANSON
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A0960017 JEND OF CONC PAY BLACK TOP NEAR BETHEL CHURCH
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A0960157 K0.5 MI N OF HARRISON CO LINE 3738.1 FT S OF FALMOUTH
A0960157 IHARRISON CD LINE 0.512 MI N OF HARRISON CO LINE SECL OF FALMOUTH
A0960157 HO.707 MI S OF SSECL OF FALMOUTH 2704.9 FT N OF HARRISON CO LINE
A0960157 E HARRISON CD LINE 3738.1 FT S OF FALMOUTH
A0960157 AHARRISON CD LINE SECL OF FALMOUTH
A0960237 MLOY US 27 NEAR BETHEL CHURCH N END OF LICKING R. RR, NEAR BUTLER
A0960237 LN END OF LICKING R. BR. E OF BUTLER-CAMPBELL CO LINE
A0960237 KJCT US 27 NEAR BETHEL CHURCH 3.919 MI TOWARD BUTLER
A0960237 KJCT US 27 NEAR BETHEL CHURCH N END OF LICKING RIVER BR
A0960237 AJCT US 27 NEAR BETHEL CHURCH 3.919 MI TOWARD BUTLER
A0960237 AJCT US 27 NEAR BETHEL CHURCH N END OF LICKING R BRIDGE
A0960237 AJCT US 27 NEAR BETHEL CHURCH 3.919 MI N OF JCT US 27
A0960237 HJCT US 27 NEAR BETHEL CHURCH 3.919 MI N OF JCT US 27
A0960237 TSOCL OF SOMERSET AT OAK HILL RD. JCT NEW US 27 AT BIRCHON
1000135 TSNW US 127 MCCREARY CO LINE
1000135 R1.322 MI. S OF SCL OF BURNSIDE MCCREARY CO LINE
1000135 GN END OF BURNSIDE REVISION JCT OF OLD AND NEW US 27
1000135 J1.731 MI NW OF NCL OF BURNSIDE SCL OF SOMERSET
A1000135 E1600 FT N OF CUMBERLAND SCL OF SOMERSET
B1000135 ES END OF TOLL BR AT NCL OF BURNSIDE 1600 FT N OF CUMBERLAND RIVER
1000135 CS END OF TOLL BR AT NCL OF BURNSIDE 1600 FT N OF CUMBERLAND RIVER
1000135 B1600 FT N OF CUMBERLAND RIVER SCL OF SOMERSET
1000335 NMO F N END OF PITMAN CREEK BRIDGE NCL OF BURNSIDE AT S END PITMAN CR
A1000335 GS END OF CUMBERLAND R BR 3785 FT N OF N END OF PITMAN BR
A1000335 FS.822 MI S OF BURNSIDE SCL OF BURNSIDE
A1000335 DS END OF CUMBERLAND R BR 3860 FT N OF N END OF PITMAN BR
A1000335 C345 FT S OF BURNSIDE SCL OF BURNSIDE
1000335 A .3860.74 FT N OF PITMAN N END BRG OVER CUMBERLAND RIVER
1000535 IJCT KY 80-W OF NCL OF SOMERSET JCT KY 1247 NEAR NORWOOD
1100535 HJCT NEW US 27 NEAR OAK HILL RD
1100535 G WCL SOMERSET CREEK BRG
1000535 D1.557 M1 N OF JCT UD 27
1000535 US 27...5 M1 S OF WCL SOMERSET
1001335 INCL OF BURNSIDE
1001335 ESCL OF BURNSIDE
1001335 ESCL OF BURNSIDE
1004535 FNCL OF SOMERSET
1004535 NWCL OF SOMERSET
1100126 DLOGAN CO LINE
1100126 CLLOGAN CO LINE
1100126 TENNESSEE STATE LINE
1110134 FF CORPORATE LIMITS OF CADIZ
A1110134 DFCL OF CADIZ
1110254 JE END OF CUMBERLAND RIVER BRIDGE
1110254 12.307 M1. W OF CUMBERLAND RIVER BR.
1110254 HWCL OF CADIZ
A1110254 6E END OF CUMBERLAND RIVER BRIDGE
A1110254 F9.022 M1 W OF WCL OF CADIZ
A1110254 BAR OVER TENN R AT EGGERNS FERRY
A1120018 FNCL OF BFDRED
A1120018 CJCT US 42 IN BFDRED
1120018 INCL OF BURNSIDE
1130267 END OF SHAWNEETOWN TOLL BRIDGE
1130267 END OF PROPOSED TOLL BRIDGE
A1130267 GOHTO RIVER
1130267 RTME ROCKS
1170209 ESCL OF DIXON
1170209 CHOPKINS CO LINE
1180100AKBY 92 JCT S OF WILLIAMSBURG
1180100AASCL OF WILLIAMSBURG
A1180100 TENNESSEE STATE LINE
A1180100 BEGINNING OF BLACKTOP NEAR SAXTON
A1180100 TENNESSEE STATE LINE
A1180100 LSAXTON
D1180100 L459 FT S OF SAXTON
E1180100 END OF BLACKTOP
1180100 TENNESSEE STATE LINE
1180100 H.489 M1 N OF TENN STATE LINE
1180100 H.376 M1 N OF TENN STATE LINE
1180100 G3.378 M1 S OF SAXTON
A1180100 BEGINNING OF BLACKTOP N OF JELLICO
A1180100 END OF BLACKTOP
1180100 O459 FT S OF SAXTON
1180100 JELLICO
A1180100 BSAXTON
1180100 ATENNESSEE STATE LINE
1180260 AAPP .45MI. N OF SAXTON SCHOOL
A1180260 HINT OLD US 25 NEAR JELLICO
1180260 GEND OF CONC AT SACK SCHOOL
1180260 FEND OF CONC AT SACK SCHOOL
A1180260 EINT OLD US 25 NEAR JELLICO
A1180260 DINT OLD US 25 NEAR JELLICO
1180260 C366 FT S OF ARCH CULVERT
1180260 R866 FT S OF ARCH CULVERT
A1180260 A0.489 M1 N OF TENN STATE LINE
1200095 INEW ECL OF VERSAILLES
1200095 GNEW ECL OF VERSAILLES
A1200095 EECL OF VERSAILLES
JCT OLD US 27
OLD US 27 NEAR BOURBON
JCT 80,15 M1 W OF NWCL SOMERSET
JCT KY80,1.501 N OF NWCL SOMERSET
SCL OF BURNIDE
S END OF CUMBERLAND RIVER BR.
S END OF CUMBERLAND RIVER BR.
JCT KY 80
NWCL OF SOMERSET
SW OF BADENSVILLE-REG OF PCC PAVING
SW OF BADENSVILLE-END OF CONCRETE
END OF RA
CHRISTIAN CO LINE
CHRISTIAN CO LINE
E END OF EGGERNS FERRY BRIDGE
E END OF CUMBERLAND RIVER BRIDGE
A1180100 M5.1 M1 S OF WILLIAMSBURG
END OF BLACKTOP NEAR SAXTON
SCL OF WILLIAMSBURG
SAXTON
459 FT S OF SAXTON
0.376 M1 N OF TENNESSEE STATE LINE
2.364 M1 N OF JELLICO
0.489 M1 N OF TENNESSEE STATE LINE
459 FT S OF SAXTON
END OF BLACKTOP NEAR SAXTON
459 FT S OF SAXTON
SAXTON
SCL OF WILLIAMSBURG
2.364 M1 N OF JELLICO
2113.2 FT N OF BR. OVER CLEAR FORK R.
APPROX. 0.45 M1 N OF SAXTON SCHOOL
2113.2 FT N OF CLEAR FORK BRIDGE
2113.2 FT N OF CLEAR FORK BRIDGE
689 FT N OF DOUBLE ARCH CULVERT
SPUR TO US 25-W
689 FT N OF DOUBLE ARCH CULVERT
SPUR TO US 25-W
NEAR SAXTON SCHOOL
W END OF SHANNON RUN BRIDGE
W END OF SHANNON RUN BRIDGE
W END OF SHANNON RUN BRIDGE
0310568 BRARREN CO LINE-SW OF PARK CITY
0301568 ABRARREN CO LINE-SW OF PARK CITY
0340744 LI64 INTER NEAR ECL OF LEXINGTON
0340744 KSCOTT CO LINE
0340744 J164 INTERCHANGE E OF LEXINGTON
0340744 IUS 60 INTERCHANGE E OF LEXINGTON
0340744 HJCT US 25 SCOTT CO LINE
0340744 GJCT IRON WORKS PIKE
0340744 FSCOTT CO LINE
0340744 EI600 FT S OF GRIMES MILL RD
0340744 DO 609 MI N ATHENS BOONESBORO RD
0340744 C JCT ROCK QUARRY RD S GRIMES MILL RD
0340744 BJCT RELOCATED US 25 STA 107600
0340744 AJCT ATHENS BOONESBORO RD E 175
0340804 HJCT RELOCATED US 25 299 FT W 164
0340804 GW END OF 175 INTERCHANGE N OF LEX
0340804 PRELOCATED HALEY AVON RD
0340804 EJCT ROUSTER RD S 164
0340804 NJCT ROUSTER RD
0340804 CJCT HUME RD 200 FT SE TO I64
0340804 PHEIME RD JCT 600 FT NW 164
0340804 AG 663 OF BRYAN STA RD
0370905 ESHELBY CO LINE
0370905 DE BANK OF KY RIVER
0370905 CIS 127
0370905 BUS 127
0370905 LO 3 MI E OF NEW US 127
0390473 CCCARROLL CO LINE
0390473 RAGARROLL CO LINE
0390473 AOSCARROLL CO LINE
0410434 QSCOTT CO LINE
0410434 NJCT SIPLE RD W HASON
0410434 MSDKCOTT CO LINE
0410434 L0 3 MI N HEEKIN RD
0410434 KKY 36 INTER AT WILLIAMSTOWN
0410434 JO 3 MI N HEEKIN RD
0410434 IC OF KY 22 BRIDGE AT DRY RIDGE
0410434 HW SIDE OF 175
0410434 GJCT KY 22 W 175
0410434 FJCT KY 22 W 175
0410434 ESTA 89364
0410434 NJCT SHERMAN MT ZION RD
0410434 NJCT CRITTENDEN MT ZION RD
0410434 NJCT CRITTENDEN-MT ZION RD
0410434 AO 3 MI N HEEKIN RD
0420773A0 W END OF BRIDGE OVER US 45
0420773A0 NJCT WITH MAYFIELD BY-PASS
0430225MRG 564 MI W OF HIG CLIFTY RD (KY720)
0430225MRG 564 MI W OF HIG CLIFTY RD (KY720)
0470069 AJCT US 31W S OF E-TOWN
0470129 FS END KYP
0470129 DS END KYP
0470129 CJCT 31W
0470129 BJ1 MI S END KYP
0470129 AJ1 MI S END KYP
0470144CRW SIDE OF KYP
0470144ACW SIDE KYP 0.8 MI S OF US 62
0470969WGO 33 MI NW OF 165
0470969J7CJ US 31W S OF E-TOWN
0500840 OS END GREEN RIVER HRG.-SW HARRODSBRKRN CO LINE
0500840 ES END GREEN RIVER HRG.-SW HARRODS661.6KI S KY474 INTER-W HORSE CAVE
0500840 DLARUE  CO  LINE
0500840 CLARUE  CO  LINE
0500840 CLARUE  CO  LINE
0500840 ALARUE  CO  LINE
0500840 ALARUE  CO  LINE
0501399 PAPERSTER  CO  LINE
0515389 PPSCCL  OF  HENDERSON
0520987 KOLDHAM  CO  LINE
0520987 JOLDHAM  CO  LINE
0520987 AOLDHAM  CO  LINE
0530799 JAFULTON  CO  LINE
0540045 PB11-164  WITH  MADISONVILLE  BY-PASS
0540045 PCCHRISTIAN  CO  LINE
0540790 WD1.218  MI  E  OF  KY  109
0540790 WCUMULLEN  CO  LINE
0560273 KECL  LOUISVILLE  AT  WATTERSON  EXPRESSWAY  BELT
0560273 H2454'  W  OF  BRECKENRIDGE  LANE
0560273 G637.02'  W  OF  WATTERSON  EXPRESSWAY
0560273 F637.02'  W  OF  WATTERSON  EXPRESSWAY
0560273 E477.3'  W  OF  OLD  MOSES  ROAD
0560273 CTUCKER  STA  RD  S  OF  PROPOSED  164
0560273 B2000  FT  W  OF  OUTER  LOOP
0560273 A448  FT  W  OF  ENGLISH  STA  RD
0560313 LNECL  OF  LOUISVILLE
0560313 KEND.  JEFFERSON  FREEWAY  INTERCHANGE
0560313 ENCL  OF  LOUISVILLE
0560313 CNECL  OF  LOUISVILLE
0560688 BT1700'  N  OF  WATTERSON  EXPRESSWAY
0560688 ASCL  OF  LOUISVILLE
0560898 TN  END  OF  US  60  INTERCHANGE
0560898 SSEND  OF  US  42  INTERCHANGE
0560898 RN  END  OF  US  65  INTERCHANGE
0560898 01900  FT  S  OF  US42
0560898 NN  END  OF  US  63  INTERCHANGE
0560898 K1700  FT  N  OF  US  60
0560898 IUS  60  1.5  MI  E  ST  MATHEWS
0560898 CSIS  31F  AT  GARDNER  LN
0560898 B922  FT  W  RRCKINRIDGE  LN
0560898 AJCT  US  31F  NEAR  GARDNER  LN
0568273 J150'  E  OF  SECOND  ST.  IN  LOUISVILLE
0568273 D0.5  MI  E  OF  NEW  ALBANY  BRG
0568313 AJCT  164, OHIO  ST.  IN  LOUISVILLE
0568313 AJCT  164, OHIO  ST.  IN  LOUISVILLE
0568313 AJCT  164, OHIO  ST.  IN  LOUISVILLE
0568368 B1700  FT  N  OF  WATTERSON  XWAY
0568798 FN  ENK.  KENNEDY  BRG
0568798 END  STRUCTURE  GREYECHELSTNUT  ST
0568798 NW  OF  ST  CATHERINE  ST
0568798 CARANDEIS  ST  FROM  BENDLEY  ST
0568798 BWOODbine  ST  LOUISVILLE
0568798 AWOODbine  ST  LOUISVILLE
0568898 QSE  END  OF  NEW  ALBANY  BRG
0568898 PUS  31W  AT  SHIVELY
0568898 MUS  31W  AT  SHIVELY
0568898 LUS  31W  AT  SHIVELY
0568898 JUS  31W  AT  SHIVELY
0568898 H1307  FT  E  OF  HARDSTOWN  RD  BRG
0568898 GE  CURB  LINE  PARK  BLVD
0568898 FINNER  BELT  LINE
0568898 EJCT  US  31W & 60  AT  SHIVELY
0568898 DJCT  US  31W & 60  AT  SHIVELY
S  END  GREEN  RIVER  BRG
NCL  OF  MUNFORDSVILLE-W  OF  US  31W
NCL  OF  MUNFORDSVILLE-W  OF  US  31W
1158'  S  BONNIEVILLE-HAMMONDVILLE  RD.
SCL  OF  HENDERSON,  S  OF  KY  812
JCT  US  41  BY-PASS
TRIMBLE  CO  LINE
TRIMBLE  CO  LINE
GRAVES  CO  LINE
WEBSTER  CO  LINE
S  END  WITH  US  41,  S  OF  MORTONVILLE
COWELL  CO  LINE
1.218  MI  E  OF  KY  109
0590315 VROONE CO LINE
0590315 OBEACHWOOD RD N OF 175
0590315 NBEACHWOOD RD S SIDE 175
0590315 MBEACHWOOD RD N SIDE 175
0590315 LBUTTERBILK RD
0590315 KBUTTERBILK RD
0590315 JRITCHIE AVE EXTENDING NW
0590315 HINTER DALE & SUMMIT IN CRESCENT PK
0590315 GERLANGER RD
0590315 FDONALDSON RD NE SIDE OF INTER
0590315 EJCT DONALDSONGERLANGER RD
0590315 DDONALDSON RD
0590315 C900 FT NE OF DONALDSON RD
0590315 BBONALDSON RD
0590315 ABORNE CO LINE
0590675 BRANT CO LINE
0590675 AGANT CO LINE
0597315 X600 FT S OF 5TH ST IN COVINGTON
0597315 NO.25M1 W OF US 25642 IN FT MITCH
0597315 UIENTER ARNOLD ST
0597315 TINTER 12TH ST
0597315 SINTER HIGHVIEW DR, 200 FT S OF 175
0597315 RN CURB ORCHARD RD
0597315 ORCHARD RD 306 FT SE OF 175
0597315 PO.25 MI W OF US 25642 IN FT MITCH
0597315 BD25 W OF US 25642 IN FT MITCH
0620661 CN END OF KY 224 INTERCHANGE
0620661 RN END OF KY 224 INTERCHANGE
0620661 AHARDIN CO LINE
0630246 RNW END ROCKCASTLE RIVER BRIDGE
0630246 AAPP 1.1MI. NW OF US25 CROSSING
0720911XACALDWEll CO LINE
0760281 G.791 M. S OF DUNCANNON ROAD
0760281 FN END BARNES MILL ROAD INTERCHANGE
0760281 DN END BARNES MILL RD. INTERCHANGE
0760281 CBYPASS RD 0.207 MI E 175
0760281 BBRAUNSMILL RD W OF 175 INTERCHANGE
0760281 AS END US 25 INTERCHANGE
0760831 OS END CLAYS FERRY BRG,FAYETTE CO LDS END US25 INTERCHANGE
0760831 CJCT US 25
0760831 BS END CLAYS FERRY BRIDGE
0760831 AJCT SIMPSON RD,E CLAYS FERRY INT.
0770720EAMORGAN CO LINE
0790483JCJCT WITH PROPOSED I24 S OF CULVERTY
0790483JAPP .2MI W OF JACKSON SCHOOL ROAD
0790483JAGRAVES CO LINE
0840182CBANDERSON CO LINE
0840182CAANDERSON CO LINE
0870557 KJCT WITH RELOCATED QUISENBERRY RD.
0870557 JUS 60 INTERCHANGE NE OF MT STERLING BATH CO LINE
0870557 I700* N IIF US 60
0870557 H700 FT W OF US60
0870557 GCLARK CO LINE
0870557 F180 FT L 164 STA 1200600
0870557 E180 FT R 164 STA 1034628.31
0870557 DGRASSY LICK RD
0870557 CPRIUllT
0870557 B200 FT L STA 833600 164
0870557 A2.75 M1 NE MT STERLING
0.25 MI W OF US 25642
NORDMAN LANE E OF BEGINNING
438 FT W TO SCHULTZ PROP
605 FT W OF BEACHWOOD RD
1192 FT NE OF BEGINNING
1210 FT E OF BEGINNING
INTER OF HIGH ST
1500 FT NE OF BEGIN PARALLEL 175
1410 FT SW OF BEGINNING 3980.7 FT E TO SCHWARTZ PROP
ERLANGER RD
418 FT SE PARALLEL TO DONALDON
220 FT S OF OLD WATSON RD
600 FT S OF VIDAX PROPERTY
ERLANGER RD
0.25 MI W OF US 25642
BOONE CO LINE
600 FT S OF 5TH ST IN COVINGTON
500 FT W
INTER PIKE ST
200 FT N OF 175
EXTENDING 796.2 FT NW
NEAR LESLIE AVE 294 FT NW OF 175
NEAR 5TH ST IN COVINGTON
NEAR 5TH ST IN COVINGTON
HART CO LINE
HART CO LINE
N END OF KY 224 INTERCHANGE
WHITTEY CO LINE
WHITTEY CO LINE
JCT US 62 E OF FODYVILLE
7.487 MI. N OF DUNCANNON ROAD
RUCKCASTLE CO LINE
N END BARNES MILL RD INTERCHANGE
KY 21 INTERCHANGE NEAR RFEA
0.086 MI N
EXTENDING NE ALONG W SIDE OF RAMP B
S END BANKSMILL RD INTERCHANGE
NS END US25 INTERCHANGE
0.136 MI NW OF BEGINNING
1.0 M1. N OF MCL OF RICHMOND
EXTENDING N 0.592 MI
E OF SALLYRVSIE NEAR KY 114
US 62 S OF CULVERT CITY
JCT WITH PROPOSED I24 S OF CULVERT
APP .2MI W OF JACKSON SCHOOL ROAD
ANDERSON CO LINE
APP .2 MI. W OF BATH CO LINE
BATH CO LINE
0.446 MI E OF BEGIN
700 FT W US60
US60 600 FT N BRIDGE 164
180 FT R 164 STA 1045600
180 FT L 164 STA 952600
180 FT L 164 STA 879600
JCT PRUITT RO
CLARK CO LINE
1180350 10.2 MI S OF SCL OF WILLIAMSBURG
1180350 H0.9 MI NW US 25 NEAR SAXTON
1180350 G4.070 MI N TENNESSEE STATE LINE
1180350 F4.070 MI N TENNESSEE STATE LINE
1180350 ERIVER RD NEAR END FRONTAGE RD 7
1180350 DUS 25 W SIDE OF I75
1180350 CKY 471 W SIDE OF I75
1180350 BJCT KY 471 W SIDE OF I75
1180350 A4.070 MI N TENNESSEE STATE LINE
1190603EAMOUNTAIN PKWY SE
1190603EO.7 MI NW OF CAMPTON
1190603EAPOWELL CO LINE
1200775CBANDERSON CO LINE
1200775CAANDERSON CO LINE

4.07 MI N OF TENNESSEE STATE LINE
0.701 MI NW OF BEGINNING
0.6 N BRG WOLF CREEK RD PLEASANT VLY TENNESSEE STATE LINE
0.16 MI N OF BEGINNING
RIVER RD 0.79 MI N OF BEGINNING
0.205 MI N
0.13 MI N OF TENNESSEE STATE LINE
TENNESSEE STATE LINE
310 FT NW OF OLD KY 15
MORGAN CO LINE
0.7 MI NW OF CAMPTON
JCT US 60 2.0 MI E OF VERSAILLES
JCT US 60 1.6 MI E OF VERSAILLES
### APPENDIX IV

#### MILEAGE DATA ATTRIBUTES

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APPENDIX V
COST OF HIGHWAYS

The generally accepted definition of annual highway costs contains factors for initial construction, maintenance, periodic resurfacing, overhead, and interest on initial expenditures. Annual cost factors have been combined in various equations so that annual road cost per mile (km) can be estimated.

One of the first equations was suggested by Agg (18) in 1929:

\[ C = r \left\{ \frac{A}{r} + \frac{B}{r} + \frac{E}{(1 + r)^n - 1} + \frac{E_1}{(1 + r)^{n_1} - 1} + \ldots \right\} \]

where
- \( C \) = total average annual road cost per mile,
- \( A \) = construction cost per mile,
- \( B \) = yearly maintenance cost (every year) per mile,
- \( E \) (or \( E_1 \)) = expenditures per mile for periodic maintenance every \( n \) (or \( n_1 \)) years (replacement is an E-value), and
- \( r \) = rate of interest in current financing.

In 1934, Johannesson (19) simplified Agg's equation by introducing a constant \( K = \frac{r}{(1 + r)^n - 1} \) as the multiplying factor for the \( E \)’s in Agg’s equation. Breed (2), also in 1934, introduced an approximate equation:

\[ C = \frac{(A + S)r}{2} + \frac{(A - S)n}{n} + B + E/n. \]

Breed introduced the term \( S \) for the estimated salvage value of the highway at the end of \( n \) years.

Bateman (20), in 1948, offered this equation:

\[ C_h = \frac{r}{l} + B + A_1 + A_2 + D \]

where
- \( C_h \) = annual cost of highway operation,
- \( l \) = value of highway or investment,
- \( A_1 \) and \( A_2 \) = annuities for periodic maintenance required at intervals for several years, and
- \( D \) = annual cost of administration.

The annuities can be expressed in terms of actual expenditures by

\[ A_1 = \frac{E_1 r}{((1 + r)^{n_2} - 1)} \]

and

\[ A_2 = \frac{E_2 r}{((1 + r)^{n_2} - 1)} \]

where \( E_1 \) = expenditure for periodic maintenance occurring every \( n_1 \) years and \( E_2 \) = expenditure for periodic maintenance occurring every \( n_2 \) years.

In 1963, Bullock (21) suggested the following equation:

\[ C = CRF_n \left\{ \frac{A + E_1 \text{PWF}_{n_1}}{n_1} + \frac{E_2 \text{PWF}_{n_2}}{n_2} - \frac{1}{Y/X} \right\} + \left( E_1 \text{PWF}_{n_1} + E_2 \text{PWF}_{n_2} \right)/X + \left( M + O + D \right) \]

where
- \( C \) = total annual cost per mile (1.61 km),
- \( CRF = \frac{r(1 + r)^n}{(1 + r)^n - 1} \) = capital recovery factor,
- \( n \) = analysis period (years),
- \( A \) = total construction and right-of-way cost per mile (1.61 km),
- \( E_1 \) = first resurfacing cost per mile (1.61 km),
- \( E_2 \) = second resurfacing cost per mile (1.61 km),
- \( n_1 \) = number of years after construction that future work is performed,
- \( Y \) = number of years from last resurfacing and end of analysis period,
- \( X \) = estimated life (years) of last resurfacing,
- \( M \) = total annual maintenance cost per mile (1.61 km),
- \( O \) = annual operation cost per mile (1.61 km),
- \( D \) = annual administrative and overhead cost per mile (1.61 km), and
- \( \text{PWF} \) = present worth factor, single payment, defined as \( 1/(1 + r)^{n_1} \).

A comprehensive relationship was offered in 1969 by Winfrey (22):

\[ C_T = - H \cdot U \]
where \( C_T \) = total annual economic cost of highway transportation,
\( H = \) total annual economic cost of the highway facility, and
\( U = \) total annual economic cost to the road user.

The term for the cost of the highway facility can be expanded to introduce the following:

\[
H = - I_a \cdot D \cdot O \cdot M
\]

where \( I_a = \) annual uniform capital cost of depreciation (return of capital) and vestcharge (return on capital),
\( D = \) annual administrative expense allocable to the highway or facility,
\( O = \) annual operating expense for traffic services, highway operations, and police services allocable to the highway of facility, and
\( M = \) annual maintenance expense for the physical components of the highway or facility.

The depreciation cost can be further expanded to

\[
I_a = (-1 + S)(CRF - r - n) \cdot iS
\]

\[
I_a = - I(CRF - r - n) + S(SF - r - n)
\]

where \( I = \) initial investment or construction outlay or the equivalent present worth of the initial investment plus subsequent investments,
\( S = \) estimated terminal value at the end of \( n \) years,
\( r = \) rate per year of vestcharge,
\( n = \) analysis period (years) or service life,
\( CRF = \) capital recovery factor, and
\( SF = \) sinking fund factor, \( i/(1 + i)^n - 1 \).

This equation may be modified to account for additional investments due to reconstruction or resurfacing in the following manner:

\[
I_a = - I_0 (CRF - r - n) + S(SF - r - n) - I_x(PWF - r - n)(CRF - r - n)
\]

where \( I_0 = \) initial investment at zero time,
\( S = \) terminal value from \( I_0 \) and \( I_x \) combined,
\( I_x = \) additional investment at age \( x \), and
\( PWF = \) single-sum present worth factor.

The final equation for the economic cost of highway transportation becomes

\[
C_T = - I(CRF - r - n) + S(SF - r - n) - K - G_K(GUS - r - n) - U(EUS - r - n)
\]

where \( K = D + O + M \) (combined for convenience),
\( GUS = \) equivalent uniform gradient factor = uniform period-end investment equivalent to the series of period-end increasing amounts,
\( EUS = \) equivalent uniform exponential increase factor = product of CRF and PWF, and
\( G_K = \) gradient increase per year.

Winfrey and Zellner (23) summarized these relationships for the annual cost of transportation in the following manner:

\[
TAC = ACC + AUC + AMC
\]

in which \( TAC = \) total annual transportation cost ($),
\( ACC = \) annual highway capital cost ($),
\( AUC = \) annual road-user time and running costs ($), and
\( AMC = \) annual highway maintenance cost ($).

Moyer and Lampe (6) used Baldock’s equation to study annual costs of flexible and rigid pavements of highways in California. Annual maintenance costs were found to range between $320 and $520 per mile ($198 and $323 per kilometer).

A detailed study of costs for both flexible and rigid pavements was completed recently by the Road Research Laboratory (25). Construction and maintenance costs were estimated from current contract costs and extrapolated to cover a period of 50 years. Cost factors were developed for a one-inch (2.5-cm) depth of pavement per one square yard (0.84 m²) of roadway surface. Four different structural designs for the two pavement types were standardized for use in the study. The classical engineering cost estimate was used as the basis for the study.

Methods of computing highway costs have been reviewed above. They range from relatively simple methods to the sophisticated method of Winfrey and Zellner (23). Cost components generally considered in the annual cost equations are:

a. initial construction costs,
b. maintenance costs,
c. surfacing and resurfacing (periodic only) costs,
d. overhead costs, and
Baldock extended the equations, using the capital recovery factor and present worth factor, to account for the value of the road over a specific period. In addition, the annual operating cost was considered. Breed also took into account the salvage value at the time of reconstruction. Winfrey's equation is probably the most inclusive and attempts to account for all reasonably relevant factors.

Annual maintenance cost is a relatively small part of the total annual cost of the highway facility. Moyer and Lampe indicated that California's average annual maintenance costs amounted to only 3 to 5 percent of the total annual pavement cost. This cost, though being small, is continuing and must be taken into consideration when determining annual road costs.

The service life of pavements must be considered properly to perform an annual cost analysis. The Federal Highway Administration statistically classifies pavements as being retired when they are resurfaced, reconstructed, abandoned, or transferred from one system to another. Baldock (21) indicated that the average life of a high-type bituminous concrete pavement was 16.8 years and for portland cement concrete pavement was 25.5 years. There is, however, a great difference in opinion on the service life because of the high variance in the resurfacing cycle and the definitions of service life and retirement used.

An average pavement life of 16 years for bituminous concrete and 25 years for portland cement concrete might seem reasonable to some but not to others. A pavement should not be "retired" before or after resurfacing; it has a residual value.