NCHRP PROJECT 10-75

RESEARCH REPORT

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CHAPTER 1 – INTRODUCTION

1.1 BACKGROUND

Pavement-type selection is one of the more challenging engineering decisions that highway administrators face today. They must balance issues of both short- and long-term performance with initial and long-term costs, as well as highway user impacts. When estimated over the life span of a pavement system, there is a certain level of risk arising from the variations in performance, costs, and vehicular traffic. These challenges are further compounded by the competitive nature of the pavement industry. Therefore, highway administrators must have a balanced and transparent process for making pavement-type selections that objectively considers both flexible and rigid pavement options representing the best solution on a specific project or roadway.

The dilemma facing the highway engineer or administrator can be summarized best by the following quote from the American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures* (1993):

> "The selection of pavement type is not an exact science but one in which the highway engineer or administrator must make a judgment on many varying factors such as traffic, soils, weather, construction, maintenance, and environment.
>
> The selection process may be facilitated by comparison of alternative structural designs for one or more pavement types using theoretical or empirically derived methods. However, such methods are not so precise as to guarantee a certain level of performance from any one alternate or comparable service for all alternatives.
>
> Also, comparative cost estimates can be applied to alternate pavement designs to aid in the decision-making process. The cost for the service of the pavement should include not only the initial cost but also subsequent cost to maintain the service level desired. It should be recognized that such procedures are not precise since reliable data for maintenance, subsequent stages of construction, or corrective work and salvage value are not always available, and it is usually necessary to project costs to some future point in time. Also, economic analyses are generally altruistic in that they do not consider the present or future capabilities of the contracting agency."

1.2 CURRENT GUIDANCE ON PAVEMENT-TYPE SELECTION PROCESS

AASHTO's current guidance on pavement-type selection is found in Appendix B of the *AASHTO Guide for Design of Pavement Structures* (AASHTO, 1993). Figure 1 outlines this process, which most highway agencies follow, in whole or in part. The following sections discuss each of the steps in the process, current weaknesses, and examples where improvements can be made.

Selection of Alternative Strategies and Consideration of Overriding Factors

Most agencies consider pavement-type alternatives based on their past practices. In many cases, the primary reason for accepting or eliminating a certain pavement type seems to be based on its past performance in the area of the project. What appears to be lacking in the process illustrated in Figure 1 is a formal mechanism for the systematic identification and evaluation of alternate strategies. The process also should incorporate improvements in materials and/or design to address the problems of poor performance. The participation of stakeholders such as the paving industry and the research community also is vital to this process.

In addition to past performance, several other factors dictate the consideration of alternatives at the project level. Examples include the type of adjacent pavement, district preference or experience, foundation factors, weather, stimulation of competition, and traffic. Prudent consideration of these factors is essential to the decision making process.

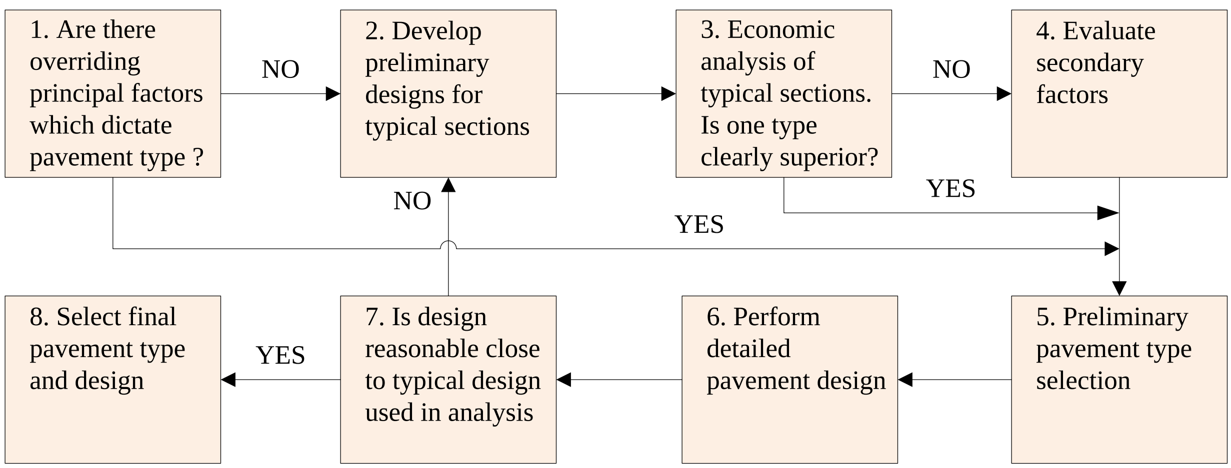

Figure 1. Pavement-type selection process in the AASHTO 1993 Guide.

Structural Design and Life Cycle Strategies of Alternatives

While most state Departments of Transportation (DOTs) use standard methodologies for pavement design, critical issues centering on the design equivalency of alternatives need to be addressed. Non-equivalency results from factors such as the use of different design lives, different factors of safety, and differences in performance requirements. The application of sound design approaches, such as a mechanistic-empirical design framework, provides a fundamental basis for defining “equivalency.” These methods aid in addressing past performance issues, evaluating new designs and materials, and estimating the timing of future rehabilitation actions.

Life cycle strategies of alternatives entail identifying the type and timing of maintenance and subsequent rehabilitation activities to ensure desired level of performance over the analysis period. Traditionally, historical performance data from the agency’s pavement management system have been used to identify life cycle strategies and their expected service lives. While this approach generally is rational, the process should ensure such strategies reflect the anticipated performance of a particular pavement type using representative and reliable historical data. If the material/structural designs of a pavement type under consideration are much

different from those available from historical data, then appropriate adjustments must be made. The process also should accommodate changes in technologies, processes, and funding levels that change over time.

Economic Analysis of Alternative Strategies

Life cycle cost analysis (LCCA) is used to determine the cost-effectiveness of pavement types. Agencies typically select an alternative with lowest life cycle cost as the preferred pavement type or consider two or more alternatives as cost equivalent when their life cycle costs are within a specific percentage (usually between 5 and 20, as determined by individual agencies).

While agencies tend to select or eliminate alternatives based on their life cycle cost estimates, it is important to take other economic and non-economic factors into consideration, such as the funding levels, overall system needs, frequency of future interventions, and sustainability. The selection process should facilitate incorporating these factors holistically.

Non-economic Analysis of Alternative Strategies

Several non-economic factors are considered to make the final pavement-type determination, such as scope of project, adjoining pavement, constructability, sustainability, designer and contractor experience, traffic control, and availability of materials. Historically, this evaluation has been subjective. The process lacks a systematic approach where both economic and non-economic factors can be weighed to reflect the agency's goals and project requirements.

Alternate Bidding

Alternate bidding is a procurement process where the contractor is permitted to select between two or more designs provided by the agency. Unlike traditional low-bid contracts, the alternate bidding process allows the agency to have more choices in pavement-type selection, and thus stimulate competition in the paving industry. This process is believed to result in cost savings for the agency, given the fact that large fluctuations in material costs can occur between the time of design and the bid letting.

While most agencies have found this procedure advantageous, they have experienced difficult issues, often contentious and some yet to be resolved, in developing equivalent alternatives. The equivalency of pavement-type alternatives is one of the primary factors in making the decision to utilize alternate bidding. As noted above, most agencies consider pavement types as equivalent when their life cycle costs are within a specific percentage of one another. This approach has triggered disagreement among various stakeholders over the selection of inputs for conducting LCCA, such as the design life assumptions, maintenance and rehabilitation strategies, discount factors, and the use of salvage value.

Therefore, a new approach is necessary to identify alternatives whose economic or non-economic factors would not foster any apparent bias in selecting one alternative over others. Furthermore, the process should be transparent and largely acceptable to stakeholders for its successful application.

1.3 RESEARCH OBJECTIVES

The overall objective of this project is to develop a Guide for Pavement-Type Selection. The guide shall include processes for consideration in making decisions regarding pavement-type selection, as well as agency-based (decision internal to the highway agency) and contractor-based (selection made by the contractor using criteria stipulated by the agency) processes.

1.4 RESEARCH SCOPE

Phase I of the project involved gathering, summarizing, and evaluating a large quantity of information on the pavement-type selection processes currently being used by States and international highway agencies. This information was gathered using questionnaires sent to state DOTs and industry groups. Any information not obtained through the questionnaires, especially on pavement-type selection in alternative contracting projects, was obtained through online literature searches. The collected information was evaluated to identify best practices for inclusion in the pavement-type selection process. Based on the findings of this evaluation, a model selection process is proposed for inclusion in the Guide for Pavement-Type Selection.

The key steps in the proposed process for an agency-based pavement-type selection include:

1. Identify of a pool of alternatives.
2. Identify feasible alternatives for a project.
3. Develop pavement life cycle strategies for each alternative.
4. Perform LCCA.
5. Evaluation using economic and non-economic factors.
6. Make final selection of the preferred alternative(s).

In traditional design-bid-build projects, an agency-based selection process typically is used. In alternative contracting, the roles and responsibilities of agencies, contractors, and designers change from traditional paradigms, resulting in the shift of risk allocation from agencies to contractors. Since the agency–contractor relationship changes with various contracting scenarios, this variable risk structure provides the necessary backdrop for understanding pavement-type selection in such scenarios. The contractor can follow the agency-based process with appropriate adjustments commensurate with their risks. In contractor-based selection, the contract provisions of the project serve as a common language and a working relationship between the parties.

1.5 REPORT ORGANIZATION

This report is organized into nine chapters; which are described below.

Chapter 1 provides the background information, including the key components of the current pavement-type selection process, current weaknesses, and examples where improvements can be made.

Chapter 2 presents the key findings of the survey and literature searches conducted in Phase I of this project. This chapter summarizes current agency practices for formal pavement-type selection, LCCA, alternate pavement-type bidding, and alternative contracting. Appendix A presents flow charts and descriptions of the current pavement-type selection processes used by responding agencies. Appendix B presents case studies of alternate pavement-type bidding and alternative contracting projects.

Chapter 3 provides an overview of the pavement-type selection process, including a flow chart outlining the entire process. The pavement-type selection guide developed as part of this project addresses agency-based selection for traditional design-bid-build and alternate pavement-type bidding projects, as well as contractor-based selection for design-build and warranty projects.

Chapter 4 outlines the steps to identify and evaluate potential pavement alternatives that should be considered in the pavement-type selection process. This chapter also presents a discussion on developing strategies for each alternative to sustain the desired performance level over the pavement's life cycle.

Chapter 5 describes LCCA, including establishing an LCCA framework, estimating initial and future costs, computing life cycle costs, and analyzing and interpreting the results of both deterministic and probabilistic analysis.

Chapter 6 provides detailed guidance on the selection of preferred alternatives based on the evaluation using economic and non-economic factors. This chapter also provides guidance on the application of an alternative preference screening matrix in selecting the preferred pavement type. Appendix C illustrates the application of the screening matrix with an example.

Chapter 7 presents a discussion of alternate bidding. On these projects, the agency develops the alternatives and specifies them in the bid document, and the contractor must choose one of the agency-provided alternatives. This chapter discusses the key steps required to facilitate successful implementation of the procedure.

Chapter 8 outlines the processes for contractor-based pavement selection on design-build and long-term warranty projects. For these projects, contractors are responsible for all or portions of the pavement design and selection processes. Generally, the project criteria require the contractor to follow processes similar to the process followed by the agency for design-bid-build processes. However, this may be modified if the contractor provides extended warranties or assumes the operation and maintenance responsibility.

Chapter 9 presents the case studies for agency-based and contractor-based type selection.

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CHAPTER 2 – OVERVIEW OF CURRENT PAVEMENT-TYPE SELECTION PRACTICES

2.1 QUESTIONNAIRE SURVEY OF EXISTING PRACTICE

In Phase I of this project, a survey was conducted to gather information of the current pavement-type selection processes used by state DOTs. A questionnaire was developed in Microsoft Excel, and an e-mail request was sent to each state DOT's pavement manager requesting that the questionnaire be completed. To gain as large a sample as possible, a second e-mail request was sent to the States not responding to the first request, and this was followed up with a telephone request to those States that did not respond to the e-mail requests. In addition, the research team visited the web sites of various state DOTs to review available policy documents.

The questionnaire asked the state DOTs to provide an electronic copy of their pavement-type selection procedures, LCCA procedures, and samples of contract documents for projects including contractor pavement-type selection. The questionnaire included questions on how certain factors (pavement performance life, discount rate, agency cost) were developed and other information that was not always apparent in the operational documents. Also requested was information on planned changes to type selection procedures and on-going research related to type selection and LCCA.

Limited information was received regarding the contractor pavement-type selection process. To supplement this information, the research team conducted extensive Internet searches to locate current research and contract documents issued by the agencies for design-build, long-lease and long-term warranty projects. The Federal Highway Administration (FHWA) Special Experimental Project No. 14 (SEP-14) web site also was utilized.

A brief questionnaire also was sent to the state paving industry associations requesting their feedback on the pavement-type selection procedures used in their respective states. Responses were received from eight industry associations.

2.2 KEY SURVEY FINDINGS

Survey responses were received from the 35 States shown in Figure 2. The information gathered was reviewed, evaluated, and summarized. The findings also were utilized in preparing a work plan for developing the Guide for Pavement-Type Selection.

2.2.1 Agencies with Formal Pavement-Type Selection

Table 1 and Table 2 present the general aspects and the key steps involved in the agencies' selection process, respectively. Of the 35 respondents, 22 have a formal process that requires the consideration of alternative pavement types on major new and reconstruction projects. LCCA is required in 21 of these 22 States. Nine States have informal procedures which they apply optionally on a case-by-case basis, while four do not have a documented procedure. Four of the

States not having formal type procedures generally build only hot mix asphalt (HMA) pavements.

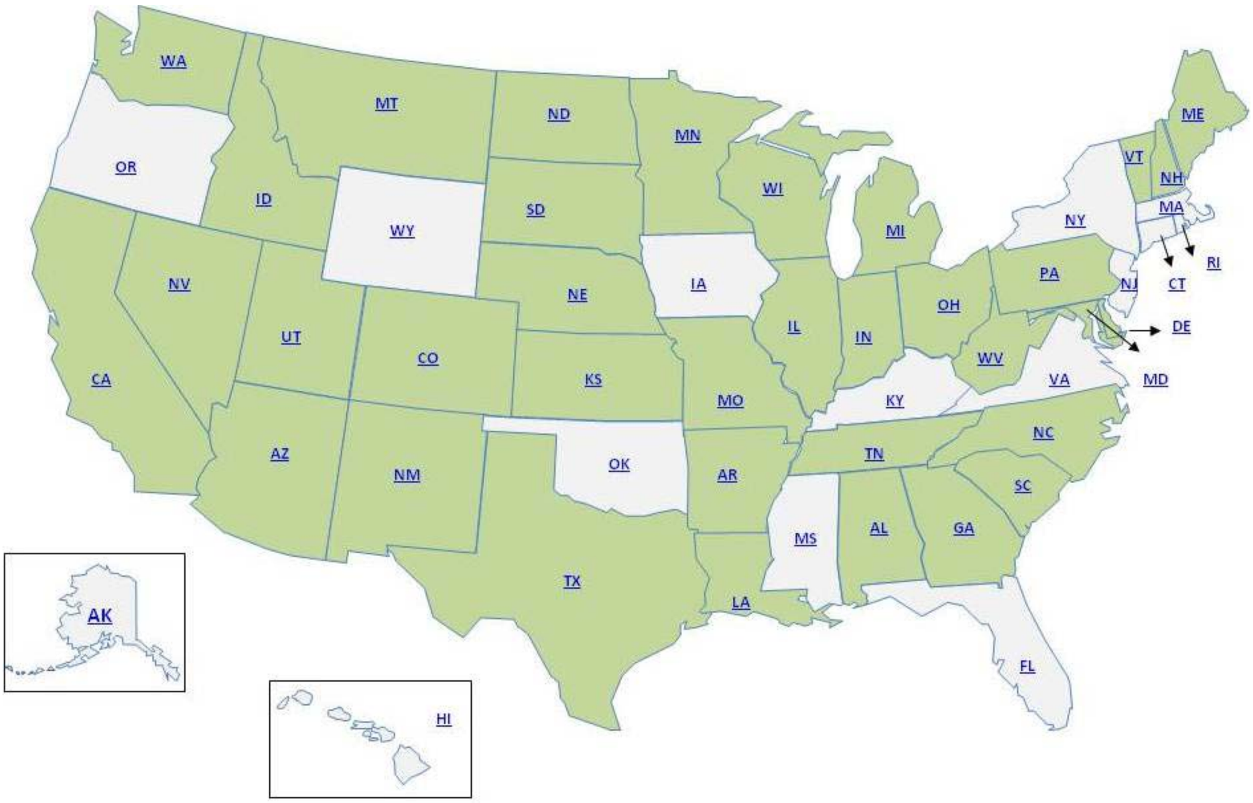

Figure 2. State DOTs responding to the survey.

Table 1. Pavement-type selection procedures.

State	Pavement Events Requiring Type Selection			Current Pavement-Type Selection Procedure			
	New Const	Re-Const	Rehab	Length of Time Current Procedure Has Been Used, years	Procedure Modified in Last 5 Years?	Modifications to Current Procedure Underway?	Number of Projects Using Alternate Bidding to select Pavement-Type
Alabama	Yes	Yes	No	≥10	Yes	No	<1
Alaska							
Arizona[1]	Yes[1]	Yes[1]	Yes[1]	23	No	No	0
Arkansas	Yes	Yes	Yes	10	Yes	No	NR
California	Yes	Yes	Yes	2	No	No	0
Colorado	NR	NR	NR	NR	NR	NR	Considering 1
Connecticut							
Delaware	NR	NR	NR	NR	NR	NR	0
Dist. of Columbia							
Florida							
Georgia	Yes	Yes	Yes	5	Yes	Yes	NR
Hawaii							
Idaho	Yes	Yes	Yes	≥20	Yes	Yes	1
Illinois	Yes	Yes	No	≥20	No	Yes	0
Indiana	Yes	Yes	Yes	2	Yes	Yes	NR
Iowa							

Table 1. Pavement-type selection procedures.

State	Pavement Events Requiring Type Selection			Current Pavement-Type Selection Procedure			
	New Const	Re-Const	Rehab	Length of Time Current Procedure Has Been Used, years	Procedure Modified in Last 5 Years?	Modifications to Current Procedure Underway?	Number of Projects Using Alternate Bidding to select Pavement-Type
Kansas	Yes	Yes	Yes	≥30	Yes	Yes	1
Kentucky							
Louisiana	Yes	Yes	NR	NR	NR	NR	44
Maine[2]	No[2]	No[2]	No[2]	N/A	N/A	N/A	0
Maryland	Yes	Yes	No	3	Yes	No	0
Massachusetts							
Michigan	Yes	Yes	Yes	10	No	No	0
Minnesota	Yes	Yes	No	≥15	Yes	No	0 (In the future)
Mississippi							
Missouri	Yes	Yes	Yes	4	Yes	No	>100
Montana[3]	No[3]	No[3]	No[3]	N/A	N/A	Yes	1
Nebraska[4]	N/A[4]	N/A[4]	N/A[4]	N/A	N/A	N/A	Several
Nevada[5]	Yes[5]	No	No	12	No	Yes	NR
New Hampshire	Yes	Yes	Yes	10	No	Yes	0
New Jersey							
New Mexico[6]	Yes[6]	Yes[6]	Yes[6]	>5	Yes	Yes	0
New York							
North Carolina	Yes	Yes	No	18	No	No	4 to 5
North Dakota	Yes	Yes	Yes	30	No	No	0
Ohio	Yes	Yes	Yes	4	Yes	No	2
Oklahoma							
Oregon							
Pennsylvania	NR	NR	NR	NR	NR	NR	2 to 3
Puerto Rico							
Rhode Island							
South Carolina	Yes	Yes	No	5	Yes	Yes	0
South Dakota	Yes	Yes	Yes	14	No	No	0
Tennessee[7]	Yes[7]	Yes[7]	Yes[7]	20	No	Yes	1
Texas[8]	Yes[8]	Yes[8]	NR	NR	Yes	Yes	0
Utah	Yes	Yes	No	Few	Yes	No	0
Vermont	Yes	Yes	No	≥10	Yes	Yes	0
Virginia							
Washington	Yes	Yes	No	5	No	No	0
West Virginia	Yes	Yes	Yes	5	No	No	0
Wisconsin	Yes	Yes	Yes	≥15	Yes	Yes	0
Wyoming							

[1] Arizona does not have a formal process for pavement-type selection. However, guidelines are provided in the state's *Preliminary Engineering and Design Manual*.
[2] No selection process, since they build only HMA.
[3] Montana does not have a formal policy for pavement-type selection since they have historically been a flexible pavement state. However, due to recent asphalt price escalation, they are performing informal pavement-type selection.
[4] Nebraska does not have a formal procedure. The decision is still based on funding, constructability, traffic, life cycles.
[5] The Nevada DOT Director and the Principal Materials Engineer are responsible for type selection. While an LCCA may be made, it is not always considered in the final selection, which "is mostly a political decision."
[6] New Mexico's procedure is fairly informal. Selection is made by a team from the district and pavement design.
[7] Tennessee's procedure not documented and is not required for all projects.
[8]In Texas, type selection is ultimately at the District's discretion
NR = No response.
N/A = Not applicable.

Table 2. Pavement-type selection factors.

State	Process Steps Included			Economic and Non-economic Factors Considered?	Type Selection Committee Recommends or Selects?
	Alternative Designs Required?	LCCA Performed?	LCCA Has Significant Impact?		
Alabama	Yes	Yes	If > 10%	Yes	No
Alaska					
Arizona	Optional	Optional	Considered	Optional	No
Arkansas	Yes	Yes		Yes	No
California	Yes	Yes	10%	Yes	No
Colorado	Yes	Yes	If > 10%	Yes	Yes
Connecticut					
Delaware	Optional	Optional		??	No
Dist. of Columbia					
Florida					
Georgia	Yes	Yes	NR	Yes	No
Hawaii					
Idaho	Yes	Yes	Considered	Yes	No
Illinois	Yes	Yes	If > 10%	Yes	Yes
Indiana	Yes	Yes	Considered	Yes	Yes
Iowa					
Kansas	Yes	Yes	Considered	Yes	Yes
Kentucky					
Louisiana	Yes	Yes	Considered	Yes	Yes
Maine	No	No	No	No	No
Maryland	Yes	Yes	If>10%	Yes	Yes
Massachusetts					
Michigan	Yes	Yes	Least LCCA Selected by Law		No
Minnesota	Yes	Yes	Yes	Yes	No
Mississippi					
Missouri	Yes	Yes	Alt bids	No	No
Montana	Optional	Optional	Optional	Optional	No
Nebraska	Optional	Optional	>15%	Optional	No
Nevada	Optional	Optional	No		No
New Hampshire	No	No			
New Jersey					
New Mexico	Optional	Optional	Optional	Optional	No
New York					
North Carolina	??	??	??	Yes	Yes
North Dakota	Optional	No	No	Optional	No
Ohio	Yes	Yes	If>10%	Yes	Yes
Oklahoma					
Oregon					
Pennsylvania	Yes	Cost > $15M	If >10%	NR	No
Puerto Rico					
Rhode Island					
South Carolina	Yes	Yes	Yes	Yes	Yes
South Dakota	Yes	No	No	Yes	Yes
Tennessee	Optional	Optional		Yes	
Texas	Optional	Optional	No	Optional	No
Utah	Yes	Yes	Considered	Yes	No
Vermont	No				
Virginia					
Washington	Yes	Yes	If >15%	Yes	Yes
West Virginia	Yes	Yes	Considered	??	No
Wisconsin	Yes	Yes	If >5%	Yes	Yes
Wyoming					

Agencies' formal selection procedures generally follow one of the following four processes (see Figure 3 through Figure 6):

Method A: Specific criteria are used for selecting the preferred pavement type based on the results of LCCA. These States stipulate the pavement types whose difference in life cycle costs exceed a specified amount (ranging from 5 to 20 percent) of the lowest cost alternative.

Method B: The law requires selection of the alternative with the lowest LCC.

Method C: LCCA may be performed, but there are no specific criteria for consideration of the results. The decision is made by the agency's pavement-type selection committee (PTSC).

Method D: The fourth pavement-type selection method is the process generally used if alternate bidding is used to make the final type selection.

The pavement-type selection processes used by each state DOT are detailed in Appendix A.

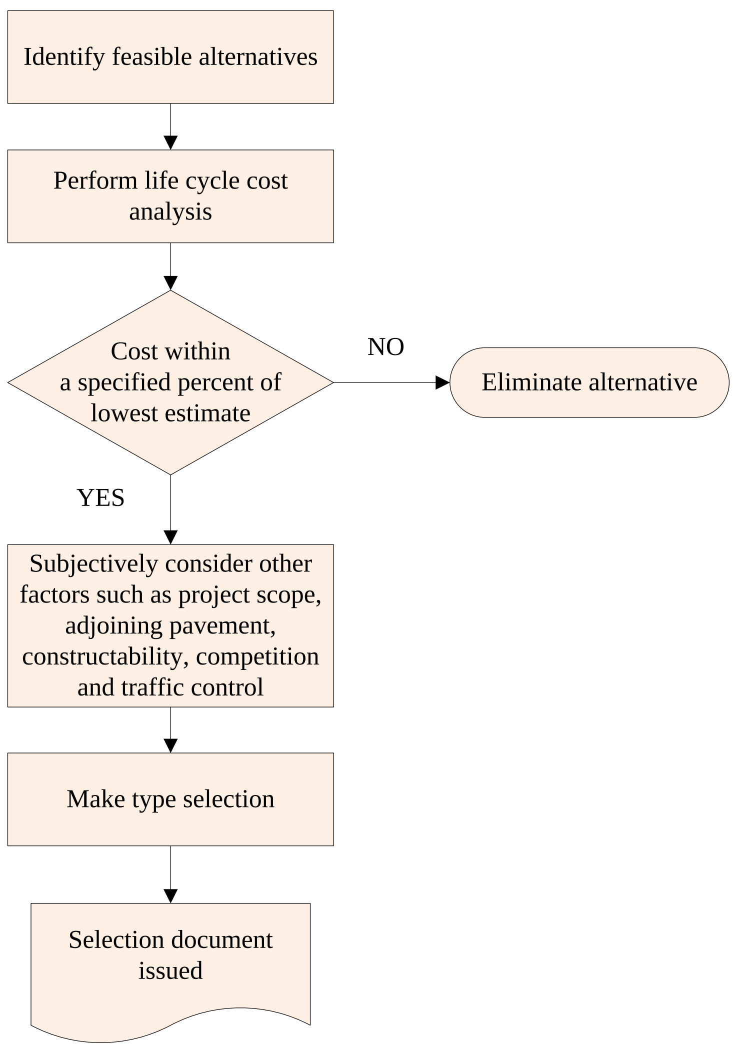

Figure 3. Pavement-type selection method A.

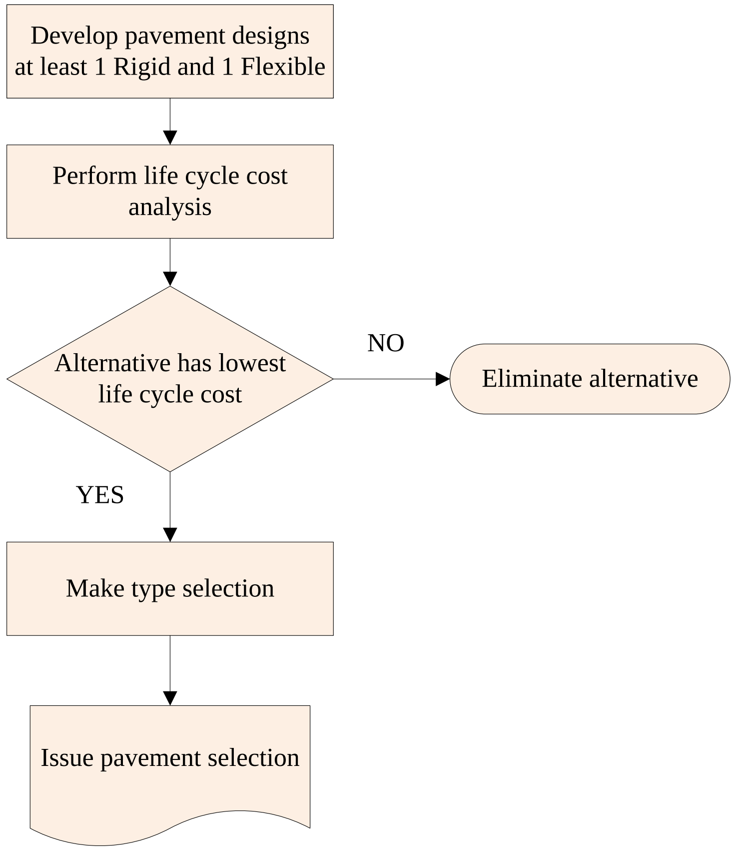

Figure 4. Pavement-type selection method B.

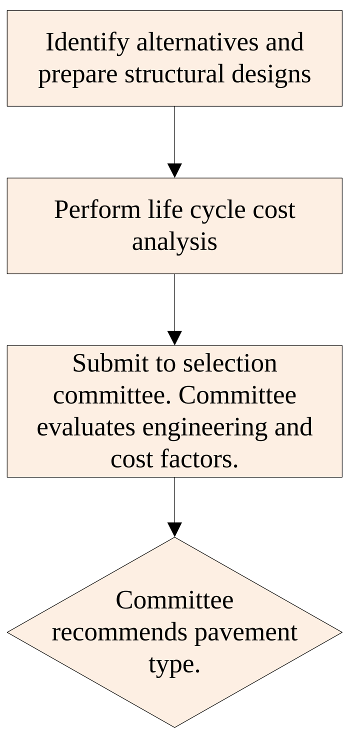

Figure 5. Pavement-type selection method C.

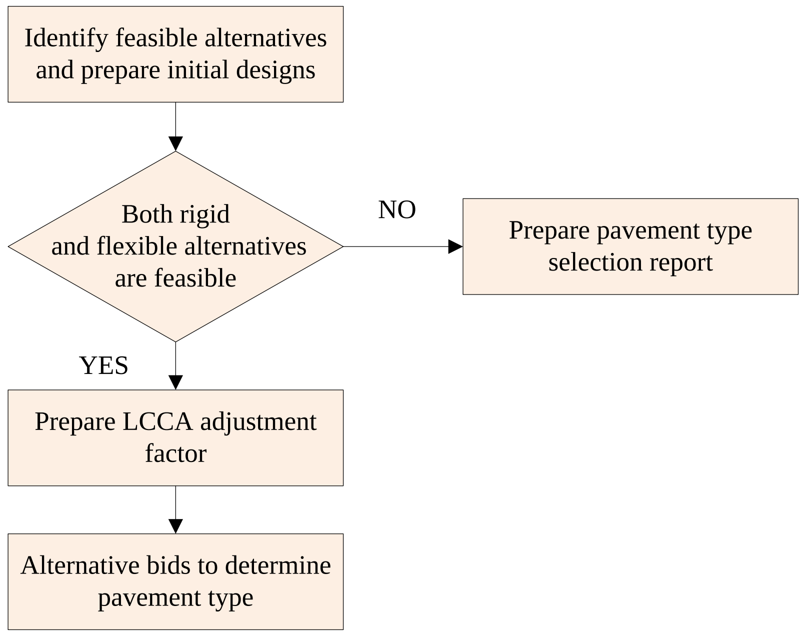

Figure 6. Pavement-type selection method D.

2.2.2 LCCA Practices of State Agencies

Table 3 summarizes the LCCA approaches used by the responding States. The key findings are as follows:

- Twenty-nine of the 35 responding States perform LCCA for new construction /reconstruction projects. Thirteen States perform LCCA for rehabilitation projects.
- Twenty-two of the 29 States have formal LCCA procedures.
- Twenty-six States use a deterministic approach for LCCA, while six utilize a probabilistic approach, and three States indicated they use both.
- Fourteen States consider road user costs. Of these States, most focus on the time delay and vehicle operating cost (VOC) components associated with work zones. In addition, five of these States combine user costs with agency costs to generate a total life cycle cost, while the other eight States keep the two costs separate.
- Twenty-four States compute the Net Present Value (NPV), ten States compute Equivalent Uniform Annual Cost (EUAC), and five States compute both.
- Most States use either a custom-developed spreadsheet or the FHWA probabilistic LCCA program RealCost.
- Most States use the Office of Management and Budget (OMB) Circular A-94 or the FHWA recommendation for establishing discount rates, while one State has a regulatory requirement (see Table 4).
- The analysis periods used range from 20 to 60 years (see Figure 7 for a breakdown).
- About half of the States include salvage value in the LCCA computation. Most use the prorated remaining life method for computing salvage, and a few use the residual/recyclable value method.

Table 3. State DOT LCCA procedures.

State	LCCA Performed?	LCCA Approach					LCCA Package Used				
		Net Present Value	Equivalent Uniform Annual Cost	Determini-stic	Probab-ilistic	User Costs	State-Developed Spreadsheet/ Software?	FHWA Probabilistic Spreadsheet *RealCost*	State-Customized Version of *RealCost*	Proprietary/ Industry Software	AASHTO DARWin
Alabama	Yes	Yes	No	Yes	No	No	No	No	No	No	Yes
Alaska											
Arizona	Optional	Yes	No	Yes	No	Yes	No	Yes	No	No	No
Arkansas	Yes	Yes	No	Yes	No	No	Yes	No	No	No	No
California	Yes	Yes	No	Yes	No	Yes	No	No	Yes RealCost (Deterministic)	No	No
Colorado	Yes	Yes	No	No	Yes	Yes	No	Yes	No	No	Yes
Connecticut											
Delaware	Optional	No	Yes	Yes	Yes	Yes	No	Yes	No	No	No
Dist. of Columbia											
Florida											
Georgia	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No
Hawaii											
Idaho	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	No
Illinois	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No
Indiana	Yes	Yes	Yes	No	Yes	No	No	Yes	No	No	No
Iowa											
Kansas	Yes	Yes	No	Yes	No	Yes	Yes	No	No	No	No
Kentucky											
Louisiana	Yes	Yes	No	Yes	No	Yes	No	No	Yes	No	No
Maine	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maryland	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No	No
Massachusetts											
Michigan	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	No
Minnesota	Yes	Yes	No	Yes	No	No	Yes	No	No	No	No
Mississippi											
Missouri	Yes	Yes	No	Yes	No	No	Yes	No	No	No	No
Montana	Optional	Yes	No	Yes	No	No	Yes	No	No	No	No
Nebraska	Optional	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Nevada	Optional	Yes	No	Yes	No	No	Yes	No	No	No	No
New Hampshire	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3. State DOT LCCA procedures.

State	LCCA Performed?	LCCA Approach					LCCA Package Used				
		Net Present Value	**Equivalent Uniform Annual Cost**	**Determini-stic**	**Probab-ilistic**	**User Costs**	**State-Developed Spreadsheet/ Software?**	**FHWA Probabilistic Spreadsheet *RealCost***	**State-Customized Version of *RealCost***	**Proprietary/ Industry Software**	**AASHTO DARWin**
New Jersey											
New Mexico	Optional	Yes	No	Yes	No	Yes	Yes	No	No	No	No
New York											
North Carolina	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No
North Dakota	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ohio	Yes	Yes	No	Yes	No	No	Yes	No	No	No	No
Oklahoma											
Oregon											
Pennsylvania	Cost > $15M	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No
Puerto Rico											
Rhode Island											
South Carolina	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No
South Dakota	No	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Tennessee	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes
Texas	Optional	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Utah	Yes	Yes	No	Yes	No	No	Yes	Yes	No	No	No
Vermont		Yes	No	Yes	No	Yes	No	Yes	No	No	Yes
Virginia											
Washington	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No
West Virginia	Yes	Yes	No	Yes	No	No	No	No	No	No	Yes
Wisconsin	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No
Wyoming											

NR = No response.
N/A = Not applicable.

Table 4. Discount rate use in LCCA.

State	Discount Rate Used for LCCA, percent	Basis for Establishing Discount Rate			
		US Office of Management & Budget Circular A-94	State Statutory Requirement	State or FHWA Recommendation	Other
Alabama	4	Yes	No	No	---
Alaska					
Arizona	4	Yes	No	No	---
Arkansas	3.8	No	No	No	Estimated
California	4	Yes	No	Yes	--
Colorado	3.3 (mean) 0.22 (std dev)	Yes	No	No	---
Connecticut					
Delaware	4	No	No	Yes	---
Dist. of Columbia					
Florida					
Georgia	3	Yes	No	No	---
Hawaii					
Idaho	4	No	No	Yes	---
Illinois	3	NR	NR	NR	NR
Indiana	4	No	No	Yes	---
Iowa					
Kansas	3.2	No	No	Yes	---
Kentucky					
Louisiana	4	No	No	Yes	---
Maine	N/A	N/A	N/A	N/A	N/A
Maryland	3	No	No	No	Unknown
Massachusetts					
Michigan	2.8	Yes	No	No	---
Minnesota	3.1	No	No	No	Estimating Office
Mississippi					
Missouri	3 to 4	Yes	No	No	---
Montana	3	No	No	Yes	---
Nebraska	NR	NR	NR	NR	NR
Nevada	4	No	No	Yes	---
New Hampshire	N/A	N/A	N/A	N/A	N/A
New Jersey					
New Mexico	3	No	No	No	Unknown
New York					
North Carolina	4	No	No	Yes	---
North Dakota	N/A	N/A	N/A	N/A	N/A
Ohio	2.8	Yes	No	No	---
Oklahoma					
Oregon					
Pennsylvania	6	No	Yes	No	---
Puerto Rico					
Rhode Island					
South Carolina	NR	Yes	No	No	---
South Dakota	NR	NR	NR	NR	NR
Tennessee	4	No	No	No	Comparison with other States in the region
Texas	N/A	N/A	N/A	N/A	N/A
Utah	4	NR	NR	NR	NR
Vermont	4	No	No	Yes	---
Virginia					
Washington	4	No	No	Yes	---
West Virginia	NR	Yes	No	Yes	---
Wisconsin	5	No	No	Yes	---
Wyoming					

NR = No response.
N/A = Not applicable.

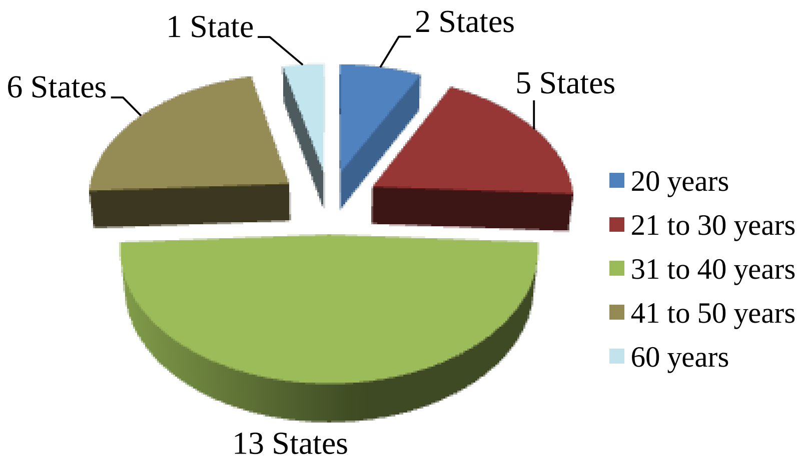

Figure 7. LCCA analysis periods for new/reconstructed pavements.

2.2.3 Maintenance and Rehabilitation Strategies of State Agencies

Future Rehabilitation

The timing of major rehabilitation treatments (particularly the first treatment) can have a significant impact on the future costs portion of the LCCA. One method of estimating rehabilitation timings is though survival/performance analysis using pavement condition and life data gathered in pavement management systems. As noted in Table 5, the timing of these rehabilitation treatments is estimated primarily using survival trend analysis or performance trend analysis.

Seventeen States include both structural and functional rehabilitation costs in their LCCA, while six States include only structural rehabilitation costs and three States include only functional rehabilitation costs (see Table 6).

Future Maintenance

Sixteen States report that they include routine maintenance in the LCCA, and 19 report including scheduled or preventive maintenance costs. Seven other States do not include any maintenance costs (see Table 6). Methods of estimating routine maintenance costs are about evenly split between the use of engineering judgment and maintenance management data.

As Table 7 shows, scheduled maintenance or preventive maintenance cost data are generated primarily through the application of unit cost data to expected contract quantities. A few States use historical cost data for similar projects or apply engineering judgment. Routine maintenance can be difficult to track because many maintenance management systems track crew production to a maintenance area, but not to a specific section of highway. Routine maintenance costs typically are applied as an annualized cost, while scheduled and preventive maintenance costs are applied at the expected points in the pavement's service life.

Table 5. Derivation of rehabilitation activity timings in LCCA.

State	Basis for Timing of Rehabilitation Activities/Costs			
	Survival Trend Analysis	**Performance Trend Analysis**	**Design Procedure Analysis**	**Other**
Alabama	No	No	Yes	---
Alaska				
Arizona	Yes	Yes	No	---
Arkansas	No	Yes	No	---
California	No	No	No	Predetermined based on historical data and climatic region
Colorado	Yes	Yes	No	---
Connecticut				
Delaware	No	Yes	No	---
Dist. of Columbia				
Florida				
Georgia	Yes	No	No	---
Hawaii				
Idaho	No	No	Yes	---
Illinois	Yes	No	No	---
Indiana	Yes	No	No	---
Iowa				
Kansas	Yes	No	Yes	---
Kentucky				
Louisiana	Yes	No	No	---
Maine	N/A	N/A	N/A	N/A
Maryland	No	Yes	No	---
Massachusetts				
Michigan	No	Yes	No	---
Minnesota	No	No	No	Panel of experts
Mississippi				
Missouri	Yes	Yes	Yes	---
Montana	No	Yes	No	---
Nebraska	NR	NR	NR	NR
Nevada	Yes	No	No	---
New Hampshire	N/A	N/A	N/A	N/A
New Jersey				
New Mexico	Yes	Yes	No	---
New York				
North Carolina	No	No	Yes	---
North Dakota	N/A	N/A	N/A	N/A
Ohio	Yes	No	No	---
Oklahoma				
Oregon				
Pennsylvania	No	Yes	No	---
Puerto Rico				
Rhode Island				
South Carolina	No	No	Yes	---
South Dakota	NR	NR	NR	NR
Tennessee	No	No	No	Experience
Texas	N/A	N/A	N/A	N/A
Utah	No	Yes	No	---
Vermont	No	No	Yes	---
Virginia				
Washington	Yes	No	No	---
West Virginia	No	No	No	Engineering judgment and instruction given in DD-641
Wisconsin	Yes	No	No	---
Wyoming				

NR = No response.
N/A = Not applicable.

Table 6. Consideration of future maintenance and rehabilitation (M&R) costs in LCCA.

State	Maintenance Costs Considered			Rehab Costs Considered	
	Routine	Scheduled or Preventive	None	Functional Rehab	Structural Rehab
Alabama	No	No	Yes	Yes	Yes
Alaska					
Arizona	Yes	Yes	No	Yes	Yes
Arkansas	No	Yes	No	Yes	Yes
California	Yes	Yes	No	Yes	Yes
Colorado	Yes	Yes	No	Yes	Yes
Connecticut					
Delaware	Yes	Yes	No	Yes	Yes
Dist. of Columbia					
Florida					
Georgia	No	Yes	No	Yes	Yes
Hawaii					
Idaho	Yes	Yes	No	Yes	Yes
Illinois	Yes	No	No	No	Yes
Indiana	Yes	Yes	No	No	Yes
Iowa					
Kansas	No	Yes	Yes	Yes	Yes
Kentucky					
Louisiana	Yes	Yes	No	Yes	Yes
Maine	N/A	N/A	N/A	N/A	N/A
Maryland	No	No	Yes	Yes	Yes
Massachusetts					
Michigan	No	Yes	No	No	No
Minnesota	Yes	Yes	No	Yes	Yes
Mississippi					
Missouri	No	No	Yes	Yes	No
Montana	No	Yes	No	Yes	No
Nebraska	NR	NR	NR	NR	NR
Nevada	Yes	Yes	No	Yes	Yes
New Hampshire	N/A	N/A	N/A	N/A	N/A
New Jersey					
New Mexico	Yes	No	No	No	Yes
New York					
North Carolina	Yes	Yes	No	No	Yes
North Dakota	N/A	N/A	N/A	N/A	N/A
Ohio	No	No	Yes	Yes	Yes
Oklahoma					
Oregon					
Pennsylvania	No	Yes	No	Yes	No
Puerto Rico					
Rhode Island					
South Carolina	No	No	Yes	Yes	Yes
South Dakota	NR	NR	NR	NR	NR
Tennessee	No	Yes	No	No	Yes
Texas	N/A	N/A	N/A	N/A	N/A
Utah	Yes	Yes	No	No	Yes
Vermont	Yes	Yes	No	NR	NR
Virginia					
Washington	No	No	Yes	Yes	Yes
West Virginia	Yes	No	No	Yes	Yes
Wisconsin	Yes	No	No	NR	NR
Wyoming					

NR = No response.
N/A = Not applicable.

Table 7. Derivation and application of maintenance costs in LCCA.

State	Derivation of Scheduled/Preventive Maintenance Costs (if included)				Method of Applying Future Scheduled/Preventive Maintenance Costs to Life Cycle Cost Stream		
	Typical Treatments & Timings Identified and Unit Costs Applied to Treatment Pay Item Quantities	Historical Project Cost Database	Engineering Judgment of Maintenance Personnel	Other	In Accordance with Identified Timings	Annualized Cost	Other
Alabama	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alaska							
Arizona	Yes	No	Yes	---	Yes	No	---
Arkansas	No	No	Yes	---	Yes	No	---
California	No	No	No	Note 1	No	Yes	---
Colorado	Yes	No	No	---	Yes	No	---
Connecticut							
Delaware	NR	NR	NR	NR	NR	NR	NR
Dist. of Columbia							
Florida							
Georgia	Yes	No	No	No	Yes	No	No
Hawaii							
Idaho	No	No	No	Note 2	Yes	Yes	---
Illinois	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indiana	Yes	No	No	---	Yes	No	---
Iowa							
Kansas	Yes	No	No	---	Yes	No	---
Kentucky							
Louisiana	Yes	No	Yes	---	Yes	No	---
Maine	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maryland	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Massachusetts							
Michigan	No	Yes	No	---	Yes	No	---
Minnesota	Yes	No	Yes	---	Yes	Yes	---
Mississippi							
Missouri	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Montana	Yes	No	No	---	Yes	No	---
Nebraska	NR	NR	NR	NR	NR	NR	NR
Nevada	No	Yes	No	---	No	No	Note 3
New Hampshire	N/A	N/A	N/A	N/A	N/A	N/A	N/A
New Jersey							
New Mexico	N/A	N/A	N/A	N/A	N/A	N/A	N/A
New York							
North Carolina	Yes	No	No	---	Yes	No	---
North Dakota	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ohio	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oklahoma							
Oregon							
Pennsylvania	Yes	No	No	---	Yes	No	---
Puerto Rico							
Rhode Island							
South Carolina	N/A	N/A	N/A	N/A	N/A	N/A	N/A
South Dakota	NR	NR	NR	NR	NR	NR	NR
Tennessee	Yes	No	Yes	---	Yes	Yes	---
Texas	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Utah	Yes	No	No	---	Yes	No	---
Vermont	Yes	No	No	---	Yes	No	---
Virginia							
Washington	N/A	N/A	N/A	N/A	N/A	N/A	N/A
West Virginia	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wisconsin	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wyoming							

Note 1. Covered as part of routine maintenance
Note 2. Current standard unit costs are shown at "future" times and converted to EUAC and net present worth.
Note 3. The cost is brought back to present worth cost, based on timelines derived from traffic volumes.
NR = No response. N/A = Not applicable.

2.2.4 Selection of Pavement-Type Alternatives

Ten state DOTs have specified differences in life cycle cost ranging from 0 to 15 percent which, if exceeded, cause the lower cost alternative to be accepted. States also undertake a process to evaluate other factors that might make it advantageous to select an alternative other than the one with the lowest life cycle cost. This may be an informal review by an individual, but it often is performed by a committee using a confidential process, where the only documentation is the recommendation of a preferred alternative. Eleven States use a PTSC to recommend the final type selection.

All of the States with formal pavement-type selection procedures consider economic and non-economic factors (most commonly, traffic level, subgrade soils, construction considerations, availability of local materials and experience, future maintenance operations, and continuity of adjacent pavements) as part of their selection process. Table 8 presents factors used in their pavement-type selection practices.

Table 8. States (with formal type selection process) considering specific economic and non-economic factors.

Factor	Percent Responding
Initial costs	100
Life cycle costs	93.3
Roadway/lane geometrics	53.3
Functional class	46.7
Traffic level/composition	80
Roadway peripheral features	40
Construction considerations	73.3
Future maintenance operations	73.3
Performance of similar pavements	60
Availability of local materials & experience	73.3
Continuity of adjacent pavements	80
Continuity of adjacent lanes	73.3
Noise issues	26.7
Subgrade soils	80
Climate	46.7
District/local preference	53.3
Recycling	40
Conservation of materials/energy	33.3
Stimulation of competition	53.3
Safety considerations	66.7
Smoothness	26.7

Most agencies use subjective evaluations of non-economic factors. Maryland has a more formal matrix for analyzing these factors, as shown in Table 9 (Maryland State Highway Administration, 2005). The final weight column in this table gives the net impact of each scoring factor on the overall rating. The weighting factors used in the matrix to develop the recommendation from the Pavement Division remain consistent regardless of the project. By using an established set of weighting factors in the scoring of the matrix on each project, a consistent and objective approach is provided for reviewing the technical information.

After consideration of the LCCA and other factors, a pavement-type selection is made. This process ranges from a discretionary selection by a district manager, to selection by a committee, to selection by the agency director.

Table 9. Maryland type selection scoring matrix.

Component	Factor	Factor Weight	Component Weight	Final Weight
Cost			45%	
	Agency cost- present worth cost	65%		29%
	User delay-	35%		16%
	*Initial and future agency			
	*LCCA			
Construction			30%	
	Duration of construction (climate)	25%		8%
	Maintenance of traffic	50%		15%
	Maintenance of access	25%		8%
	*Utilities and future maintenance			
	*Material sources			
	*Reliability of construction			
Design and Environment			25%	
	Traffic and geometry	55%		14%
	Adjacent pavement and structure	25%		6%
	Environmental impact	20%		5%
	*Community concerns			
	*Future planning			

Note: (*) non-scoring elements

2.3 ALTERNATIVE CONTRACTING

The FHWA established SEP-14, "Alternative Contracting," and allowed state DOTs to experiment with various non-traditional procurement methods for better and expedited delivery of projects. Since the inception of SEP-14, several studies have looked at the procurement practices of various agencies and evaluated their effectiveness and experiences. The SEP-14 web site serves as an important source of information on alternative contracting projects (FHWA, 2009).

2.3.1 Alternate Pavement-Type Bidding

The Missouri DOT was one of the first state agencies to experiment with alternate bidding procedures, back in 1996-1997. Following Missouri's request, FHWA approved the use of alternate pavement-type bidding under SEP-14. Missouri's procedure calls for the use of alternate bidding on all projects where a determination of pavement type is required. To date, Missouri has used alternate bidding on over 100 projects. Louisiana also has made extensive use of alternate bidding. Louisiana has used alternate bidding on over 40 projects. Several States have made limited use of alternate bidding. Table 10 provides a list of alternate bidding projects approved by the FHWA under SEP-14. In addition to these 11 States, 3 other States (North Carolina, Nebraska, and Tennessee DOTs) have reported using alternate pavement-type bidding.

The AASHTO Subcommittee on Construction conducted a survey in 2009 on alternate pavement-type bidding practices in the U.S. and Canada (Oie et al, 2009). This survey reported that 17 of 40 responding States use alternate pavement-type bidding procedures, and 12 States use a bid adjustment factor to account for life cycle cost differences between pavement-type alternatives. A literature review was conducted to gather information on the alterative bidding practices of various state agencies. Examples are presented in Appendix B.

Table 10. Alternate pavement-type bidding projects under FHWA's SEP-14.

State	Brief Description/Location
Alabama	Appalachia corridor projects
Arizona	State Route 303L
Colorado	SH 392: I25 to 15th Street — SA# 17138
Idaho	I-84, Garrity IC to Ten Mile IC
Indiana	US 31 at Kokomo, Indiana Ten other projects at various locations in Indiana
Kansas	US 400 around Dodge City K-18 from Manhattan to I-70
Kentucky	I-65 Simpson County US 27 Laurel County I-65 Warren-Barren-Edmonson Counties
Michigan	M-6 Southbelt and other projects
Montana	Programmatic approval
Ohio	I-70 in Clark and Madison counties
Pennsylvania	Contracting/project delivery

The state-of-the-practice survey of alternative bidding practices indicated the following:

- State agencies generally follow their own pavement-type selection process and thickness design procedures in developing pavement-type alternatives.
- LCCA is an integral part of the alternative selection process. However, the key LCCA inputs, such as the analysis period and discount rates, differ according to each agency's practices.
- The results of LCCA are used to establish the equivalency of the pavement-type alternatives and determine the bid adjustment factor (C) to account the difference in future M&R costs between them.
- Most state DOTs adhere to the 10 percent threshold; however, Louisiana and Washington DOTs use 20 and 15 percent thresholds, respectively, for accommodating pavement types in their alternate bid.
- The bid evaluation model appears to change with agency practices. Some state DOTs use the (A+B+C) model to factor in the difference in user delay costs (B factor) associated with the project completion time between the alternatives, whereas other state DOTs apply an adjustment factor only for future M&R costs.

2.3.2 Best-Value Alternative Bidding (A-D)

The Iowa DOT experimented with best-value alternate bidding under SEP-14. FHWA approved this contracting technique in 2008 after a 2-year trial period. Iowa released specification DS-

09010, "*Developmental Specifications for Best Value Alternative (A-D) Bidding*," outlining the bidding and contract award procedure. This method expands the number of alternatives for bidders and allows the contracting agency to receive the best value based on individual alternatives selected by each bidder (FHWA, 2008).

Under this method, the proposal will contain a set of pavement sections that includes a baseline configuration and other better alternatives. The proposal also will include a dollar value that the agency is willing to pay for the better alternative over the baseline section. The agency pre-determines the dollar value for each alternative section that it includes in the proposal. The contractor is allowed to choose either the baseline section or any of the alternate sections. The contract is awarded to the bidder who submits the lowest bid total (A) minus the sum of alternative differentials (D) - i.e., A-D. The case studies of Iowa DOT projects that used this contractual procedure are presented in Appendix B.

2.3.3 Design-Build Projects

Figure 8 shows the total number of design-build projects proposed, active, or completed by each of the state DOTs, as of December 2007. Little information is available in the literature on pavement-type selection, as practiced by state DOTs in design-build projects. Therefore, an effort was made to compile information from past design-build projects. The compilation effort included the collection and review of agencies' policy documents and the requests for proposals (RFPs) for past design-build projects in the U.S. and Canada. Table 11 provides a list of design-build projects considered in this study. The compiled information provided includes excerpts on pavement-type selection, thickness design, quality assurance and warranty terms obtained from the project RFPs. The available documents were acquired from the state DOT web sites. Table 12 presents a summary of pavement-type selection and design practices of selected case studies. More detailed information is presented in Appendix B.

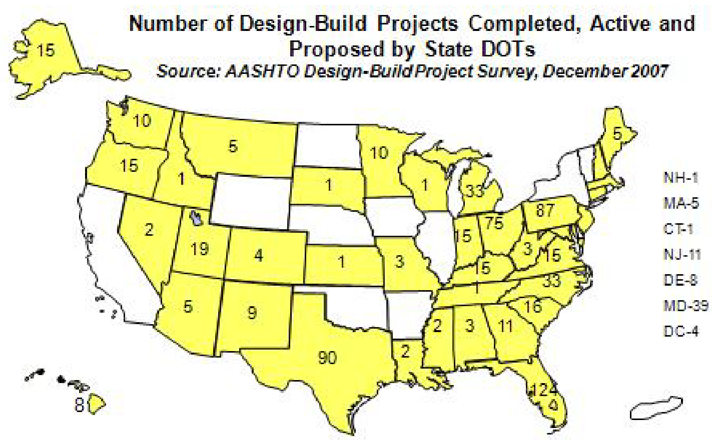

Figure 8. Design-build projects by state DOTs (AASHTO, 2007).

Table 11. Design-build projects studied.

State	Project
Colorado	120th Avenue Connection
Florida	General
Indiana	Interstate 70 –Marion County
Maryland	Intercounty Connector (ICC) Contract A
Michigan	M-115, Clare County 9 Mile Road over I-75 Bridge Replacement
Minnesota	T.H. 169 – St. Peter
Missouri	The New I-64
North Carolina	TIP Project R-2404A (Windsor Bypass)
Ohio	SR 562
Utah	I-15 CORE Corridor Expansion
Washington	Interstate 405
Nova Scotia	Highway 104 Cobiquid Pass
Ontario	Highway 407

Table 12. Summary of design-build case studies.

State	Case Study	Proposal Evaluation Method	Who specifies Pavement Type?	Who determines pavement thickness?	Does Agency provide minimum thickness?
Colorado	120th Avenue Connection	Adjusted Score	Agency	Agency	Yes
North Carolina	Windsor Bypass	Adjusted Bid	Agency	Agency	Yes
Minnesota	T.H. 169 - St. Peter	Adjusted Bid	Agency	Agency	Yes
Utah	I-15 CORE	Fixed-Price Best-Design	Contractor	Contractor	Yes
Washington	I-405	Adjusted Score	Agency	Contractor	Yes
Florida	RFP Not Available	Best Value (or) Low Bid	Agency	Project specific	No
Indiana	I-70	Low Bid - Technical	Agency	Agency	Yes
Ohio	SR 562	Low Bid	Agency	Agency	Yes
Missouri	The New I-64	Fixed Price-Best Value	Contractor	Contractor	No
Maryland	ICC Contract A	Best Value - Low Bid	Contractor	Contractor	No
Michigan	M-115 Clare County	Best Value - Performance Contracting	Agency	Contractor	Yes
Michigan	9 Mile Road over I-75	Low Bid	Agency	Contractor	Yes
Nova Scotia	Highway 104 Cobiquid Pass	Not Available	Contractor	Contractor	No
Ontario	Highway 407 ETR	Not Available	Contractor	Contractor	No

2.3.4 Public Private Partnerships – Design-Build Operate & Maintain (O&M)

Public private partnerships involve several contractual agreements based on the degree of contractor participation in project delivery and financing (see Figure 9). From the pavement-type selection perspective, the design-build O&M scenario adequately covers the contractual requirements of other arrangements. The FHWA Innovative Program Delivery web site provides examples of public private partnership projects (FHWA IPD, undated):

- Route 3 North - Boston, Massachusetts.
- Dulles Greenway - Loudoun County, Virginia.
- South Bay Expressway (formerly SR 125 South) - San Diego County, California.
- SH 130 (Segments 5-6) - Austin, Texas Metropolitan Area.
- Chicago Skyway - Chicago, Illinois.
- Indiana Toll Road – Indiana.

Agency Responsibility ⟷ ***Contractor Responsibility***

Public Private Partnerships Options			
New Build Facilities	Design Build	Design Build Operate (Maintain)	Design Build Finance Operate
Existing Facilities	O&M Concession		Long Term Lease
Hybrid			Lease Develop Operate

Private Contract Fee Services
Other Innovative Partnerships

Figure 9. Contractual arrangements of Public Private Partnerships (FHWA IPD, undated).

In typical public private arrangements (excluding design-build), the agency delegates the responsibilities of pavement design and type selection to bidders. The bidders are required to prepare a detailed report documenting the assumptions, considerations, and decisions used in this process. Some agencies allow any approved process methodology, while others prescribe specific ones to be used. The pavement design and type selection report typically requires the following:

- Pavement design details by location, including structural layer materials, general specifications, and thicknesses.
- Design criteria used in determining the pavement design(s), including annual average daily traffic, percentage heavy vehicles, pavement material strength factors, and design life.
- Design methods adopted in developing the pavement design(s) and the rationale for their selection.
- Life cycle strategies, including the periods for resurfacing, reconstruction, maintenance and other rehabilitation measures.
- LCCA methodology and the relevant inputs, including the analysis period and discount factors.

The contractors are required to comply with the agency-specified performance criteria to ensure threshold performance standards of facilities. The contractors are required to have a maintenance plan that includes performance requirements, measurement procedures, threshold values at which maintenance is required, inspection procedures and frequencies, and subsequent maintenance to address noted deficiencies, for pavement elements. See Table 13 for typical performance criteria specified in the contract provisions of Texas DOT's SH 130 Segments 5 and 6 project.

Table 13. Typical performance criteria in Public Private Partnership projects.

Parameter	Criteria for Intervention
Pavement Condition	Score for each auditable section below 90
Rutting	3 percent of wheel path length with ruts greater than ¼ inch in depth in each auditable section. Rut depth at any location greater than ½ inch.
International Roughness Index (IRI)	98% of length in each auditable section greater than to 95 inches/mile.
Failures such as potholes, base failures, punchouts and jointed concrete pavement failures	Occurrence of any failure exceeding allowable limits set forth by the agency.
Edge drop-offs	Instances of edge drop-off greater than 2 inches.
Skid Number	Skid number for 0.5-mile section in excess of 30.

Upon termination of the contract, the agency specifies hand back requirements that entail compliance with minimum performance standards or residual life for pavements. The residual life requirements may vary from 5 to 10 years.

2.3.5 Performance Warranty

State agencies have been experimenting with warranty contracts since the early 1990s. Currently, 22 States have experimented with warranties for HMA in more than 700 projects, and 17 States have used warranties for Portland cement concrete (PCC) in more than 370 projects. Table 14 presents the FHWA’s compilation of pavement warranties practices. The length of the warranty period ranges from 1 to 25 years. Based on the warranty period, the warranty types are classified as:

- Materials and workmanship warranty.
- Short-term performance warranty.
- Long-term performance warranty.

Table 15 provides a comparison of the important aspects of the three warranty types. As noted in this table, an agency retains the responsibility for structural designs in short-term performance warranty contracts, indicating that the pavement type is selected by the agency using the conventional process. On the other hand, the contractor is responsible for structural designs in long-term warranty contracts, indicating that the pavement-type selection can be made by either the agency or the contractor. Examples of long-term warranty include New Mexico Highway 44 and Virginia I-81.

Table 14. Summary of pavement warranty use in paving projects (as of 2000).

Agency	Number of Projects	Typical Warranty Period (Yrs)			Are longer periods being considered?	Who will do thickness design?
		HMA	PCC	Pavement Preservation		
CA	12			1	Yes	
CO		3-5	5-10	N/A	Yes	Contractor
FL	2			5	Yes	Agency
HI	0	3-5	N/A	N/A	No	
IL	6	5			No	Agency
IN	8	5			No	Agency
KS	11	15	15		Yes	Contractor
KY	3	10	10		No	Agency
LA	2	3	3	-	No	Agency
MI	300+	3 or 5	3 or 5	2-3	Yes- 10yrs	Agency
MN	10	5				
MO	2	3				
MS	5	7	10	5	No	Agency
NC	0			21	No	Agency
NM	1	20	-	-	Yes	Private
OH	309	3-5-7	7	2-3	No	Agency
OR		3			Yes	Agency
SC		3	-	-	Yes - 15yrs	Agency
SD	1	3-5-7	7	2-3	No	Agency
TX	11				Long-term maintenance contracts	Contractor
WA		5	5		No	Agency
WI	28	5	5	2	Yes	Agency

Table 15. Comparison of pavement warranty types.

Aspect	Materials & Workmanship	Short-term Performance	Long-term Performance
Typical Period	2 - 4 years	5 - 10 years	More than 10 years
Type of specifications	Agency's current standard specifications for specific treatment	Agency specified minimum materials and construction requirements acceptable for project	Agency specified minimum structural design, material design, materials, and construction requirements acceptable for project
Agency responsibility	Structural design, material design, evaluation	Structural design, evaluation	Evaluation
Contractor responsibility	Correct defects in pavement caused by elements within their control	Material design, quality control, and pavement performance for warranty period	Structural design, material design, quality control, and pavement performance for warranty period
Acceptance of project	In accordance with agency's normal practices	Initial: construction activities. Final: after specified warranty period is completed	Initial: construction activities. Final: after specified warranty period is completed

2.4 INDUSTRY TYPE SELECTION INPUTS AND CONCERNS

Letters were sent to all of the state industry associations representing the HMA and PCC pavement contractors. Eight associations responded, and the following summarizes their responses:

- Seven of the respondents were familiar with their state DOT's type selection process, and one was somewhat familiar.
- Two of the respondents indicated that they have the opportunity to review and comment on the results of the State's LCCA and/or the final type selection.
- Items of concern to industry:
  - Use of stage construction on HMA gives a first cost advantage to HMA.
  - Tough ride specifications give an advantage to HMA.
  - PCC designs are more conservative than HMA.
  - Initial performance periods used for HMA are too short.
  - HMA maintenance intervals are too short.
  - Salvage value not included.
  - HMA designs are too conservative.
  - Not considering increased service lives of improved designs and materials.
  - Estimating LCCA over 40 years is a not-realistic.
  - LCCA is done 2 to 3 years before bid letting and does not reflect market costs at the time of construction.
  - Not consistently applying LCCA.
  - Need to include engineering, pavement marking, and construction traffic control costs in the LCCA.
  - Should select discount rate based on OMB A-94.
  - Need to include user delay costs in the LCCA.
  - Need to reflect the effects of contract asphalt price escalation clauses in the LCCA process.
  - Historical maintenance costs should be included in the LCCA.
- Three respondents thought that alternate bidding was beneficial in that it reflects current market costs in the selection. However, one respondent believed alternate bidding should be based solely on first cost, with no adjustment factor for future costs.
- One respondent indicated his state DOT had used design-build contracting on three projects. The DOT provided the pavement design on all projects and specified the pavement type on two of the projects. On a project where the contractor was allowed to select the pavement type, a 15-year design life was used for HMA and 40 years for PCC. The respondent felt this showed a bias for HMA pavements.

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CHAPTER 3 – OVERVIEW OF THE PROPOSED PAVEMENT-TYPE SELECTION PROCESS

One of the earliest discussions on pavement-type selection was contained in *The Informational Guide on Project Procedures*, published by AASHO on November 26, 1960 (AASHO, 1960). This guidance has served as the basis of all pavement-type selection procedures developed since 1960. The philosophy expressed is still relevant today and serves as a foundation for the new Guide for Pavement-Type Selection. The following is an excerpt from this guide:

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 judgment 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, participating local government preference and recognition of local industry.
14. Traffic safety.
15. Availability of and adaptations of local materials or of local commercially produced mixes.

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."

The development of the mechanistic-empirical pavement design guide (MEPDG), pavement management systems, and extensive maintenance and rehabilitation cost records makes the development of more rational and less subjective selection pavement-type selection procedures possible.

3.1 OVERVIEW OF THE PROCEDURE

A schematic of the pavement-type selection process to be presented in the Guide for Pavement-Type Selection is shown in Figure 10. The following are key steps of the procedure:

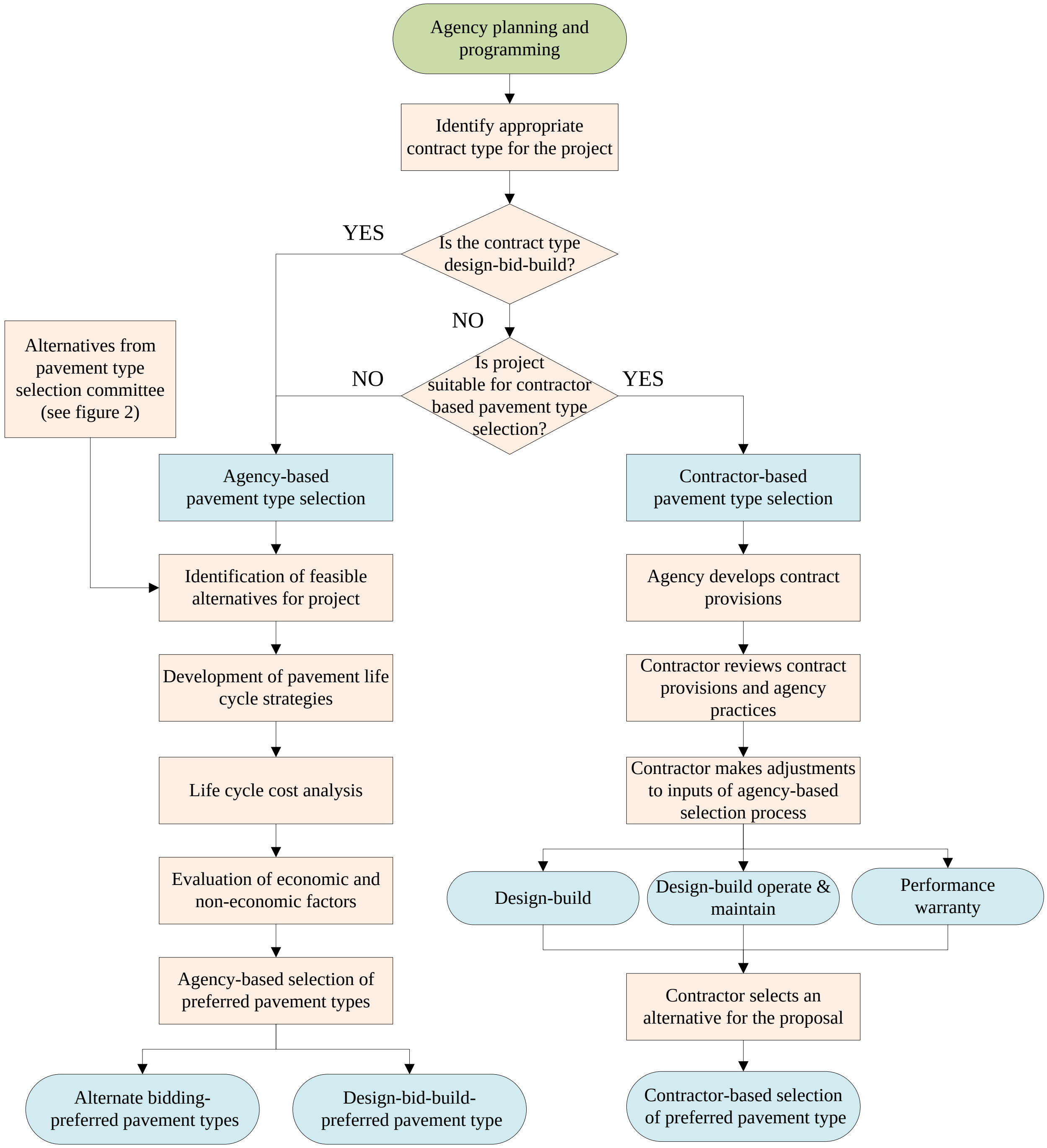


Figure 10. Overview of the pavement-type selection process.

Agency-based Selection

1. Identify of a pool of alternatives.
2. Identify feasible alternatives for a project.
3. Develop pavement life cycle strategies for each alternative.
4. Perform LCCA.

5. Evaluation using economic and non-economic factors.
6. Final selection of the preferred alternative(s).

Contractor-based Selection

1. Agency performs risk assessment.
2. Agency develops contract provisions.
3. Contractor reviews agency practices and contract provisions.
4. Contractor performs risk assessment.
5. Contractor selects pavement type.
    a. Follows agency allowed process.
    b. Specification criteria for contractor's selection.

Regardless of who performs the pavement-type selection, the key steps involved in the process are same for both agency and contractor type selection.

In alternate bidding, all of the steps used in traditional bidding are followed because the agency establishes the alternatives for the contractor to select during bidding. For design-build and warranty projects, contractors are responsible for all or portions of the pavement design and selection processes. Generally, the project criteria require the contractor to follow processes similar to the process followed by the agency for design-bid-build processes. However, this may be modified if the contractor provides extended warranties or assumes the operation and maintenance responsibility.

3.2 APPLICATION OF THE PROCEDURE

The pavement-type selection procedure is detailed and requires a rigorous effort to achieve constructive results. Therefore, the procedure should be used only on projects that are significant enough in scope to yield benefits that outweigh the costs of having performed the type selection process. Each State should develop policy guidance on the type of projects warranting formal type selection. The following are the types of factors that should be considered:

- Initial pavement construction/material costs on new or reconstructed pavement projects.
- Length of new or reconstructed pavements.
- Square yardage of new or reconstructed multi-lane pavements.

The policy should address when the type selection process will be applied to projects such as the following:

- Bridge approaches.
- Lane additions.
- Ramps.
- Collector/distributor lanes.
- Acceleration/deceleration lanes.

CHAPTER 4 – IDENTIFICATION OF PAVEMENT ALTERNATIVES AND DEVELOPMENT OF PAVEMENT LIFE CYCLE STRATEGIES

4.1 DEVELOPMENT OF POTENTIAL ALTERNATIVES

A key step in the pavement-type selection process is the identification of pavement alternatives to be considered. Typically, the choice of alternatives is left to the individual designer. Depending on the experience of the designer, the alternatives evaluated may be limited to what has been considered in the past.

As shown in Figure 11, the selection of potential alternatives should be a comprehensive and transparent process involving the agency, contractors, and the research community. This activity should be overseen by a PTSC composed of agency design, construction, and maintenance personnel, and should occur on an annual or biennial basis. The committee is responsible for ensuring that a broad range of input was received on existing and innovative techniques. The output of the process is a list of alternatives that should be considered, given regional factors, type and size of projects, and type of traffic the route is expected to carry.

One of the key components of alternative identification is determining what does or not work in the state or area of the state where the project will be constructed. The source of data for making this determination is the State's pavement management system. Pavement management systems traditionally include the regular collection of highway condition data and a database that sorts and stores the data collected. These data should be used to identify pavement designs and materials that are not performing as expected. Where pavements perform better than expected, this input can be fed into the LCCA. Where pavement performance is not as good as expected, an evaluation should be made to determine if the deficiencies can be corrected through design or material modifications. This process may also identify regions of the state or specific traffic conditions where there are differences in performance. This evaluation will result in a list of pavement alternatives that, based on past performance, are suitable for consideration. This should not preclude the consideration of designs not previously constructed in a particular state. In those cases, performance estimates can be based on the experiences of other state agencies and the application of analysis tools such as the MEPDG.

It is important that the process allow for innovative approaches to be included in the type selection process. One source of innovation is the pavement industry. The industry associations represent a broad spectrum of contractors who do business across the country. In this capacity, they see designs and techniques being used in one state but not another. In addition, the industries sponsor centers and institutes responsible for developing improved techniques and materials. The alternative evaluation process should have formal procedures for the PTSC to request input from and meet with industry associations when developing proposed alternatives. The performance of these innovative approaches needs to be quantified for the LCCA and M&R schedules used in the LCCA process.

The alternatives identified could be evaluated using the agency's structural design process to prepare a design catalog of appropriate solutions that include the agency's design strategies and

policies and are based on information and data included in the agency's pavement management performance and construction databases.

The third major component of the alternative identification process is a program for monitoring and evaluating the results of ongoing research programs. As promising items are identified, steps should be taken to construct and evaluate test sections and demonstration projects. Alternatives showing positive results from the test sections should then be added to the type selection alternatives list.

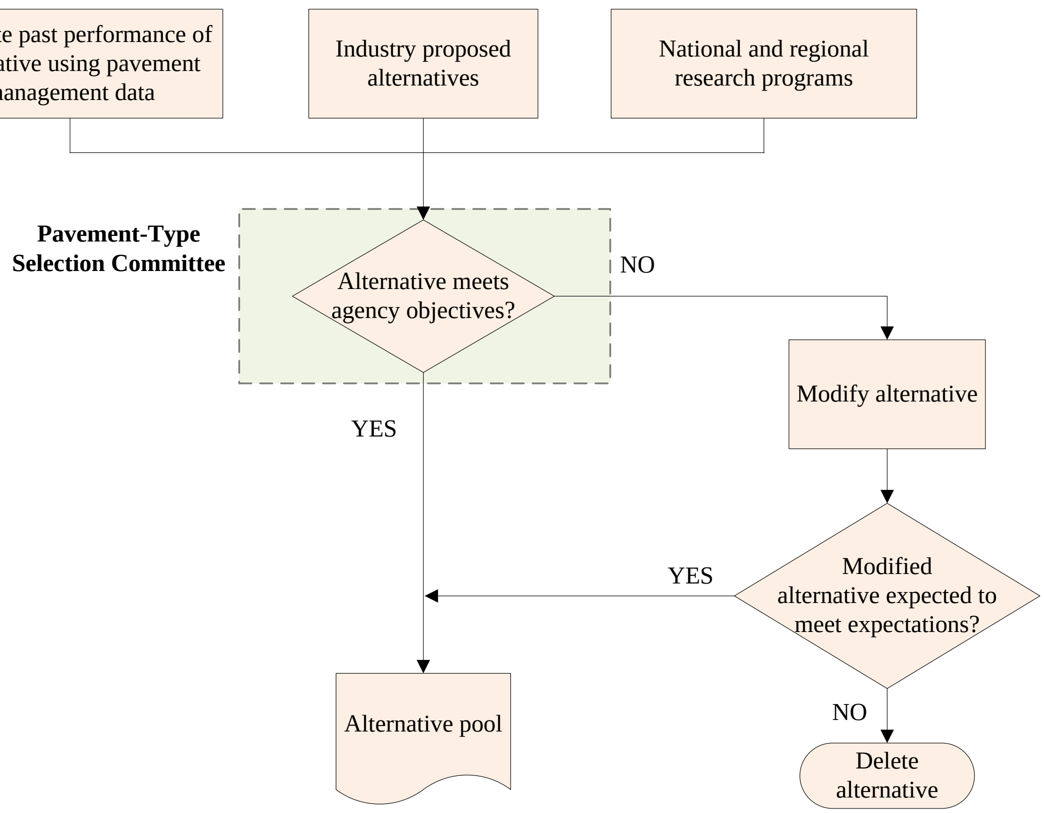


Figure 11. Process for determining alternatives to be considered in pavement-type selection.

4.2 IDENTIFICATION OF ALTERNATIVES FOR A SPECIFIC PROJECT

Within the broad group of alternatives, certain choices may be inappropriate for a specific project under consideration. The factors or constraints that should be considered in evaluating alternatives for a specific project are listed in Table 16.

In practice, the broadest range of alternatives (including the various forms of recycling) should be considered on each project. However, certain alternatives may be appropriate for certain classes of roads or under certain traffic conditions. In addition, there may be certain project features that may limit the number of feasible alternatives. Decisions regarding the identification of alternatives at the project level should be documented in the pavement selection document.

Table 16. Project-level alternative identification factors.

Functional Class	Functional classification is the process by which highways and roadways are grouped into classes or systems according to the character of traffic service that they are intended to provide. There are three typical highway functional classifications: arterial, collector, and local roads. All highways and roadways are grouped into one of these classes, depending on the character of the traffic (i.e., local or long distance) and the degree of vehicle access that they allow. Within the alternatives pool may be some alternatives that are not appropriate for specific functional classes.
Traffic Level/ Composition	The percentage of commercial traffic and frequency of heavy load applications have a major effect on the alternatives appropriate for a specific project. Agencies may choose to establish minimum structural requirements to ensure adequate performance and service life for minor facilities where traffic is unknown. For heavily trafficked facilities in congested locations, the need to minimize the disruptions and hazards to traffic may dictate the selection of those strategies having long initial service life with little maintenance or rehabilitation designed at a high level of reliability.
Existing Pavement Condition and Historical Condition Trends	The condition of the existing pavement and its historical performance, as determined through manual or automated distress surveys and smoothness testing, can significantly impact the identification of alternatives for both reconstruction and rehabilitation projects. Overall condition indicator values, specific distress types, severities, and amounts, and ride quality measurements help define the structural and functional needs of the pavement. Such needs are better addressed by some alternatives than others, thus helping narrow the list of feasible alternatives.
Detailed Evaluation of Existing Pavement Properties	Results of destructive (coring) and nondestructive testing and other on-site evaluations (drainage, friction) provide information on the causes of pavement distress and the structural and functional capacities of the existing pavement. Again, certain alternatives are better than others at addressing the pavement problems.
Sustainability	Consideration of impact of alternatives on future generations. Includes evaluating factors such as recyclability, carbon footprint, energy consumption over the life of the pavement (user and agency)
Roadway Peripheral Features	Peripheral features such as guardrails, curbs and gutters, traffic control devices, overhead clearances, on-grade structures, and weigh-in-motion installations may play important roles in the selection of alternatives. Such features may have special bearing on rehabilitation work where grade changes are limited. For example, in some cases, recycling or reconstruction may be more desirable than an overlay.

4.3 DEVELOP ALTERNATIVE PAVEMENT STRATEGIES

In this step, each feasible alternative is assigned a strategy consisting of the initial structure (whether new or rehabilitated) and the probable M&R activities covering the selected analysis period.

4.3.1 Determine Pavement Performance and M&R Activity Timing

New, reconstructed, and rehabilitated pavements deteriorate due to a combination of traffic- and environmental-related stresses. The deterioration prompts the need for various forms of upkeep over a long time period to sustain the structural integrity and capacity of the pavement, as well as its functional characteristics (smoothness, friction). For each alternative strategy, the expected performance life must be determined for the initial pavement structure and each future rehabilitation treatment projected to occur over the chosen analysis period. It also entails identifying the timings and extents of anticipated maintenance treatments. The resulting

information can then be used to establish the sequence and timings of future M&R activities treatments, as illustrated by the life cycle model in Figure 12.

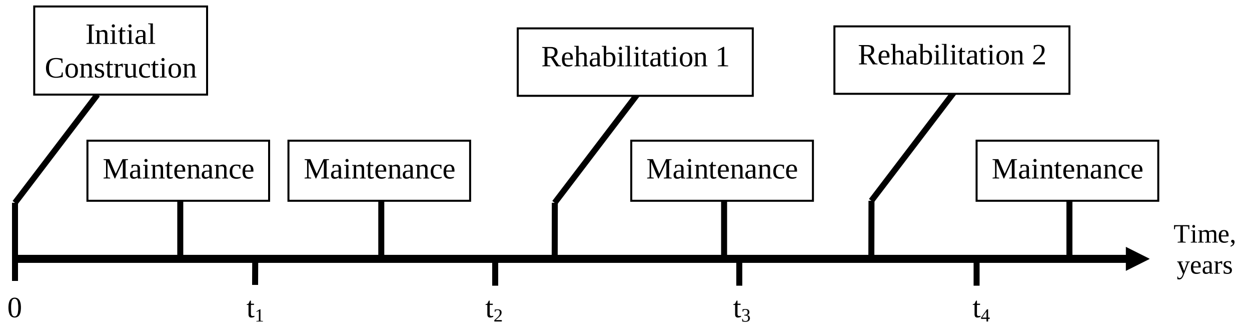


Figure 12. Example pavement life cycle model.

The traditional approach for establishing M&R activities is to use historical experience documented in the pavement management system. The pavement management system should provide at least a general indication of the types of M&R treatments that have been applied to specific types of pavement. If individual distress data are available, then critical forms of distress and modes of failure may be identified, allowing for greater perspective on appropriate M&R treatments (i.e., whether current and/or past M&R practices are acceptable, or whether deviations are needed).

4.3.2 Service Lives of Initial Pavement and Future Rehabilitation Treatments

The service life of a pavement is defined as that period of time from completion of construction until the structural integrity of the pavement is considered to be unacceptable, requiring rehabilitation or replacement. In the example in Figure 12, the service life of the initial asphalt pavement structure is about t_1 years, corresponding to the timing of the first HMA resurfacing. Similarly, the service life of the first resurfacing is about t_2 years, corresponding to the timing of the second HMA resurfacing. It should be noted that, in economic analysis, service life generally is considered the average or median life of the pavement (i.e., the time associated with 50 percent probability of the need for structural rehabilitation). This is different than the design life, which represents a time period over which traffic loadings were estimated for design at a specified level of reliability, with a relatively low probability of the need for structural rehabilitation. The actual life until major rehabilitation is needed depends on many other factors (such as materials durability, climate conditions, and construction quality) and may be shorter or longer than the design life of the pavement.

Pavement service life can be estimated using various techniques, ranging from expert modeling using the opinions of experienced engineers to detailed performance prediction modeling using historical pavement performance data to construct survival curves. Because of the potential for bias, the only time the former approach should be considered is when reliable historical performance data are not available or are greatly limited (for instance, if the pavement or rehabilitation types being considered are substantially different, due to changes in traffic or use of new materials or technologies). Experience-based estimates often can be made in conjunction with data trends from other similar climatic locations.

The pavement management system should be the primary source for developing service life estimates of pavement structures and rehabilitation treatments anticipated for each strategy. Depending on the data available, a variety of analyses can be performed to develop service life estimates. The most common analyses are performance trend analysis and survival analysis. Brief descriptions of these two techniques are provided below. It should be noted that, for both techniques, the reliability and accuracy of results depend greatly on the number of data points available for analysis. The more pavement sections representative of a particular pavement type, the better. And, in the case of performance trend analysis, the more time-series condition measurements, the better. It is important to assess how closely the pavement sections used in the life analyses represent the alternative pavement designs used in the type selection. If the initial design pavements used in the selection process are much improved over those available from pavement management files that represent deficient pavement designs and materials, then adjustments must be made to the results of the performance and survival analysis results. An obvious example for jointed concrete pavements is if the previous design does not use dowel bars and the new one considered in the type selection does. An obvious example for HMA pavements is if the previous design does not use Superpave mixtures and binders and the new one considered in the type selection does.

<u>Performance Trend Analysis</u>

In performance trend analysis, historical condition data for pavements similar to those for each pavement strategy are compiled and plotted as a function of time. A best-fit regression curve is then fitted through the data and projected out to a threshold condition level representative of the need to perform structural rehabilitation. The corresponding time at which the threshold level is reached reflects the average age at time of rehabilitation or the estimated service life of the pavement.

Performance trend analysis is essentially a four-step process.

In step 1, existing pavement sections with structural designs, traffic loadings, and functional classes that are similar to the pavement alternatives being considered (i.e., same pavement family) are identified, and their historical data are extracted from the pavement management system or other records. Careful attention should be given to the acceptability of the pavement sections. Were they built with drastically different materials than the pavement alternatives currently being evaluated? Were there design and/or construction issues that substantially influenced performance? Were traffic loadings significantly altered, thereby influencing performance? Sections with these kinds of issues may warrant removal from the analysis.

Step 2 entails creating time-series plots of pavement performance using the available condition data for each family of pavements and developing best-fit linear or non-linear models relating pavement condition to age. To the extent possible, the time-series performance plots should include separate trends for overall condition indicators (e.g., pavement condition index [PCI]), ride quality (e.g., International Roughness Index [IRI], present serviceability rating [PSR]) and key structural distress types (e.g., rutting and cracking for asphalt pavements, faulting and cracking for concrete pavements). Agencies utilizing the PCI indicator also should consider developing structural condition index (SCI) trends, which represent the structural component of PCI.

In creating the time-series performance plots, some filtering of the data may be needed, such as when a significant improvement in pavement condition is observed from one year to the next. Such increases likely indicate a rehabilitation or significant maintenance intervention. To negate their influence, the post-treatment condition data should be removed.

Figure 13 illustrates the change in ride quality over time for a particular pavement family (full-depth asphalt pavements located on interstate highways). The 242 data points represent the IRI values recorded for individual pavement sections with similar design and traffic characteristics. An exponential trend line has been fitted through the dataset reflecting the central tendency for the progression of roughness over time.

In step 3, an acceptable threshold condition level must be identified to serve as the trigger for major rehabilitation. IRI levels of 125 to 175 in/mi are typical triggers for major rehabilitation—the lower end of this range being more suitable for interstates and the higher end for lower volume arterials.

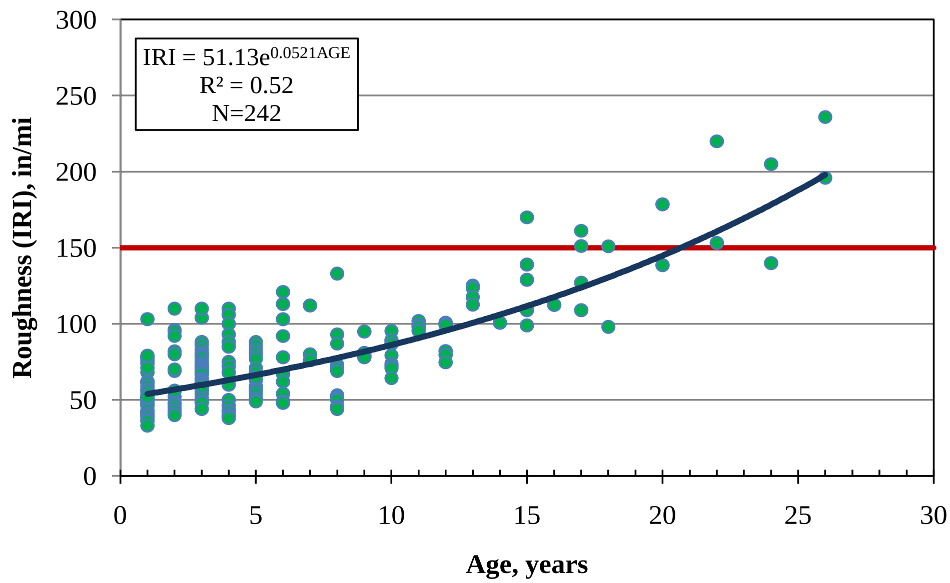


Figure 13. Roughness progression curve for a family of pavements.

With the development of pavement performance/condition trends and the establishment of a specific condition threshold, an estimate of service life can be made for each pavement family (step 4). Figure 14 illustrates this step utilizing the IRI progression curve shown in the previous figure and a threshold IRI value of 150 in/mi. In this example, it can be seen that, where the model trend line intersects the threshold IRI, the estimated service life is about 18 years. Depending on the nature of each performance/condition model, there may be a need to project the model forward so that it reaches the threshold condition level.

If a probabilistic LCCA will be conducted, then an estimate of the variation in expected pavement life will be needed. In the development of the performance/condition model, a confidence level (67 percent representing one standard deviation) can be defined that allows for

the development of confidence bands around the model trend line. In Figure 14, the estimated standard deviation for functional (ride quality) life is about 2.5 years.

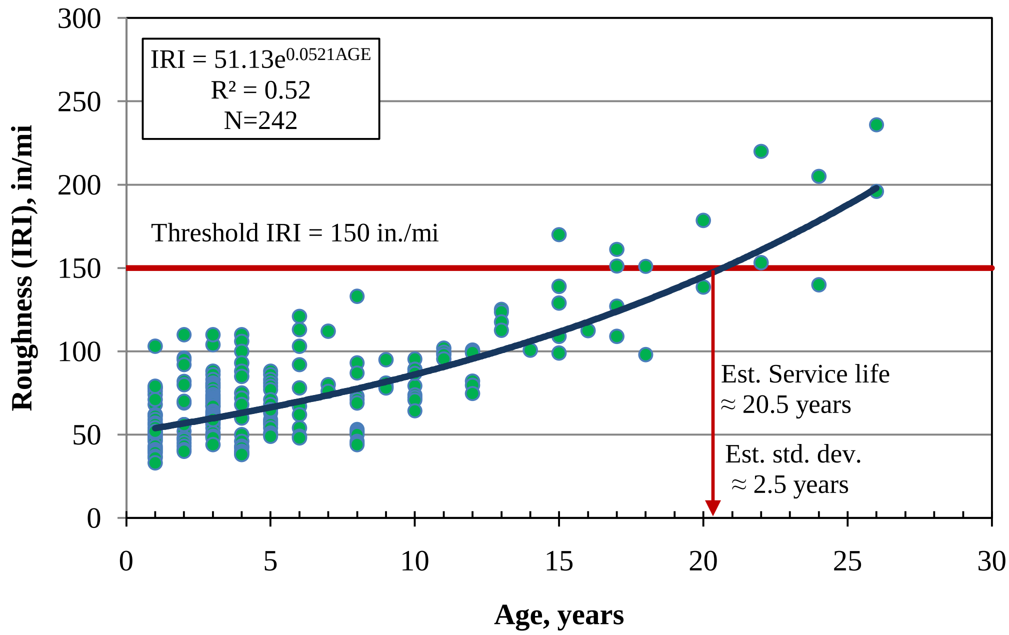


Figure 14. Functional life estimation for a family of pavements.

<u>Survival Analysis</u>

A procedure successfully used in the highways arena for estimating pavement service life is survival analysis (alternatively known as failure analysis). This technique uses historical construction and rehabilitation data for a family of pavements to construct a survival curve that depicts the probability of survival with time (or traffic loadings). "Survival" of a pavement section is defined as the non-occurrence of failure or, in other words, the non-occurrence of major rehabilitation.

Survival analysis begins with an assessment of the survival status of each pavement family section at the time of the analysis. As illustrated in Table 17, the age of each family pavement section that has failed is determined by subtracting the construction year from the rehabilitation year. Using the age data from this table, a life table like the one shown in Table 18 can be produced. These data can then be used to construct a survival curve like the one shown in Figure 15. Using a value of 50 percent pavement sections surviving (or, conversely, 50 percent sections failed), an estimate of the median life (and standard deviation) for a pavement with similar features and loading conditions can be developed and used in LCCA.

These survival relationships also can be analyzed to evaluate the appropriateness of selected design features and their impact on pavement service life. These survival curves should consider age and traffic and be based on the actual trigger or threshold values that cause some major rehabilitation activity to be taken for those roadway segments that have yet to be rehabilitated.

Table 17. Performance history of a selected pavement family.

Section	Year Constructed	Year Rehabilitated	Age at Failure	Age in 2010
US 51 (MP 112.25 - 118.89)	1988	2006	18	—
US 51 (MP 140.51 - 145.69)	1988	2007	19	—
US 69 (MP 18.65 - 26.33)	1986	2003	17	—
US 60 (MP 26.33 - 31.54)	1987	2007	20	—
US 60 (MP 50.87 - 59.32)	1987	2006	19	—
US 281 (MP 0.00 - 4.92)	1990	2008	18	—
US 281 (MP 18.63 - 27.72)	1990	2008	18	—
US 281 (MP 54.32 - 62.26)	1990	—	—	20
US 281 (MP 62.26 - 69.44)	1991	2006	15	—
Rt 27 (MP 11.66 - 19.34)	1984	2001	17	—
Rt 27 (MP 30.02 - 35.21)	1984	2003	19	—
Rt 64 (MP 0.00 - 8.84)	1992	—	—	18
Rt 89 (MP 45.33 - 53.71)	1991	2009	18	—
Rt 89 (MP 53.71 - 60.07)	1992	—	—	18
Rt 115 (MP 6.22 - 10.65)	1986	1999	13	—
Rt 133 (MP 45.92 - 49.77)	1992	2009	17	—
Rt 133 (MP 49.77 - 58.23)	1991	—	—	19
Rt 205 (MP 7.40 - 14.36)	1987	2003	16	—
Rt 456 (MP 78.84 - 89.75)	1989	2006	17	—
Rt 456 (MP 96.28 - 104.47)	1989	2009	20	—
		Mean (Standard Deviation)	17.6 (1.8)	

Table 18. Pavement survival analysis life table.

Pavement Section Age, years	Cumulative No. of Failed Pavement Segments	Cumulative No. of Censored Pavement Sections[a]	Number of Pavement Sections Left in Study	Proportion of Pavement Sections Failed	Proportion of Pavement Sections Surviving
0	0	0	20	0.00	1.00
13	1	0	19	0.05	0.95
14	1	0	19	0.05	0.95
15	2	0	18	0.10	0.90
16	3	0	17	0.15	0.85
17	7	0	13	0.35	0.65
18	11	2	7	0.61	0.39
19	14	3	3	0.82	0.18
20	16	4	0	1.000	0.000

[a] Censored pavements are those that are still in service at time of analysis.

The preferred method is to develop pavement survival curves within each district or region and to confirm those survival relationships periodically. However, it could be difficult to identify a sufficient number of sections in a specific geographical region from which to develop a pavement family survival curve. Another drawback to the survival analysis approach is the ability to account for the benefits or improvements in pavement design and materials. This drawback can be overcome by combining the survival analysis with the application of mechanistic-empirical methods to estimate pavement lives after local calibration or validation. This would be a consistent and distress-dependent approach to determine the impact on the use

of non-conventional materials and design features that are not represented adequately in the pavement management database.

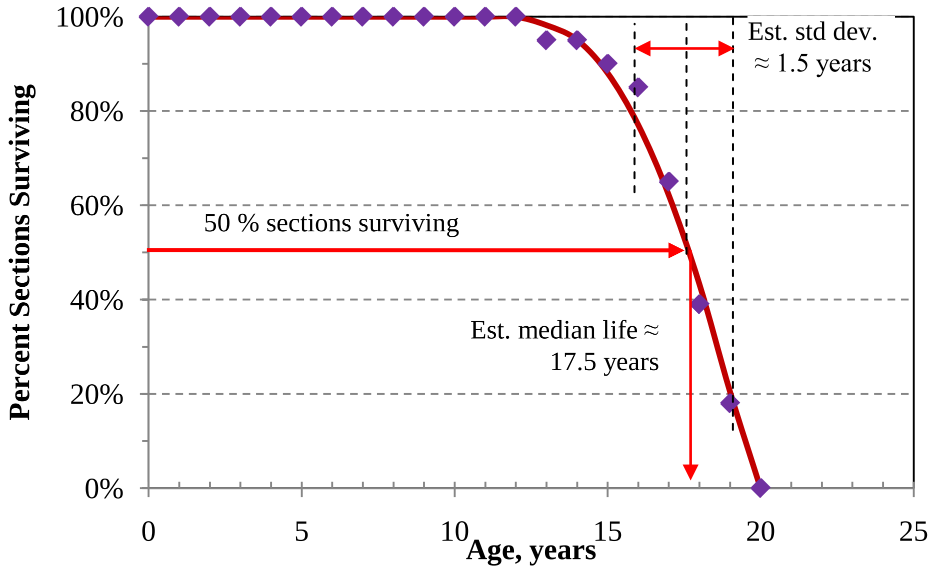


Figure 15. Pavement survival curve for selected pavement family.

4.3.3 Timing and Extent of Functional Rehabilitation Treatments

Many times, there is a need to improve only the functional characteristics of pavements (e.g., thin overlays to address smoothness and/or friction deficiencies or diamond grinding to restore texture for improved friction). As with structural rehabilitation treatments, pavement management and other historical records should be consulted to identify the expected timings and extents of these actions, if needed.

4.3.4 Timing and Extent of Maintenance Treatments

Between the time a pavement is constructed and the time it is rehabilitated (or rehabilitated and then rehabilitated again), it is likely that there will be several maintenance treatments applied. Maintenance treatments may range from routine activities (pothole/spall repairs) to preventive activities (crack sealing, joint resealing, surface treatments) to major repairs (slab replacements, full-depth repairs, localized skin patching).

The ideal LCCA captures all forms of maintenance costs, since the type, timing, and extent of maintenance activities will be different for each pavement alternative. However, because routine reactive-type maintenance costs generally are not very high and not substantially different between pavement types, they typically are ignored in the LCCA. The focus of maintenance costs should be on the timing and extent of preventive and major forms of maintenance. Again, pavement management and other historical records should be consulted to develop this information.

4.3.5 Data Inventory Needs

Pavement performance depends on attributes such as the structural layer properties, construction methods and quality, subsequent M&R activities, traffic composition, and environment. To establish reasonable life cycle models, using performance or survival analyses, an agency requires a comprehensive collection of data on these attributes. The key information required for developing life cycle models includes the following:

- Project Location Information – Highway number, beginning and ending reference points, direction, lanes, county, urban/ rural location, functional class and climatic region.
- Construction History – Original construction year, original pavement cross section (layer thickness and material types), subsequent M&R history (year, and treatment type).
- Materials and Construction Quality Database – Material types, mix designs, laboratory testing, key material characteristics of in-place materials, construction techniques, as-built thicknesses, quality assurance (QA) attributes, pay factors, specifications.
- Performance Database – Historical condition data in terms of distress indices, IRI, key distresses and survey dates, both before and after major rehabilitation activities.
- Traffic Composition – Historic estimates of annual average daily traffic (AADT), percentage of trucks, equivalent single axle loads (ESAL), and traffic growth rates.
- Cost Data – Cost of new construction, maintenance costs, rehabilitation costs, user costs, regional cost factors.
- Environment and Drainage Data – Climatic data, ground water table, drainage and shoulder characteristics.

While most agencies maintain this information, as stand-alone inventories or in some combination with others, it is essential to integrate each of the inventory types meaningfully using a common electronic format. Location referencing generally is used as a primary key to relate the data inventories with each other. The referencing method forms the crosswalk between different inventories for data integration with its ability to relate the data to the physical location on the pavement network. Such integration is essential for grouping pavement sections with similar designs, traffic, and material characteristics. The groupings identify pavements that are likely to have identical performance.

The integrity of the data inventories can be affected by quality issues such as incorrect, incomplete, or erroneous records. Examples include missing pavement sections, inconsistencies within a pavement section between the original pavement type and the sequence of M&R activities, missing or clearly inaccurate layer type and thickness information, and questionable time intervals (too short or too long) between events. To obtain robust estimates of pavement service life, it is critical to utilize good quality data that is accurate and complete. This necessity underscores the need for a comprehensive quality control and audit process. Statistical procedures can be used in identifying and flagging anomalies.

Furthermore, there is a continuous change in technologies and processes over time, as improvements in materials, design, and construction take place. This change drives the need for additional data to accommodate these improvements in the pavement-type selection process. Therefore, there is a need for frequent update of the data inventories on a regular basis (at least annually).

CHAPTER 5 – LIFE CYCLE COST ANALYSIS

5.1 INTRODUCTION

Selecting a pavement type based solely on initial costs allows for more to be accomplished with a specified annual budget, but it does not account for long-term costs paid by taxpayers and facility users.

Therefore, the pavement-type selection process should consider both initial and future costs in the economic analysis of alternatives. In the economic analysis, costs occurring at different points in the pavement life cycle should be discounted by taking the time value of money into account for comparing or combining with initial costs. In accomplishing this, the LCCA serves as an ideal tool for taking initial and future costs into consideration and, as a result of the focus placed on best value, the decision-making process is greatly improved. Although experience-based estimates can be used in quantifying LCCA inputs, it is highly recommended that all available, applicable, and reliable data be used in this effort. The quality of LCCA results is only as good as the quality of the inputs. Figure 16 presents the LCCA process described herein.

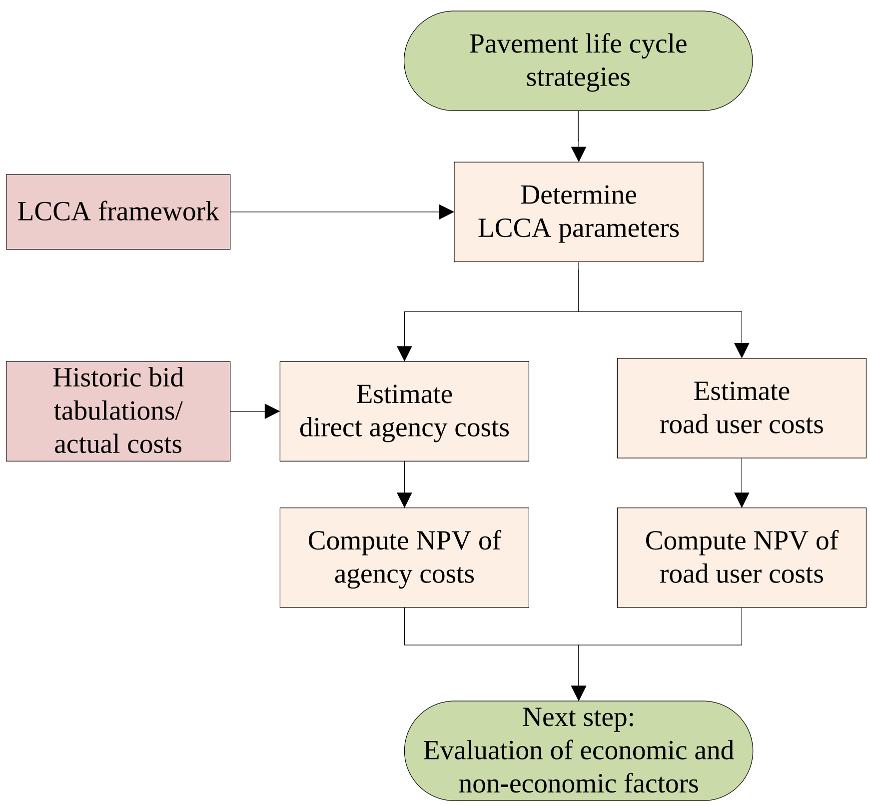


Figure 16. Process for conducting pavement LCCA.

5.2 ESTABLISH LCCA FRAMEWORK

This section discusses the fundamental economic indicators required for establishing the LCCA model. Additional information on economic indicators can be obtained from the FHWA's most current guidance on LCCA (FHWA, 2004).

5.2.1 Analysis Period

As the FHWA and many economic experts have long recommended, the analysis period for LCCA must be sufficiently long to distinguish any differences between pavement alternatives and generally such that each alternative pavement strategy includes at least one future major rehabilitation event. Typical design lives for new/reconstructed highway pavements range from 10 to 20 years for asphalt structures and 20 to 30 years for concrete structures. Design lives of structural rehabilitation activities, such as conventional, mill-and-fill, recycled HMA overlays of asphalt pavements and PCC overlays, major concrete pavement restoration (CPR), and HMA overlays of concrete pavements, generally are a little shorter than these respective ranges.

For new/reconstruction projects, an analysis period of at least 40 years is considered appropriate. For rehabilitation projects, an analysis period of at least 30 years is considered appropriate. Longer analysis periods may be warranted for long-life pavement designs, and greater effort must be made to make reliable long-term forecasts.

Finally, it must be emphasized that the chosen analysis period is to be applied to all pavement strategies being considered in the LCCA. No alternative should be analyzed over a time period that is different from the other alternatives.

5.2.2 Economic Analysis Technique

FHWA guidance recommends than the NPV economic formula be used. The NPV should be applied using constant dollars and a real discount rate selected in accordance with the procedure described in Section 5.2.3.

5.2.3 Discount Rate

The discount rate represents the real value of money over time and is used to convert future costs to present-day costs. Based on the survey of state DOT practices, typical real discount rates range from 3 to 5 percent. The discount rates used should be those provided in the OMB Circular A-94, appendix C, or developed based on the agency's economic factors.

5.2.4 Cost Factors

Cost factors are subdivided into two basic categories: direct/agency costs and indirect/user costs.

Direct/agency costs are the costs forecasted to be incurred by the transportation agency for a given pavement strategy over the chosen analysis period. They are embodied by the initial

construction/rehabilitation event, the sequence of future M&R events, and the salvage value of the pavement strategy at the end of the analysis period.

User costs are the costs incurred by the highway user over the life of the project. Although borne by the highway user, these costs must be given serious consideration by the highway agency, since the agency acts as the proxy for public benefit.

More discussion on direct/agency costs and user costs is provided in Sections 5.3 and 5.4, respectively.

5.2.5 Statistical Computation Approach

As discussed earlier, there are two basic approaches for computing life cycle costs—deterministic and probabilistic.

Deterministic Approach

For a given pavement strategy, a single value is selected (usually the value considered most likely to occur, based on historical evidence or professional experience) for each input parameter (e.g., costs, pavement life), and the selected values are used to compute a single projected life cycle cost. Because each input parameter is represented by only one value, the uncertainties and variations known to exist in these variables in the real world are not fully accounted for in deterministic LCCA.

Probabilistic Approach

For a given pavement strategy, sample input values are randomly drawn from the defined frequency distributions, and the selected values are used to compute one forecasted life cycle cost value (see Figure 17). The sampling process is repeated hundreds or even thousands of times, thereby generating many forecasted life cycle cost values for the pavement strategy. The resulting forecasted costs can then be analyzed and compared with the forecasted results of competing alternative, to identify the most economical strategy considering the uncertainty of the inputs. Probabilistic simulation requires the use of either a computerized spreadsheet program equipped with the necessary probabilistic distribution functions or a stand-alone computer program that is properly hard-coded to perform the simulation.

It is recommended that the probabilistic LCCA approach be used when reliable historical data exist to model one or more of the input parameters (e.g., standard deviations of discount rate, unit costs, pavement service life). These can be obtained from agency files (variable bid prices, survival analysis of pavement lives to get means and standard deviations and annual discount rates over time). If such data cannot be obtained, then a deterministic approach can be used, supplemented with sensitivity testing of key input parameters. For alternate bidding applications, the deterministic and probabilistic (at a specified probability) approaches can be used.

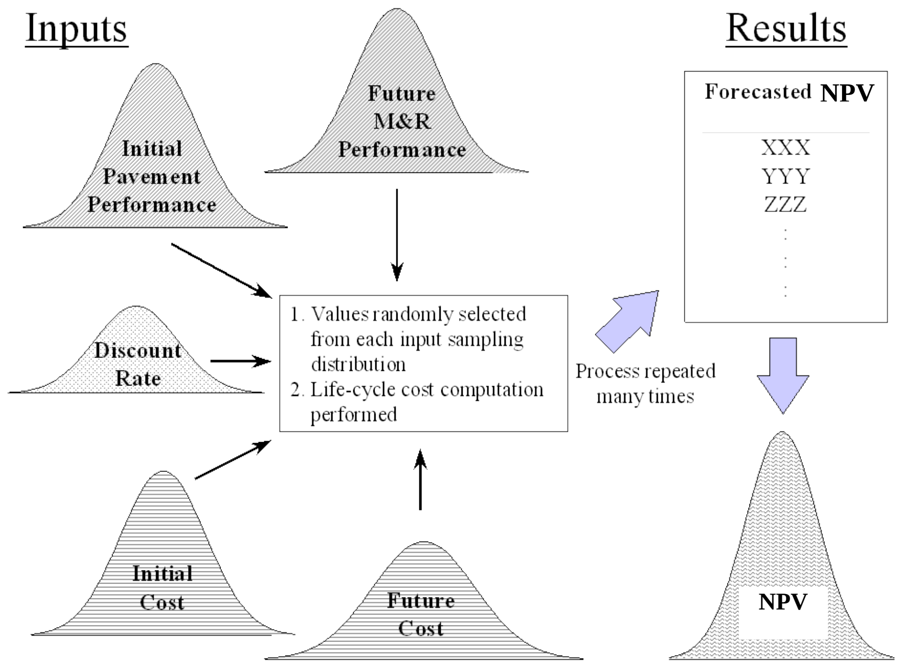


Figure 17. Illustration of the probabilistic LCCA process (ARA, 2004).

5.3 ESTIMATE DIRECT/AGENCY COSTS

Direct/agency costs include the physical cost of the pavement structure/treatment associated with an event and may include certain supplemental costs, such as engineering costs and materials testing costs. In both cases (physical and supplemental costs), only the differential costs between pavement alternatives are considered in the LCCA; costs common to all alternatives cancel out and are excluded from the calculations (Walls and Smith, 1998).

The costs of building, maintaining, and rehabilitating pavements as part of each alternative pavement strategy are an important element of LCCA. Using reliable, up-to-date unit price estimates for each activity/material pay item associated with the initial structure (whether new/reconstructed or rehabilitated) and future M&R treatments will ensure a fair and accurate computation of life cycle costs. This step involves estimating these unit costs and combining them with estimated pay item quantities to develop the physical costs of pavement activities for use in the LCCA. It also entails determining salvage value.

A third aspect of direct/agency costs are the supplemental costs associated with construction and M&R activities. These costs can be categorized into administrative, engineering, and traffic control costs. Their inclusion in the LCCA depends on whether substantive differences can be identified among the alternative pavement strategies.

5.3.1 Physical Costs of Pavement Activities

The key to estimating physical costs is identifying and obtaining sufficient and reliable unit cost data for the pay items that will go into the initial structure and individual M&R treatments. The best sources for these data are the historical bid tabulations for projects undertaken in recent

years (preferably, within the last 5 to 7 years) on highways within the region. These data often are compiled and summarized on a regular basis for project estimating purposes.

Unit cost estimates can be developed using the unit price data from the lowest bid or three lowest bids tendered on projects of comparable nature. Each average unit price must be adjusted to present day dollars to account for the effects of inflation, and consideration should be given to filtering out prices biased by projects that included small quantities of a particular pay item. Using inflation-adjusted and quantity-filtered unit price data, the mean cost of each pay item, as well as key variability parameters (standard deviation, range), can be computed for use in the LCCA. Figure 18 and Figure 19 illustrate the process of normalizing unit cost data and developing best estimates for both deterministic and probabilistic LCCA applications.

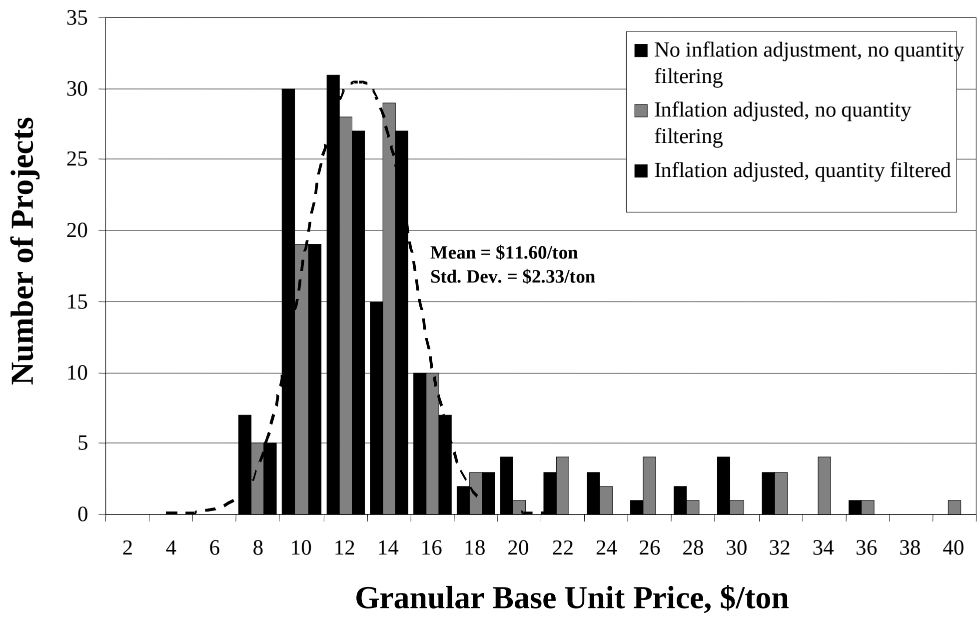


Figure 18. Example of pay item unit price development.

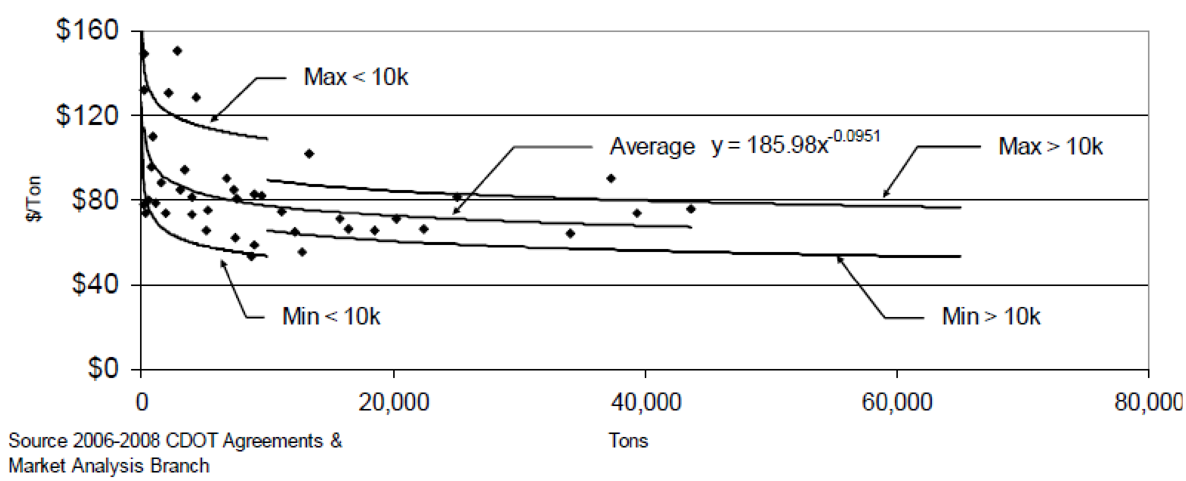


Figure 19. Colorado DOT's process for estimating initial costs (CDOT, 2011).

In cases where new materials/technologies are expected to be used and no or little regional cost data are available, estimates should be derived using data available from other sources. Pavement industry groups can be consulted to help identify appropriate sources.

Unit cost data obtained from other sources may need to be adjusted to account for geographical differences in construction costs. The United States Air Force has developed adjustment factors for each state that can serve this purpose (AFCESA, 2007). The most recent listing of adjustment factors is shown in Table 19.

Table 19. Construction cost location adjustment factors (AFCESA, 2007).

State	Factor	State	Factor	State	Factor	State	Factor
Alabama	0.82	Indiana	0.96	Nebraska	0.94	Rhode Island	1.11
Alaska	1.90	Iowa	0.98	Nevada	1.24	South Carolina	0.88
Arizona	0.97	Kansas	0.93	New Hampshire	1.06	South Dakota	0.96
Arkansas	0.85	Kentucky	0.91	New Jersey	1.17	Tennessee	0.85
California	1.18	Louisiana	0.94	New Mexico	0.98	Texas	0.85
Colorado	1.04	Maine	1.06	New York	1.07	Utah	1.02
Connecticut	1.13	Maryland	1.02	North Carolina	0.84	Vermont	1.00
Delaware	1.02	Massachusetts	1.12	North Dakota	1.04	Virginia	0.93
Florida	0.86	Michigan	1.12	Ohio	0.96	Washington	1.06
Georgia	0.84	Minnesota	1.12	Oklahoma	0.91	West Virginia	0.95
Hawaii	1.74	Mississippi	0.88	Oregon	1.06	Wisconsin	1.08
Idaho	1.03	Missouri	0.97	Pennsylvania	1.04	Wyoming	0.98
Illinois	1.20	Montana	1.14				

5.3.2 Salvage Value

At the end of the analysis period there is generally some type of value that can be accorded to the remaining pavement section. This value is referred to as salvage value in economic analysis and is made up of two components: remaining service life and asset value. Remaining service life is the structural life remaining in the pavement at the end of the analysis period. Because different pavement strategies have differing design lives, the end of the analysis period very often does not coincide with end of the pavements design life. FHWA is developing a depreciation approach for remaining life and residual/recycle components; the remaining life depreciation will include both functional and structural lives, while the residual/recycle component is expected to be based on a standard accounting process.

Asset value is the value of the in-place pavement materials less the cost to remove and process the materials for reuse. For example, the existing pavement may have value as aggregate for a new pavement. Its asset value would be its value as aggregate less the cost of removal, transportation, and processing to meet specifications.

One method of determining the value of a pavement’s remaining life is to determine the depreciated value (at the end of the analysis period) of the costs of initial construction and subsequent M&R. Depreciation is an accounting term used to attribute costs across the life of the asset. Straight-line depreciation is the simplest and most commonly used technique for estimating value at the end of the analysis period.

Depreciation can be applied to both the structural and functional life components of a pavement (see Figure 20). A functional improvement cost relates to those treatments that do not add structural capacity. Typically, this includes preventive and corrective maintenance and improvements to the pavement ride, such as surface treatments, thin overlays, and localized mill-and-fill treatments. In computing the depreciation of functional treatments, the life of the treatment cannot exceed the pavement structural life.

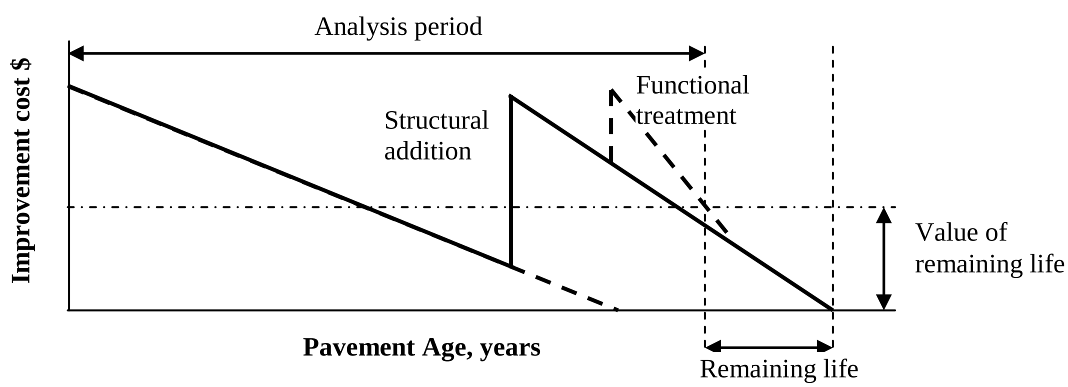
The salvage value is a combination of the depreciated values of the structural and functional treatments applied to the pavement in the year the analysis period ends, plus the asset value of the existing pavement (See Figure 21).

Asset value of the existing pavement is:

$Asset value = Value as aggregate (or recycled pavement) – removal cost – processing cost

Salvage value is:

Salvage value = $217,500 + Asset value



Annual Depreciation = Cost of Improvement / Life Span

Figure 20. Example of structural and functional depreciation curves.

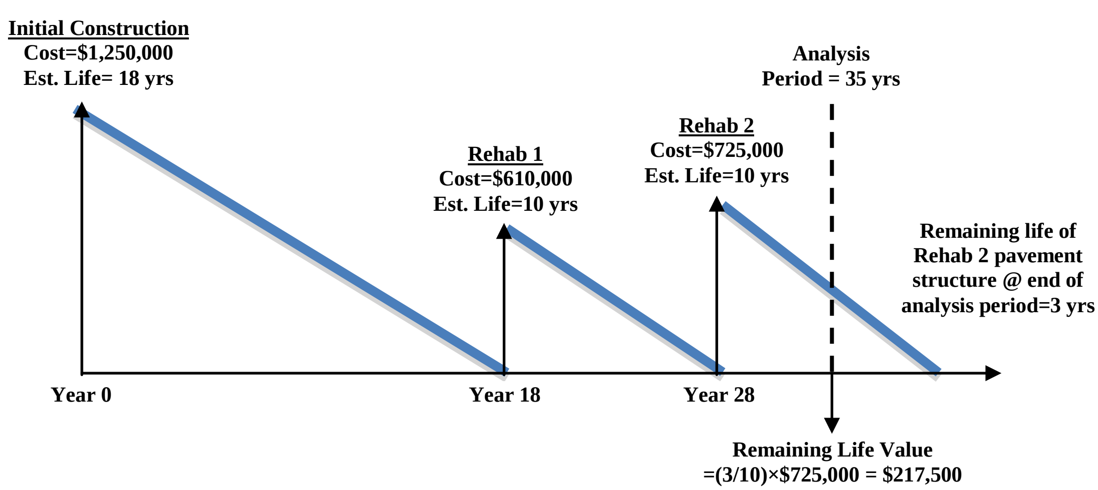


Figure 21. Illustration of remaining life value.

5.3.3 Supplemental Costs

Brief descriptions of supplemental costs are provided below. Each category is applicable only to the series of anticipated future M&R events.

- Administrative Costs—Contract management and administrative overhead costs.
- Engineering Costs—Design and construction engineering costs, construction supervision costs, and materials testing and analysis costs.
- Traffic Control Costs—Traffic control setup and communications costs.

If the supplemental costs of the different alternatives are approximately the same, then these costs can be ignored and only the physical costs should be considered. If there are significant differences, the process of developing estimates for all events should proceed. Because estimating these costs can be difficult and time-consuming, an alternative method to consider is to specify them as a percentage of the total project-level pavement costs.
Table 20 illustrates this simple and straightforward application using a value of 5 percent to represent engineering costs. As can be seen, the percentage is applied equally to each event in each alternative strategy.

Table 20. Example application of estimating supplemental costs.

Event	Cost Item	Pavement Type 1	Pavement Type 2
Rehabilitation No. 1	Total Pavement Costs	$1,250,000	$1,560,000
	5% Engineering Costs	$62,500	$78,000
	Total	$1,312,500	$1,638,000
Rehabilitation No. 2	Total Pavement Costs	$575,000	$350,000
	5% Engineering	$28,750	$17,500
	Total	$603,750	$367,500

5.4 ESTIMATE INDIRECT/USER COSTS

User costs are an aggregation of time delay costs, VOCs, crash costs, environmental costs, and discount costs associated with work zones or any time during normal (non-restricted) operating conditions. In many instances, since the absolute value of user costs of the project far exceed the direct agency costs, users costs are evaluated independently from the direct costs.

Currently, it is recommended that only the work zone user costs involving time delay and vehicle operation be included in project-level LCCA. VOCs under normal operating conditions generally are an insignificant factor because today's highways are not allowed to get rough enough (IRI>190 in/mi) to generate significant differences. Other user cost components are difficult to collect and quantify.

The user costs of concern in a LCCA are the differential or extra costs incurred by the traveling public as a result of one pavement alternative being used instead of another. For instance, an alternative that requires more frequent or longer lane closures for M&R will lead to added user costs due to increased delay, greater fuel consumption, and so on. Also, an alternative that

provides a significantly lower overall level of serviceability during normal operating conditions will yield increased VOCs as a result of exposure to more pavement roughness.

For each pavement alternative being considered in an LCCA that will include user costs, each major work zone projected to occur for that alternative over the chosen analysis period must be evaluated as a separate event because traffic (volume and operating characteristics) and work zone characteristics (timing, duration, frequency, scope, operational speeds, etc.) will vary, leading to different costs for each event.

Detailed guidance for computing work zone time delay and VOCs originally was provided in the FHWA LCCA Interim Technical Bulletin (Walls and Smith, 1998). An updated version of this document is expected to contain no significant changes to the procedures for computing user costs, but it should feature up-to-date values for a number of user cost input parameters.

The FHWA RealCost software (FHWA, 2004) can be used to calculate work zone time delay and VOC user costs for competing pavement alternatives in accordance with the procedures and recommended inputs given in the updated bulletin.

5.4.1 User Cost Components

Seven user cost components that are important to work zone activities are identified in the FHWA model. Three of the components are associated with traffic operating under free-flow conditions, and the other four are associated with the queue that develops when traffic operates under forced-flow conditions brought on by a work zone. Descriptions of these components are as follows:

- Free Flow (Level of Service A)—The costs associated with free-flow conditions arise from speed change and result in three work zone-related user cost components: speed change delay, speed change VOC, and reduced speed delay.
  - Reduced Speed Delay is the additional time necessary to traverse the work zone at the lower posted speed. It depends on the upstream and work zone speed differential, and the length of the work zone.
  - Speed Change Delay is the additional time necessary to decelerate from the upstream approach speed to the work zone speed, and then to accelerate back to the initial approach speed after traversing the work zone.
  - Speed Change VOC is the additional vehicle operating cost associated with decelerating from the upstream approach speed to the work zone speed, and then accelerating back to the approach speed after leaving the work zone.
- Forced Flow (Level of Service F)—When instantaneous traffic demand exceeds work zone capacity, traffic flow breaks down and a queue develops (Walls and Smith, 1998). Queuing situations impose four work zone-related user costs that only apply to vehicles that encounter a physical queue.
  - Stopping Delay is the additional time necessary to come to a complete stop from the upstream approach speed (instead of just slowing to the work zone speed) and the additional time to accelerate back to the approach speed after traversing the work zone.

- ➢ Stopping VOC is the additional vehicle operating cost associated with stopping from the upstream approach speed and accelerating back up to the approach speed after traversing work zone.
- ➢ Idling VOC is the additional vehicle operating cost associated with stop-and-go driving in the queue. The idling cost rate multiplied by the additional time spent in the queue is an approximation of actual VOC associated with stop-and-go conditions. When a queue exists, stopping delay and VOC replace the free-flow speed change delay and VOC.
- ➢ Queue Delay is the additional time necessary to creep through the queue under forced-flow conditions.

Total user costs are calculated by multiplying the quantity of the various "additional" user cost components by the unit cost for those components, and then summing the costs of each component (Walls and Smith, 1998). For instance, for the time delay components, the additional time incurred as a result of speed changes and stops made because of the work zone is multiplied by the values of time of the vehicles affected. Similarly, for VOC components, the additional number of speed changes and stops experienced by vehicles because of work zones is multiplied by unit costs that reflect the added costs of fuel, oil, tire wear, and vehicle maintenance and depreciation. If work zones involve detours that result in additional mileage driven by users, then the additional miles are multiplied by unit costs that reflect the added operating expenses.

The following inputs typically are required for calculating work zone user costs:

- Work zone characteristics.
  - o Projected duration of work zones.
  - o Work zone directionality, length, and posted speed.
  - o Number and capacity of lanes open.
  - o Duration of lane closures.
  - o Timing of lane closures (hours of the day, days of the week, seasons of the year).
  - o Availability and physical and traffic characteristics of alternative routes.
- Traffic characteristics.
  - o Overall projected AADT.
  - o Associated 24-hour directional hourly demand distributions.
  - o Vehicle classification distribution of the projected traffic streams. For simplification, three broad vehicle classes are recommended:
    - ▪ Passenger cars and other 2-axle, 4-tired passenger vehicles (classes1-3).
    - ▪ Single-unit trucks, 2-axle, 4-tired or more commercial trucks (classes 4-7).
    - ▪ Combination-unit trucks (classes 8-13).

5.5 DEVELOP EXPENDITURE STREAM DIAGRAMS

Expenditure stream diagrams are graphical or tabular representations of direct agency expenditures over time. They are developed for each alternative pavement strategy to help the designer/analyst visualize the magnitudes and timings of all expenditures projected for the analysis period. As shown in Figure 22, costs normally are depicted by upward arrows and benefits (e.g., salvage value) by downward arrows.

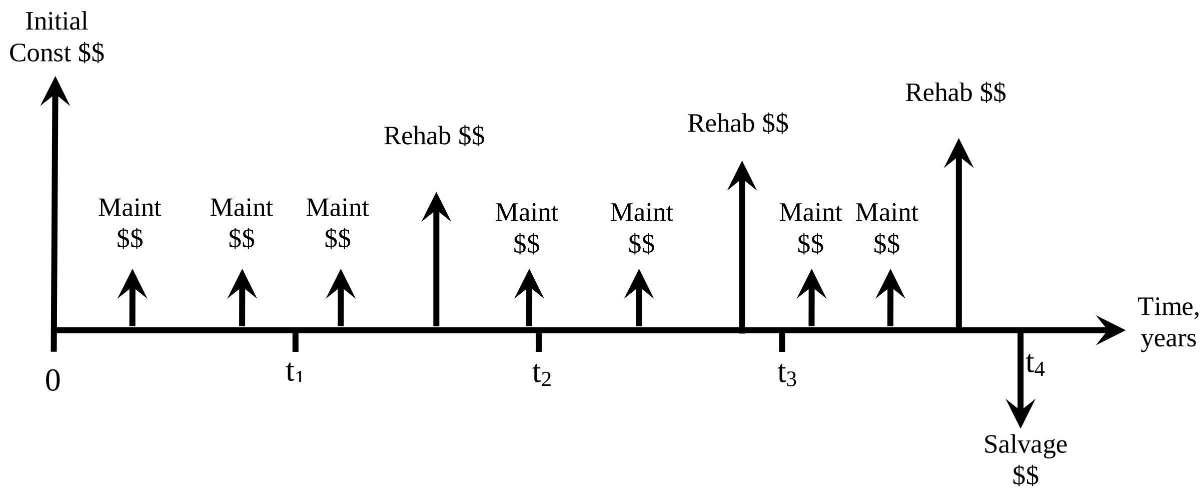


Figure 22. Example expenditure stream diagram.

5.6 COMPUTE LIFE CYCLE COSTS

Once the expenditure stream for each alternative pavement strategy has been developed, the task of computing projected agency life cycle costs is undertaken. The user costs are not included in the computation of agency costs.

For deterministic analysis, computing agency costs involves converting all projected future costs (including salvage, if appropriate) to present day values using a specified discount rate. The initial construction cost and all converted costs are then summed together to produce the NPV. Probabilistic analysis involves random selection of values from each input parameter's sampling distribution through hundreds or thousands of iterations to generate an array of forecasted costs. When performing a probabilistic simulation, it is important to make sure that each iteration represents a scenario that can actually occur. Two particular modeling errors with the potential to create unreal scenarios are as follows (Walls and Smith, 1998):

- Lack of appropriate pre-defined relationships between input parameters—Although each randomly selected value for a given iteration may be legitimate on its own, reality may dictate that certain relationships exist between the input parameters. For example, since higher traffic volume generally is linked with shorter pavement life for a given design cross-section, it is important to establish an appropriate sampling correlation between these two inputs. Such a correlation would ensure that, for each iteration, a sample from the high side of the traffic probability distribution is countered with a sample on the low side of the pavement life probability distribution, and vice versa.
- Lack of fixed limits on input sampling distributions—For some types of sampling distributions, the limits for sampling are not among the criteria used to define the distribution (e.g., in defining a normal sampling distribution, only the mean and standard deviation are needed). However, it is important to know the minimum and maximum values for sampling, so that reasonable values are used in the probabilistic simulation. Misleading simulation results can be expected, for instance, if the distribution for a cost or pavement service life parameter allows negative values to be selected.

5.7 ANALYZE/INTERPRET RESULTS

Regardless of whether deterministic or probabilistic life cycle costs are computed, the results must be analyzed and interpreted carefully to evaluate the cost-effectiveness of a pavement strategy. Because the outputs of each computational approach are different, the ways in which they are evaluated and interpreted also are different.

In addition to cost-effectiveness, other economic and non-economic factors should be considered in the selection process. Chapter 6 discusses in detail the evaluation of alternatives using economic factors.

5.7.1 Analysis of Deterministic Life Cycle Cost Results

In the analysis of deterministic results, it is common to compute the percent difference in life cycle costs of the alternative strategies. If the percent difference between the two lowest cost strategies is greater than some established minimum requirement—usually set according to the tolerance for risk (5 and 10 percent are common)—then the lowest cost strategy is considered as the cost-effective one.

5.7.2 Analysis of Probabilistic Life Cycle Cost Results

In the analysis of probabilistic results, the likelihood of an alternative's cost-effectiveness is evaluated with those of other alternatives. This approach involves comparing NPV distributions of different alternatives at a specified level of probability. A probability level between 75 and 85 percent will provide reliable estimates. Figure 23 shows the cumulative probability distributions of NPV for two alternative strategies at 50 percent (mean value) and 75 percent probabilities. The figure indicates that the alternative B has a lower NPV than alternative A at both probability levels.

Suppose that alternative A had a slightly lower mean NPV ($1.608 million instead of $1.611 million) and a more dispersed distribution, as shown in Figure 24. In such cases, the tails of the frequency distribution curves should be evaluated for any potential cost-associated risks. The distribution curves shown in Figure 12 indicate clear differences in the forecasted NPV at the tails. For alternative A, there is potential for a cost underrun if the true NPV is low (say, less than $1.45 million). This opportunity for cost savings is called *upside risk*. If, on the other hand, the true NPV is high (say, greater than $1.75 million), there is a potential for a cost overrun associated with alternative A. This chance for financial loss is called *downside risk*.

In the cumulative distributions shown in Figure 25, it can be seen that there is a 10 percent probability that the NPV of alternative A will be less than alternative B by as much as $26,000. At the other end of the spectrum, there is a 10 percent probability that alternative A will exceed the cost of alternative B by up to $41,000. Although many agencies may find this information insufficient for identifying the most cost-effective strategy, to some risk-averse agencies it may provide enough assurance that the allocated budget is best served by choosing alternative B. In other words, there is a greater risk of the true cost of alternative A exceeding the cost of alternative B than vice versa.

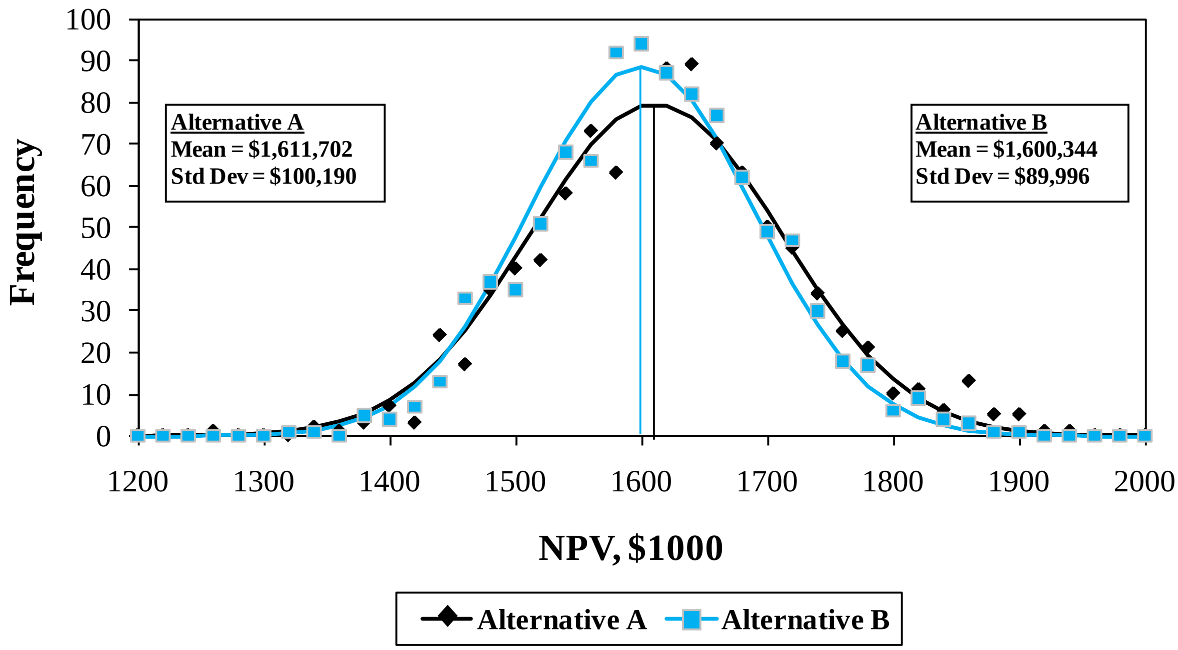


Figure 23. NPV frequency distributions for alternative strategies A and B.

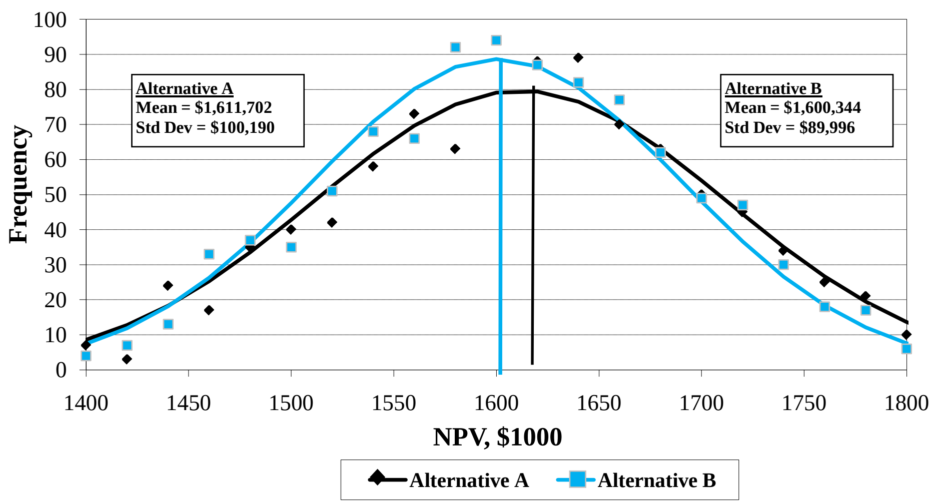


Figure 24. Risk assessment—NPV frequency distributions.

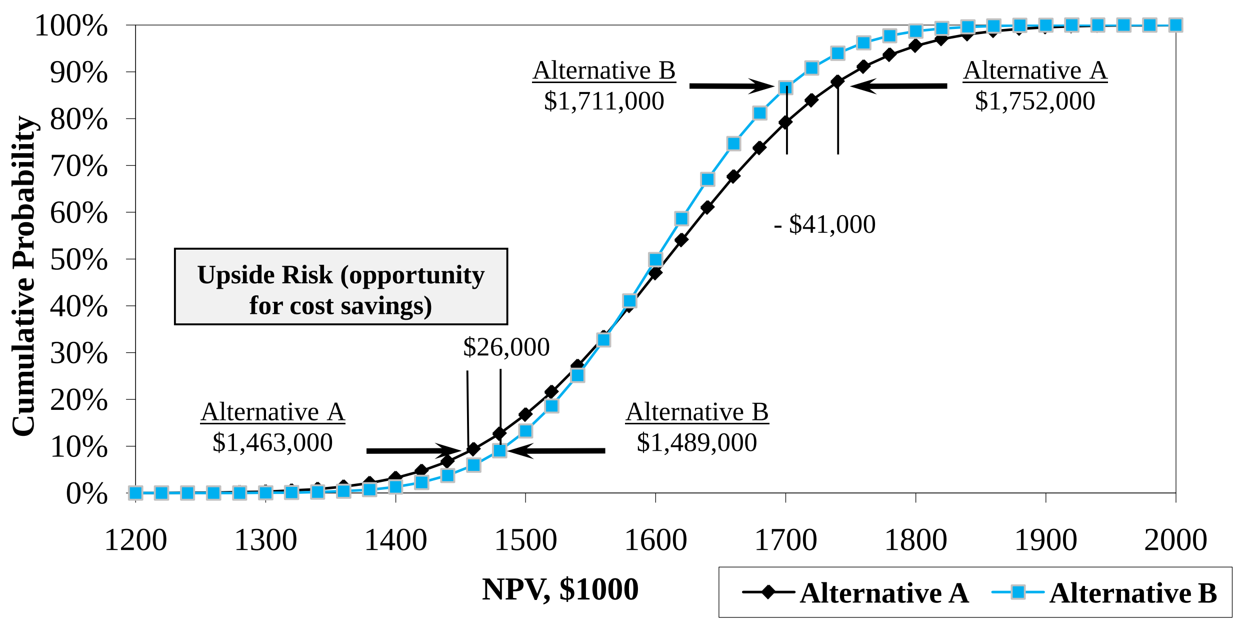


Figure 25. Risk assessment—NPV cumulative distributions.

5.7.3 Re-evaluate Strategies

In the final step of the LCCA process, information resulting from the LCCA is re-evaluated to determine if any modifications to the alternative strategies are warranted, prior to making a final decision on which alternative to use. Such adjustments may entail changes to the original structure or rehabilitation treatment, revisions to the maintenance of traffic plans, reductions in construction periods, or changes in future M&R activities.

Probabilistic sensitivity analysis can provide insight on the refinement of strategies. This technique uses correlation analysis and tornado plots (Figure 26) to show the impacts of key input parameters on life cycle costs. Inputs found to be driving the LCCA results can be scrutinized to determine if actions can be taken to improve cost-effectiveness.

Figure 26 presents an example showing the correlation coefficients of factors influencing the NPV of a pavement alternative. The correlation coefficient is a statistical measure that indicates the strength of linear association between two variables. A correlation coefficient of +1 indicates that two variables are perfectly related in a positive linear sense, while a value of -1 indicates perfect negative correlation; values closer to zero indicates poor or no correlation; and other intermediate values indicate partial correlation between variables.

In this example, the NPV of the pavement alternative is positively correlated with cost factors, while negatively correlated with the discount factor and pavement service life estimates. Among the factors influencing NPV, the initial construction cost appears to be the dominating factor followed by the service life of the original pavement. In other words, in order to reduce the NPV of this pavement alternative, a strategy to reduce initial construction cost would be more effective than other possible strategies.

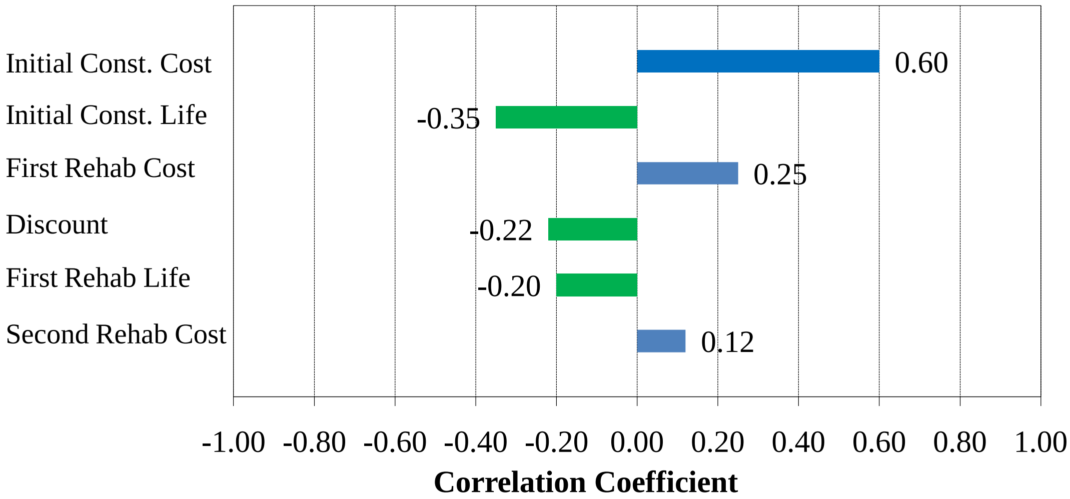


Figure 26. Sensitivity of factors affecting the NPV of a particular pavement strategy.

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CHAPTER 6 – SELECTION OF PREFERRED PAVEMENT ALTERNATIVES

Selection of the preferred pavement strategy alternative requires the evaluation of both economic and non-economic factors (factors used by the responding states are shown in Table 8). The process involves three steps: (1) consideration of the economic factors, (2) consideration of the non-economic factors, and (3) weighing the non-economic factors against the economic analysis to select the preferred alternative. The outcome of this process is a single preferred pavement type for traditional design-bid-build projects and multiple preferred pavement types for alternative bid projects. The process is illustrated in Figure 27

6.1 ECONOMIC SELECTION FACTORS

Before selecting the cost-effective alternative as the preferred strategy, it is imperative to take financial aspects into consideration. The agency evaluates the pavement-type alternatives on the basis on these aspects and their importance. The following list describes the economic factors that should be included in the evaluation:

- **Initial costs**. Agencies may set maximum funding levels for individual projects so that the entire system can be maintained at a desired level. Such constraints may result in eliminating some alternatives, particularly those with high initial costs, even though the alternatives are attractive from a life cycle cost perspective. The evaluation should determine if the first costs of an alternative exceed the available resources or would impact the management of the overall system.
- **User costs**. Alternatives with high user costs require special evaluation, even if the overall life cycle cost is low. High user costs indicate the potential for a high degree of user dissatisfaction, or a negative impact on the traveling public. When high user costs are computed, the agency should review the project design and construction sequencing to determine if the impacts to the user can be reduced. In cases where high user costs cannot be reduced, consideration should be given alternatives with a lesser impact. The evaluation should determine if the user costs of an alternative are excessive and would have a greater-than-desired impact on the user.
- **Rehabilitation costs**. Certain alternatives may provide a low overall life cycle cost but require several rehabilitation activities to maintain the desired functional and structural performance level. Such costs may have an impact on the management of the entire system. Frequent interventions may result in higher work zone user costs and impacts on local business and the community. The evaluation should determine if an alternative that requires frequent rehabilitation actions may be suitable for the project.
- **Maintenance costs**. Certain alternatives may require a disproportionate maintenance effort over their lifetime that exceeds the resources available for applying the maintenance. This maintenance effort may exceed the personnel and/or equipment available for applying the maintenance. The evaluation should focus on the maintenance actions that an alternative may require to maintain performance levels over its life.

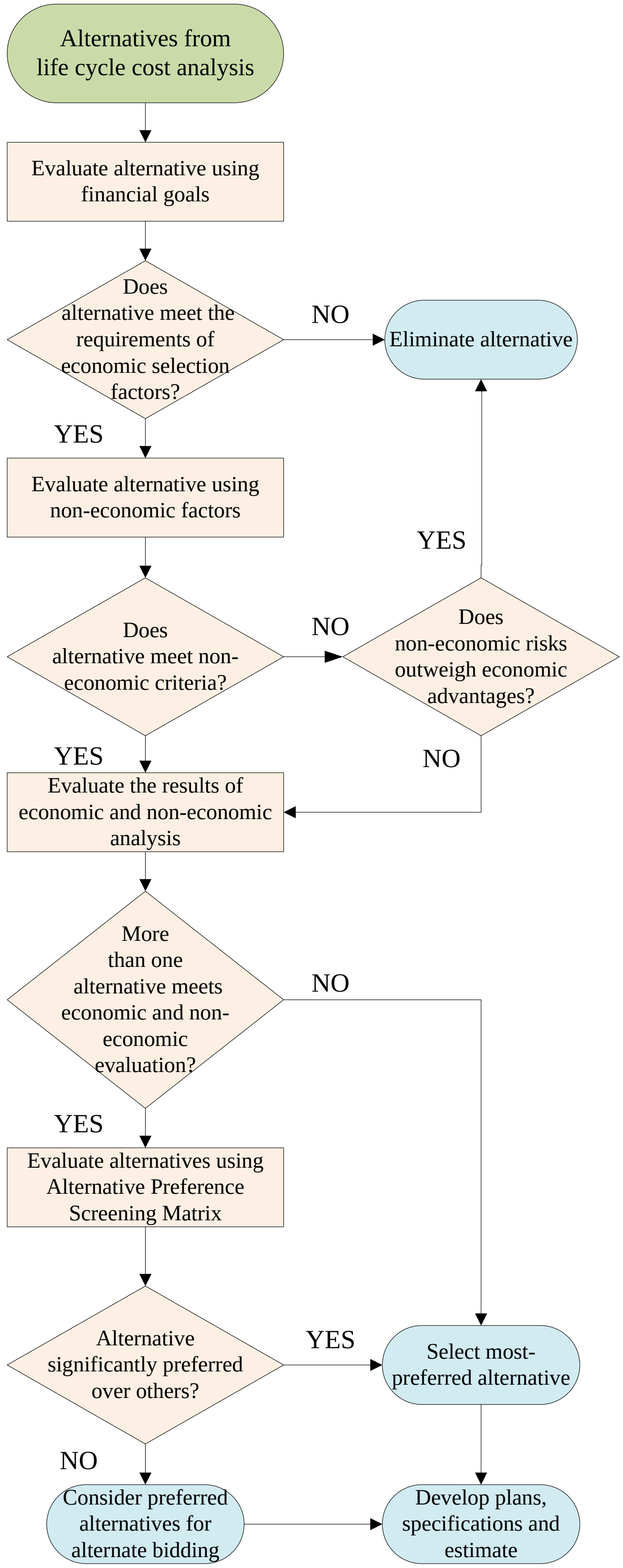

Figure 27. Selection of preferred pavement-type alternative(s).

- **Direct agency life cycle costs**. The life cycle costs indicate the aggregation of estimated initial and future costs normalized to their time value. The evaluation of this factor helps to eliminate alternatives that are not feasible from a cost perspective (i.e., alternatives with significantly higher life cycle costs than the other alternatives). If the percent difference between the two lowest cost strategies is greater than some established threshold, then the lowest cost strategy is accepted as the most economical one. If, on the other hand, the percent difference is less than this threshold requirement, then the life cycle costs of the two strategies are deemed equivalent, thereby leaving the analyst with the option of re-evaluating the strategies or allowing other factors to dictate the strategy selection process. The percent difference threshold value between two competing alternatives will depend on the accuracy of the data collected by the agency; agencies typically use a value between 5 and 20 percent. This value should be determined and set by the PTSC. Where data is available the impact of the variances of the LCCA input variables on the variance of the NPV variance should be considered in establishing the percent difference threshold value.

6.2 NON-ECONOMIC FACTORS

In addition to economic factors, numerous non-economic factors must be weighed in making a pavement-type selection for a specific project. The importance or weighting of these factors may vary from project to project. The following list describes the factors that should be included in pavement-type selection. This is not an exhaustive list; other factors and project-specific conditions should be considered as necessary.

- **Roadway/lane geometrics**. Lane widths may be fixed by design standards, yet there will be occasions, especially with rehabilitation design, where it is necessary to work with varying widths. Lane widths also play a major role in where wheel loads will be located. Overall, lane width can be important in determining the width and type of shoulder, as well as the type of pavement. Longitudinal grades and the absence or presence of vertical curves can be important pavement design considerations, as they may influence drainage features and even the type and speed of traffic to use the facility. Slower traffic produces larger deformations, stresses, and strains in a pavement structure and requires special materials considerations.
- **Continuity of adjacent pavements**. When filling a gap between two similar pavement types, it may be preferable to continue a similar pavement type to avoid a hopscotch pattern and provide for continuity of maintenance operations and experience.
- **Continuity of adjacent lanes**. Non-uniform sections can result in differential pavement performance and condition across the width of the roadway. Consistent performance across the width of the roadway is preferred. (The preferred uniformity is applicable to driving lanes only and not existing shoulders that will remain shoulders.)
- **Traffic during construction**. Speed of construction, accommodating traffic during construction, safety to traffic during construction, ease of replacement, anticipated future widening, seasons of the year when construction must be accomplished, and others related factors may have a strong influence on the strategy selections in specific cases. Construction considerations can be especially important for the design of rehabilitation

projects. For example, limited overhead clearances may preclude an overlay or limit its thickness such that pavement-type selection is affected. Other geometric factors, such as roadway width, guardrail heights, and cut-fill slopes often impact the design decision.

- **Availability of local materials and experience**. The availability and adaptability of local material may influence the selection of a pavement strategy. Also, the availability of commercially produced mixes and the equipment capabilities of area contractors may influence the selection, particularly on small projects.
- **Conservation of materials/energy**. Selection of a pavement strategy may be influenced by the criticality of materials supply as well as by the energy requirements of materials production. The construction energy requirements associated with various pavement types may be an additional consideration.
- **Local preference**. The issues raised by consideration of municipal or local government preferences and local industries may be outside the control of most highway engineers. However, the highway administrator often must take these preferences into consideration, especially if other factors do not yield a clear pavement-type preference.
- **Stimulation of competition**. Most agencies consider it desirable to encourage improvements in products and methods through continued and healthy competition among the paving industries and materials suppliers. Where alternate pavement designs have comparable initial costs, including the attendant costs of earthwork, drainage facilities, and other appurtenances, and provide comparable service life or life cycle cost, the highway agency may elect to take alternate bids to stimulate competition and obtain lower prices.
- **Noise issues**. Noise can have a significant impact on quality of life and is costly to mitigate after the fact. Tire–pavement noise mitigation is particularly important on urban highways. The life of the low-noise surface should be considered, as some deteriorate rapidly. Construction noise also can be an issue, influenced by factors such as the equipment type, traffic rerouting, and day/night operations. So certain alternatives may have noise intensity issues in sensitive settings or may have noise duration issues due to longer periods of construction and/or M&R.
- **Safety considerations**. 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 influence the pavement strategy selected in specific locations. In the context of non-skid surfaces, it is important to consider the profile and texture durability (i.e., how long the desirable characteristics are going to last). Excessive ruts on the surface often increase the likelihood of safety hazards such as hydroplaning, insufficient friction, and loss of control of the vehicle, especially in wet weather and at high speeds.
- **Subgrade soils**. For new locations or reconstruction, the ability of the foundation to support construction equipment and processes may be an important concern. Sometimes it is necessary to stabilize subgrade soils with cementitious materials to provide a suitable working platform. Such stabilized subgrades often have not been considered as part of the pavement structure. The load-carrying capability of a native soil, which forms the subgrade for the pavement structure, is of paramount importance in pavement performance. Even for small projects, 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 soils not only directly affect the pavement structural design

but also may, in certain cases, dictate the type of pavement economically justified for a given location. As an example, problem soils that change volume with time require a pavement structure able to conform to seasonal variations in longitudinal and transverse profile. An approach sometimes used is to provide for staged construction to accommodate large expected deformations over time.

- **Experimental features**. In some instances, it is necessary to determine the performance of new materials or design concepts by field testing under actual construction, environmental, or traffic conditions. The incorporation of such experimental features may dictate the strategy selected.
- **Future needs**. Future needs on geometric or capacity changes during the analysis period are evaluated to determine if the use of staged construction is warranted.
- **Maintenance capability**. It is necessary to determine if the maintenance unit responsible for the pavement section has the experience and equipment to maintain all pavement alternatives being considered.
- **Sustainability**. Sustainability in pavements is achieved through practices emphasizing energy efficiency, emissions reduction, and resource conservation. These strategies strive toward an approach that balances environment conservation, societal needs and economic development in existing practices. The sustainable practices include increased use of recycled materials, industrial by-products and local materials, decreased use of energy-intensive materials and construction processes, improvements in material production and processes, techniques that preserve or increase the longevity of pavements and eco-friendly design alternatives. Life Cycle Assessment (LCA) methods are typically used in evaluating the environmental impact of materials, equipment and processes used in pavements. The LCA-based environmental impacts can be incorporated qualitatively or quantitatively (as in costs) in the pavement-type selection process proposed in this Guide.

6.3 WEIGHING OF ECONOMIC AND NON-ECONOMIC FACTORS USING ALTERNATIVE PREFERENCE SCREENING MATRIX

The pavement-type selection process should weigh both economic and non-economic factors to ensure that the agency goals and policies are incorporated in decision making. An alternative preference screening matrix is recommended for this purpose. The screening matrix is a decision support tool that is designed to help agencies determine whether there are advantages in selecting one alternative over others and whether these alternatives should be evaluated more closely. The following sections describe how to set up the screening matrix and evaluate the results obtained.

Step 1: Identify and Group Evaluation Factors

The economic and non-economic factors that have a potential impact on the pavement-type selection process for a given project are identified and grouped. The factors identified in Sections 5.2 and 6.2 are suggested for use. A suggested grouping structure and sample factors are listed in Table 21. The factor groups could include economic factors, construction factors, local factors, maintenance factors, traffic and safety factors, environmental factors, and others. Agencies are expected to modify the grouping structure as necessary to best suit their goals,

expectations, and project requirements. The evaluation factors and groups may vary from project to project within an agency.

Step 2: Assign Group and Individual Factor Weights

Next, weights must be assigned to each of the factor groups and each factor within a group to reflect their importance to the pavement-type selection process for a given project. Table 22 and Table 23 illustrate the group and factor weighing scheme, respectively. The factor groups and factors within a group can be assigned either equal or unequal weights, but the sum of all group weights and all the factor weights within each group must equal 100 percent.

Step 3: Assign Preference Rating of Individual Factors

To facilitate a comparative evaluation of alternatives, the evaluation factors are assigned with preference ratings using pre-determined criteria. The purpose of the ratings is to quantify the relative advantages and disadvantages among the alternatives for each evaluation factor. When an alternative offers significant advantages associated with a given evaluation factor, then the alternative is rated with a high preference for that factor.

Table 21. Grouping structure of the alternative preference screening matrix.

General Version	Example
Group A Factor A1 Factor A2 … Factor AN	Economic factors initial costs future rehabilitation costs … user costs
Group B Factor B1 Factor B2 … Factor BN	Construction factors continuity of adjacent lanes traffic during construction …. lane geometrics
Group C Factor C1 Factor C2 … Factor CN	Local factors availability of local materials district/local preferences …. stimulation of competition
Group D Factor D1 Factor D2 … Factor DN	Other factors noise subgrade soils … experimental features

Table 22. Group weights of the screening matrix.

General Version		Example	
Group	**Score**	**Group**	**Score**
A	W_A	Economic factors	50%
B	W_B	Construction factors	25%
C	W_C	Local factors	10%
D	W_D	Other factors	15%
	Total score = 100		Total score = 100

Table 23. Factor weights of the screening matrix.

General Version		Example	
Group A	Score	Economic Factors	Score
A1	W_{A1}	Initial costs	30%
A2	W_{A2}	Future rehabilitation costs	25%
A3	W_{A3}	Road user costs	20%
AN	W_{AN}	Future maintenance costs	25%
	Group total = 100		Group total = 100

The rating scheme can be discrete or continuous. While a discrete rating scheme is simple to use, a continuous rating scheme provides more flexibility. As with factors, groups, and weights, it is recommended that agencies develop their own rating guidelines that reflect their goals and expectations. As first step, each agency should query decision makers on what factors they currently use in making pavement type decisions and what additional factors identified in Sections 5.2 and 5.3 should be considered in a formalized process. Several test runs should be made on several older projects to determine if the proposed screening process results in pavement selections that are acceptable to the agency. The PTSC can help establish these guidelines for the agency's use.

Table 24 provides sample guidelines on rating individual factors on a discrete scale. For example, the Initial Cost factor is assigned a preference rating of "high" when the initial cost value of an alternative is within a 5 percent difference of the lowest values of all candidates or "low" if the initial cost difference of the alternative exceeds 10 percent of the lowest value.

Table 24. Sample rating guidelines for the alternative preference screening matrix.

Factor	Low	Medium	High
Initial costs	Cost > 10 %	Cost >5% and <10 %	Cost within 5 %
Life cycle costs	Cost > 20 %	Cost >10% and <20 %	Cost within 10 %
User costs	User cost > 20 %	User cost >10% and < 20%	User cost within 10 %
Future rehabilitation costs	Cost > 10 %	Cost >5% and <10 %	Cost within 5 %
Future maintenance costs	Cost > 10 %	Cost >5% and <10 %	Cost within 5 %
Roadway/lane geometrics	Significant complexity to accommodate	Moderate complexity to accommodate	Easy to accommodate
Continuity of adjacent pavements	Significant issues	Some significant issues possible	No significant issues
Continuity of adjacent lanes	Significant issues	Some significant issues possible	No significant issues
Availability of local materials and experience	Lack of local experience	Some experience	Commonly used
Traffic during construction	Very difficult to accommodate	Somewhat difficult to accommodate	Easy to accommodate
Noise	Much higher noise likely	Some increased noise possible	No difference in noise generated
Subgrade soils	Significant issues for construction	Some issues possible for construction	No significant issues for construction
District/local preference	No preference	Some preference	Significant preference
Safety considerations	Significant issues related to safety features	Some issues related to safety features	Better safety features

Table 24. Sample rating guidelines for the alternative preference screening matrix.

Factor	Low	Medium	High
Conservation of materials/energy	Much higher materials/ energy use	Somewhat higher materials/energy use	No significant difference
Stimulation of competition	Very few capable contractors	Some experience	Common experience for each
Maintenance capability	Little to no local experience	Some experience	Common experience for each
Future needs	Very difficult to accommodate	Somewhat difficult to accommodate	Easy to accommodate
Experimental features	Common technology	National but no local experience	New and unproven technology

Step 4: Score Pavement-Type Alternatives

Upon assigning preference ratings, the numerical weighted scores of evaluation factors and groups are calculated for each alternative. Ratings of “low,” “medium,” and “high,” if used, should be converted to numerical scores. Table 25 presents example criteria for converting these ratings to a numerical scale.

Table 25. Example criteria for preference rating.

Preference Rating	Numerical Score
No difference	0%
Low	20%
Medium low	40%
Medium	60%
Medium high	80%
High	100%

For a given alternative, the numerical scores of each evaluation factor are multiplied by their corresponding factor weights to calculate the weighted scores of factors. The sum of weighted scores of factors within each group is the unweighted score of that group. The example in Table 6 calculates weighted score for individual factors within the Economic Factors group and the unweighted score for that group. The weighted group scores are then calculated by multiplying their unweighted score by their corresponding group weights (see Table 27). The sum of weighted group scores is the total score for that alternative; it should not exceed 100 percent.

Step 5: Interpret Results

Based on the final scores of alternatives, the “best possible” pavement-type alternatives are selected.

When the final score of an alternative is higher than that of other candidates, the alternative with the highest score may be much better suited than others. However, when the final scores of multiple alternatives are comparable, any of these alternatives could be selected. Such cases are well suited for alternate bidding. If no alternative appears to be satisfactory, further investigation is needed.

Agencies should determine their own criteria to interpret the screening matrix results. An agency can develop a threshold value to determine how different the alternatives are. For instance, if the difference in the final scores of two alternatives is more than 10, the alternative with the higher score can be selected as the preferred one.

Recognizing that the project goals and the choice of feasible alternatives are unique to each project, the guide recommends the application of informed judgment and agency experience in the selection process, with or without a threshold criterion in place. The screening matrix provides a systematic framework for practical decision making by setting "musts" and "wants" of an ideal choice for the project, exploring and prioritizing alternatives based on their strengths and weaknesses, and choosing the most-preferred alternative(s).

Table 26. Example of the calculation of weighing scores for individual factors.

Economic Factors	Individual Factor Weight	Preference Rating	Numerical Rating	Weighted Score
Initial costs	30%	Medium	60%	18.0%
Future rehab costs	25%	High	100%	25.0%
User costs	20%	Low	20%	4.0%
Future maintenance costs	25%	Medium-low	40%	10.0%
Total un-weighted score for *Economic Factors*				57%

Table 27. Example of the calculation of weighted group scores.

Group	Group Weight	Unweighted Group Score	Weighted Group Score
Economic factors	50%	57%	28.5%
Construction factors	25%	45%	11.3%
Local factors	10%	25%	2.5%
Other factors	15%	15%	2.3%
Total score of the matrix			44.5%

Table 28 provides a template worksheet of the screening matrix. Users can add or eliminate any number of alternatives, groups, and individual factors within a group, as appropriate.

6.4 SELECTION OF PREFERRED ALTERNATIVES

The following approach is recommended for use in selecting preferred pavement types:

1. Upon completion of the LCCA, the alternatives are evaluated using the economic factors listed in Section 5.2. If an alternative fails to meet the economic criteria, then the alternative is eliminated.
2. The alternatives that meet the economic criteria are then evaluated using the non-economic factors listed in Section 6.2.
    - If an alternative fails to meet the non-economic criteria, further evaluation may be necessary to ascertain whether the non-economic factors unduly override its inclusion. If the risks from non-economic factors outweigh the economic advantages, then the alternative is eliminated.
    - If there are no non-economic factors to override its inclusion, the alternative is selected as a qualified alternative.

Table 28. Alternative preference screening matrix worksheet.

Factor	Factor Weight	Alternative 1		Alternative 2	
		Rating	**Weighted Score**	**Rating**	**Weighted Score**
Group A					
Factor A1	W_{A1}	$R_{A1-Alt1}$	$W_{A1}*R_{A1-Alt1}$	$R_{A1-Alt2}$	$W_{A1} * R_{A1-Alt2}$
Factor A2	W_{A2}	$R_{A2-Alt1}$	$W_{A2} *R_{A2-Alt1}$	$R_{A2-Alt2}$	$W_{A2} *R_{A2-Alt2}$
Factor A3	W_{A3}	$R_{A3-Alt1}$	$W_{A3} *R_{A3-Alt1}$	$R_{A3-Alt2}$	$W_{A3} *R_{A3-Alt2}$
Factor AN	W_{AN}	$R_{AN-Alt1}$	$W_{AN} *R_{AN-Alt1}$	$R_{AN-Alt2}$	$W_{AN} *R_{AN-Alt2}$
Group A unweighted total	100%		$\Sigma(W_{Ai}*R_{Ai-Alt1})$		$\Sigma(W_{Ai} * R_{Ai-Alt2})$
Group B					
Factor B1	W_{B1}	$R_{B1-Alt1}$	$W_{B1}*R_{A1-Alt1}$	$R_{B1-Alt2}$	$W_{B1}*R_{A1-Alt2}$
Factor B2	W_{B2}	$R_{B2-Alt1}$	$W_{B2} *R_{A2-Alt1}$	$R_{B2-Alt2}$	$W_{B2} *R_{A2-Alt2}$
Factor B3	W_{B3}	$R_{B3-Alt1}$	$W_{B3} *R_{A3-Alt1}$	$R_{B3-Alt2}$	$W_{B3} *R_{A3-Alt2}$
Factor BN	W_{BN}	$R_{BN-Alt1}$	$W_{BN} *R_{AN-Alt1}$	$R_{BN-Alt2}$	$W_{BN} *R_{AN-Alt2}$
Group B unweighted total	100%		$\Sigma(W_{Bi}*R_{Bi-Alt1})$		$\Sigma(W_{Bi}*R_{Bi-Alt2})$
Group C					
Factor C1	W_{C1}	$R_{C1-Alt1}$	$W_{C1}*R_{A1-Alt1}$	$R_{C1-Alt2}$	$W_{C1}*R_{A1-Alt2}$
Factor C2	W_{C2}	$R_{C2-Alt1}$	$W_{C2} *R_{A2-Alt1}$	$R_{C2-Alt2}$	$W_{C2} *R_{A2-Alt2}$
Factor C3	W_{C3}	$R_{C3-Alt1}$	$W_{C3} *R_{A3-Alt1}$	$R_{C3-Alt2}$	$W_{C3} *R_{A3-Alt2}$
Factor CN	W_{CN}	$R_{CN-Alt1}$	$W_{CN} *R_{AN-Alt1}$	$R_{CN-Alt2}$	$W_{CN} *R_{AN-Alt2}$
Group C unweighted total	100%		$\Sigma(W_{Ci}*R_{Ci-Alt1})$		$\Sigma(W_{Ci}*R_{Ci-Alt2})$
Group D					
Factor D1	W_{D1}	$R_{D1-Alt1}$	$W_{D1}*R_{A1-Alt1}$	$R_{D1-Alt2}$	$W_{D1}*R_{A1-Alt2}$
Factor D2	W_{D2}	$R_{D2-Alt1}$	$W_{D2} *R_{A2-Alt1}$	$R_{D2-Alt2}$	$W_{D2} *R_{A2-Alt2}$
Factor D3	W_{D3}	$R_{D3-Alt1}$	$W_{D3} *R_{A3-Alt1}$	$R_{D3-Alt2}$	$W_{D3} *R_{A3-Alt2}$
Factor DN	W_{DN}	$R_{DN-Alt1}$	$W_{DN} *R_{AN-Alt1}$	$R_{DN-Alt2}$	$W_{DN} *R_{AN-Alt2}$
Group D unweighted total	100%		$\Sigma(W_{Di}*R_{Di-Alt1})$		$\Sigma(W_{Di}*R_{Di-Alt2})$
Subtotals	**Group Weights**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**
Group A	W_A	$\Sigma(W_{Ai}*R_{Ai-Alt1})$	$W_A *\Sigma(W_{Ai}*R_{Ai-Alt1})$	$\Sigma(W_{Ai}*R_{Ai-Alt2})$	$W_A *\Sigma(W_{Ai}*R_{Ai-Alt2})$
Group B	W_B	$\Sigma(W_{Bi}*R_{Bi-Alt1})$	$W_B *\Sigma(W_{Bi}*R_{Bi-Alt1})$	$\Sigma(W_{Bi}*R_{Bi-Alt2})$	$W_B *\Sigma(W_{Bi}*R_{Bi-Alt2})$
Group C	W_C	$\Sigma(W_{Ci}*R_{Ci-Alt1})$	$W_C *\Sigma(W_{Ci}*R_{Ci-Alt1})$	$\Sigma(W_{Ci}*R_{Ci-Alt2})$	$W_C *\Sigma(W_{Ci}*R_{Ci-Alt2})$
Group D	W_D	$\Sigma(W_{Di}*R_{Di-Alt1})$	$W_D *\Sigma(W_{Di}*R_{Di-Alt1})$	$\Sigma(W_{Di}*R_{Di-Alt2})$	$W_D *\Sigma(W_{Di}*R_{Di-Alt2})$
Grand total	100%		**Final Score- Alt 1**		**Final Score- Alt 2**

3. The alternatives that meet both economic and non-economic criteria are considered as qualifying alternatives.
    - If there is only a single qualifying alternative, it is selected as the most-preferred alternative.
4. When there are two or more qualified alternatives, then the economic and non-economic aspects of these alternatives are weighed using an alternative preference screening matrix to identify the most preferred type. The screening matrix is used to evaluate if there are considerable differences among the alternatives.
    - If there is a clear cut preference among the alternatives, the most advantageous alternative is recommended for selection.
    - Conversely, if the differences between all or some of the alternatives are not significant, then the similar alternatives could be considered for alternate bidding.

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CHAPTER 7 – PAVEMENT-TYPE SELECTION IN ALTERNATE BIDDING PROJECTS

7.1 THE CONCEPT OF ALTERNATE BIDDING

In alternate bidding projects, the agency develops “equivalent alternatives,” which typically include a flexible and a rigid pavement alternative. The equivalent alternatives provide equivalent benefits to society. The agency develops a life cycle cost adjustment value (C) to account for differences in future costs between the alternatives. This factor is then added to one or all the alternatives so that the final costs are compared on a level basis. The C factor is determined by the agency’s estimated difference in present value of the future M&R costs between the two pavement-type alternatives. The total costs are then compared, and the alternative with lower total costs is selected as the successful bid, as illustrated in Figure 28.

In the (A-D) method, the agency specifies the baseline design with other items of the project scope-of-work, which are constituted in the base bid price. The agency then specifies “superior alternatives” for the bidders to select and the associated differential price (D) the agency is willing to pay. The contract award is based on the lowest responsible bid that includes the sum of the base and differential bid prices. The bid evaluation of best-value alternate bidding is illustrated in Figure 28.

Alternate Bidding	**Best-value Alternate Bidding (A-D)**
$Lower\ of \begin{cases} low\ Alt_1 bid + PW_{M\&R} Alt_1 \\ low\ Alt_2 bid + PW_{M\&R} Alt_2 \end{cases}$ OR $Lower\ of \begin{cases} low\ Alt_1 bid + \\ low\ Alt_2 bid + C \end{cases}$ $C = PW_{M\&R} Alt_2 - PW_{M\&R} Alt_1$	$Lower\ of \left\{ \begin{matrix} low\ Baseline\ bid \\ low\ Alt_1\ bid + D(Alt_1) \\ low\ Alt_2\ bid + D(Alt_2) \\ \ldots. \\ \ldots. \\ low\ Alt_n\ bid + D(Alt_n) \end{matrix} \right\}$

Figure 28. Bid evaluation of alternate bidding contracts.

7.2 EQUIVALENT PAVEMENT DESIGNS

The equivalency of pavement types is the core concept in alternate bidding. The Pavement-Type Selection Policy published in the Federal Register on November 9, 1981, states that the use of alternate bids may be permitted as requested by the contracting agency, where the agency’s pavement-type selection process provides two or more initial designs that are deemed equivalent (FHWA, 1999). Per the definition of the 23 CFR 626 Non-Regulatory Supplement, the equivalent designs are designed to perform equally, and provide the same level of service, over the same performance period and have similar life cycle costs.

FHWA's current policy does not encourage alternate bidding, as it is hard to establish "truly equivalent" pavement designs. The agency issued an informational memorandum in November 2008 (reproduced in Appendix D of this report) that includes the following guidance:

> **Designs Must Be Equivalent** - The 23 CFR 626 Non-Regulatory Supplement defines "equivalent designs" as designs that perform equally, provide the same level of service, over the same performance period, and have similar life cycle costs. It is difficult for two pavement structures utilizing different materials to be truly equivalent, so engineering judgment is required in the determination of what is and what is not "equivalent design". The performance period (analysis period) should be long enough to cover at least one major rehabilitation cycle. Life cycle cost should be considered similar when the Net Present Value (NPV) for the higher cost alternative is within less than 10 percent higher than the lowest cost alternative. This difference is appropriate due to the uncertainty associated with estimating future costs and timing of maintenance and rehabilitation. It should be highlighted that no design methodology or analysis procedures currently available will output "equivalent designs" using design lives and analysis periods typically used for high-type facilities.
>
> **SEP-14 Approval needed if Using Adjustment Factors** - Some States have utilized price adjustments to account for differences in life-cycle costs for the alternate pavement types to determine the lowest responsive bidder. If adjustment factors are used, approval under Special Experimental Project #14 (SEP-14) is required. It is recommended that prior to utilizing any adjustment factors that appropriate stakeholders be provided an opportunity to provide input. Adjustment factors should include, at a minimum, anticipated maintenance costs, anticipated rehabilitation costs, and salvage value.

It is challenging to define and develop alternatives that have both equivalent performance criteria and equivalent life cycle costs. The initial costs and service life used in the LCCA are established based on the selection of the initial structural design. To be equivalent, the alternatives should be designed for the same conditions, such as the traffic level, reliability, structural design and analysis life, and performance criteria. In other words, the structural designs should be developed to result in the same magnitude of relative distresses and roughness at the end of the design period.

While it is feasible to develop equivalent alternative designs using the appropriate inputs to the design procedure, the rehabilitation strategies of these designs generally will be different over the life of the pavement, both in frequency and type of strategy. This results in differences in the future cost streams of the various alternatives. As noted in the FHWA memorandum, States have overcome this issue by using price adjustments to account for differences in future costs under SEP-14.

Then there is the issue of using proper inputs to the state DOT's procedure for each alternative structural design. Issues regarding the non-equivalency of alternatives may arise when different design lives, reliability factors, performance requirements, or improper inputs are used. If design procedures are not properly calibrated to local conditions, then this becomes an even more

challenging problem. There always will be debate over whether two or more alternate designs are truly equal.

Current mechanistic-empirical design procedures provide the framework for developing approximately equivalent pavement designs using predicted performance levels. These methods provide a more fundamental basis for defining “equivalent.” However, it should be noted that mechanistic-empirical procedures must be validated and, as needed, calibrated to local conditions and management policies before use.

7.3 LESSONS LEARNED FROM CASE STUDIES

Missouri, Kansas, and Louisiana have reported the experience gained from their alternate bid projects (MoDOT, 2005; Alvers, 2009; Gisi, 2009; Temple et al, 2004). The alternate bidding practice apparently has stimulated competition by attracting bidders from both HMA and PCC industries. This competition appears to have worked out to the agencies’ advantage through significant cost savings, especially when the commodity prices have shown pronounced fluctuations in recent years.

Experience suggests that the unit prices of work items used at the time of pavement-type selection usually do not reflect the prices at the time of bidding. The fluctuations in price could cause the agency to choose a non-economical (higher life cycle costs) pavement type over the other. Alternate bidding helps to mitigate these negative impacts of price fluctuations on pavement-type selection. As the type selection is made at the time of bidding, and the bid prices reflect truer material and construction costs, alternate bidding has made the selection process less dependent on commodity price fluctuation.

There are still some contentious issues, yet to be resolved, that have concerned the industry groups over the concept of equivalent designs, M&R sequence, and LCCA inputs. These concerns primarily stem from the design life assumptions used in the LCCA. To obtain more reasonable design life assumptions, the state DOTs should establish M&R scenarios based on their historic maintenance and performance records, rather than using prescriptive guidelines. The agencies can employ performance prediction tools, such as the locally calibrated MEPDG, along with techniques such as pavement survival analysis and performance trend analysis in developing realistic scenarios.

However, the current LCCA methodology does not adapt well to technological advancements such as noise reduction strategies, the use of emerging materials, and the value of recycled materials. An agency’s historical records often lack adequate evidence to develop scenarios for such advancements. In such cases, the agency should apply sound judgment coupled with robust engineering analysis to reconcile the differences, if any, between the historical and estimated performance.

The industry groups also have expressed disagreement on the inputs used in the LCCA, such as the use of salvage value, analysis period, and discount rates. The calculated life cycle costs of pavement design alternates are sensitive to these input parameters, such that any incorrect application will unfairly favor one pavement type to another.

The early involvement of industry groups in the process development and independent third-party review will help agencies achieve consensus for best practices and troubleshooting during implementation. For instance, Louisiana first developed LCCA criteria for alternate bidding through an internal committee and later sought review and comments from the industry groups to reach a consensus (Temple et al, 2004). This strategy helped the agency to develop a final procedure with endorsements from industry groups and the FHWA.

7.4 PROPOSED PAVEMENT-TYPE SELECTION PROCESS

Because the agency establishes the alternatives for alternate pavement-type bidding, it is recommended that the pavement-type selection generally follow the agency's process. The agency can follow these steps in developing a pavement-type selection process for alternate bidding projects:

1. *Identify potential pavement-type alternatives*.

   This step involves developing a formalized process for identifying a broad group of alternatives using the approach discussed in Chapter 4. The PTSC identifies a list of alternatives to be considered in the selection process based on what does or does not work, in the State's experience.

2. *Identify feasible pavement-type alternatives*.

   This step involves developing criteria for identifying feasible alternatives at the project level from the broad group of alternatives, through engineering review and non-economic selection factors. This approach is discussed in Chapter 4.

3. *Establish suitability criteria of alternate bidding projects.*

   This procedure may not be suitable for all types of paving projects. Factors such as the project type (new construction or rehabilitation), project size and scope, market trends of commodity prices, relative competitiveness of the pavement alternatives, and others influence the suitability of alternate bidding. The agency should determine their own criteria for executing this procedure in paving projects.

   - No preferred alternative – This procedure is appropriate for projects when there is no clear preference among alternatives. The agency can use a "cutoff" difference based on total costs or the alternate preference screening matrix to select equivalent alternatives.
   - Periods of commodity price uncertainty – This procedure is suitable when the prevailing commodity prices (at the time of contract letting) may not reflect historical material and construction costs, especially during periods of uncertain price trends in the market. In such instances, agencies can use this procedure to manage some of the risks in market price fluctuations, as the type selection is made at the time of contract letting.

- Appropriate application – This procedure is advantageous where the pavement cost items impacted by the alternate bid are likely to influence the final determination of the lowest responsive bidder for the project.
- Lack of historical price data for pavement alternatives – This procedure can be used when an agency lacks historical price data for certain alternatives.

4. *Develop pavement life cycle strategies*.

   The initial structure of the equivalent alternatives should be designed for the same design conditions, such as the traffic level, reliability, and life, and similar terminal performance thresholds. In other words, the structural designs should be developed to result in the same magnitude of relative distresses and roughness at the end of the design period.

   Realistic sequencing of the timing and extent of M&R activities is vital to the determination of the LCCA adjustment factor. The agency should develop realistic M&R strategies based on the approach recommended in Section 4.3.

5. *Develop guidelines for conducting LCCA.*

   This step is identical to the approach discussed in Chapter 5. Since LCCA plays a vital role in developing equivalent alternatives and bid evaluation, consensus among the stakeholders is emphasized.

6. *Develop criteria for establishing equivalency of design alternatives.*

   Recognizing the difficulties in developing truly equivalent alternatives, equivalency is established on the basis of life cycle costs. Highway agencies typically use a cutoff difference ranging up to 20 percent of total costs in selecting equivalent alternatives. The cutoff difference should be established based on the average differences in the bid costs of previous alternate bid contracts. If the agency does not have sufficient data available for establishing the cutoff value, local experience with the life cycle cost differences of alternatives in design-bid-build projects should be taken into consideration until more comparative data can be collected from alternate bid contracts.

   As an alternate approach, the guide for Pavement-Type Selection proposes the use of the alternative preference screening matrix in identifying equivalent alternatives. This approach is discussed in detail in Section 6.3.

7. *Establish criteria for determining bid adjustment factor.*

   While it is feasible to design the initial structure of pavement alternatives for the same conditions using appropriate inputs, the required M&R activities, their timing, and associated costs will be different for equivalent alternatives over the life of the pavement. This results in differences in the future cost streams of the various alternatives. Therefore, to compare the final costs of alternatives on a level basis during bid evaluation, an adjustment factor is utilized.

The agency should pre-determine the approach on how the future costs are to be included. For instance, some agencies may include only the direct cost components of future M&R activities, while other agencies may include associated user delay costs. e.g. Pennsylvania Department of Transportation (PennDOT, 2009). To avoid any conflicts, a consensus is required among stakeholders on the approach to be used in determining future costs for bid adjustment factor.

8. *Use of comparable project specifications.*

The agency should ensure that the project specifications do not encourage bias in the contractor's selection of one alternative over another. The contractual provisions should provide comparable opportunity for each alternative.

- Specifications of material quantities – The agency should identify any risks associated with the differences in quantifying materials for pay items. The imprudent use of measurement units for pay items for different paving materials, such as tonnage versus cubic yards, could create issues regarding the uniformity in the method of payment between alternatives.
- Commodity price adjustment – The agency should not allow adjustment factors for material prices as it is difficult to administer equal treatment to various alternate materials.
- Incentive/disincentive provisions for quality – The agency should identify any potential bias in using quality-based incentive/disincentive structure of different pavement types. The use of end-result or performance-related specifications helps to reconcile any inherent biases in these areas. Performance-related specifications also promote contractor innovation and allow for more opportunity for competitive bidding.

The selected alternatives should be comparable and competitive, thus providing reasonable chances for contractors to win the bid with either of the alternatives. However, it should be recognized that alternatives cannot always be competitive, especially during periods of significant price fluctuation.

9. *Involve industry in developing and reviewing the proposed process.*

There may be concerns and conflicting interests among various stakeholders over many aspects of alternate bidding procedures, such as the appropriateness of rehabilitation strategies, LCCA inputs, and other design life assumptions. Upon drafting the process, the agency can involve the stakeholders in reviewing and finalizing the proposed process.

10. *Implementation of the alternate bidding procedure.*

The agency can evaluate the proposed process through implementation projects. Efforts should be made to identify lessons learned, stakeholder feedback, and impending issues. Based on the evaluation, the agency can further refine the process for use in future

projects. The agency also should develop a mechanism to evaluate and review the process periodically.

7.5 SELECTION OF ALTERNATIVES FOR ALTERNATE PAVEMENT-TYPE BIDDING

The Guide for Pavement-Type Selection suggests the use of alternative preference screening matrix for identifying equivalent pavement types. As discussed in Chapter 6, when an alternative meets the economic criteria and there are no non-economic risks to outweigh its inclusion, then the pavement type is considered as a qualified alternative. When there are two or more qualifying alternatives, their comparative advantages and disadvantages are analyzed using the screening matrix against the project requirements and agency policies. The alternatives are ranked and assigned with numerical scores. Based on the final scores, the screening matrix indicates whether there is a clear preference among the alternatives. When there are no significant differences among them, the alternatives may qualify for alternate bidding. Some level of engineering judgment may be necessary in establishing the equivalency of alternatives. Figure 29 presents a flow chart of this procedure.

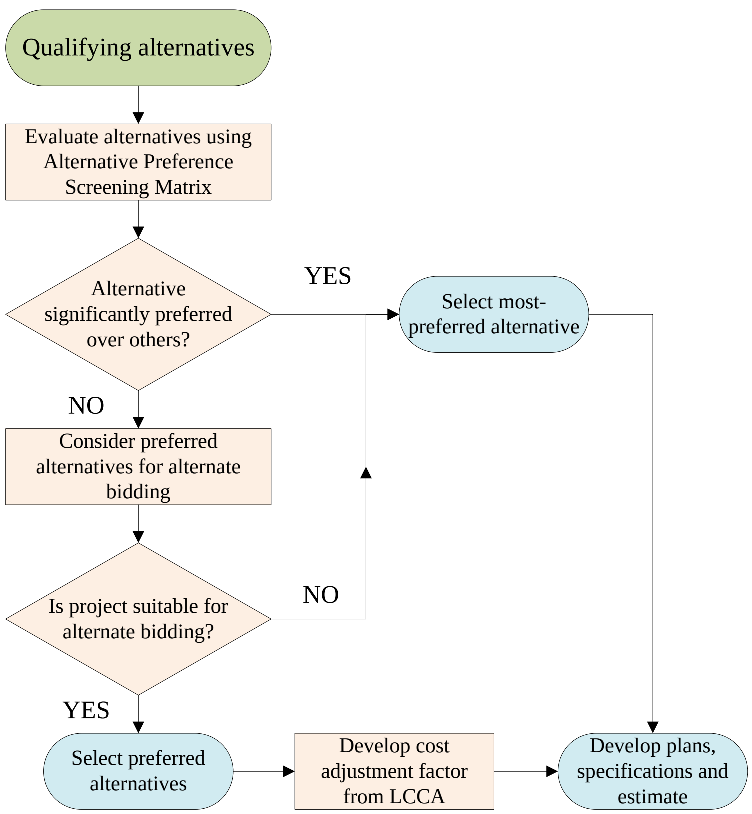

Figure 29. Selection of equivalent pavement-type alternatives for alternate bidding.

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CHAPTER 8 – CONTRACTOR-BASED PAVEMENT-TYPE SELECTION

8.1 OVERVIEW

In the traditional design-bid-build method, the highway agency is responsible for defining the scope and requirements of the project, performing the complete design, soliciting bids and awards the construction contract to the lowest responsive bidder to build the project. The contractor delivers construction services as defined in the standard plans and specifications issued by the agency. The contractor assumes no responsibility for the delivered product except with regards to materials and workmanship quality for a limited time period. The agency has the entire responsibility and risk for design, construction, and post-construction performance of the pavement.

With the inception of alternative contracting methods, highway agencies strive for better "value for money" through specific project objectives relating to construction time, innovation, safety, quality and costs. Examples include lane rental, interim completion dates, performance contracting, short-term and long-term performance warranties, and design-build and design-build-finance-operate contracts. In alternative contracting, the agency defines the scope and requirements of the project and communicates to potential bidders through proposal solicitations or bid documents, while the winning contractor offers services as specified in the agency's contract provisions.

These contracting initiatives have shifted the roles and responsibilities of agencies, contractors, and designers from traditional paradigms, which have in turn resulted in the shift of risk allocation from agencies to contractors, thus opening up new challenges in program delivery and facility management.

8.2 PAVEMENT-TYPE SELECTION IN ALTERNATIVE CONTRACTING PROJECTS

This section briefly discusses various alternative contracting or delivery methods to provide necessary background information to understand pavement-type selection and associated risks in such scenarios. Although these contracting approaches include much more than pavement-type selection, the discussion focuses on how to deal with the selection process under such scenarios.

Table 29 and Figure 30 summarize the transfer of control and risks from the agency to the contractor for different alternate delivery strategies. Table 30 describes the key aspects of various alternative contracting. Note that many of these methods are considered experimental for trial evaluation and require approval under the FHWA's SEP-14 or Public Private Partnership programs. The information presented herein indicates that how the agency-contractor relationship changes typically changes with various contracting scenarios and project objectives.

The contractor undertakes greater responsibilities and risks in long-term projects than in traditional contracts, particularly when the contractor services are extended into the O&M phase of the project. The contractual responsibilities define the contractor's involvement in pavement-type selection.

Table 29. Responsibilities and risks of agencies in various project delivery methods.

Strategy	Sub-strategy	Description	Agency Control/Risk
Own Forces	Total Project	Agency manages, designs, and constructs project with own forces	Agency has total control and accepts all risks.
	Construction	Agency manages and constructs project with own forces, and retains design consultant for design work	Agency has total control and accepts all risks except for design errors or omissions.
Design Bid Build (DBB)	Agency Managed DBB	Agency performs detailed designs and estimates, manages project and contracts out construction to contractors	Agency is responsible for all risks related to designs and future performance and transfers construction tasks and risks to contractors.
	General Engineering Consultant (GEC)	Agency retains a GEC as an agent to manage the design and design consultants	Agency transfers control of design and design management tasks and risks to GEC, who may be liable for errors or omissions. Agency is responsible for future performance.
	Construction Manager (CM)	Agency retains CM as an agent to manage construction contractors	Agency transfers control of construction and construction management tasks and risks to CM, who may be liable for errors or omissions. Agency is responsible for future performance.
	Program Management Consultant (PMC)	Agency retains a PMC as an agent to manage the project including consultants and contractors	Agency maintains control of project scope and transfers project management tasks and risks to PMC, who may be liable for errors or omissions. Agency is responsible for future performance.
Construction Manager at Risk (CMAR)	Agency may also retain a GEC and PMC	Agency retains a CMAR contractor in final design, who participates in design review, estimating, and value engineering and at some agreed point guarantees a fee to manage and carry out construction	Agency transfers a share of control of scope through design to the CMAR contractor and all of the control and risk of the management and execution of construction. CMAR. However, the agency bears full risk of future performance and therefore must perform or specify method and process for type selection and design.
Design-Build (DB)	Agency may also retain a GEC and PMC	GEC completes design through preliminary engineering (approximately 30 percent). Agency retains a DB contractor to complete design and construct the project	Agency maintains control of scope through concept design (30 percent) after which control and risk of design and construction is transferred to DB contractor. Agency. However, the agency bears full risk of future performance and therefore must perform or specify method and process for type selection and design.
Design-Build-Operate-Maintain (DBOM)	Design Build Operate or Design Build Operate & Maintain	As for DB plus contractor is responsible for the operations and maintenance of the facility for a specified period	Agency transfers control and risk of operations and maintenance to the contractor. The contractor is responsible for future performance during the contract period.
Turnkey	Could be used for DB or DBOM	Agency prepares a performance specification that is bid on by turnkey contractor, who may also participate in financing the project	Agency controls scope of performance specification after which control and risk of conceptual/detail design and construction transfers to turnkey contractor, including operations and maintenance if DBOM.

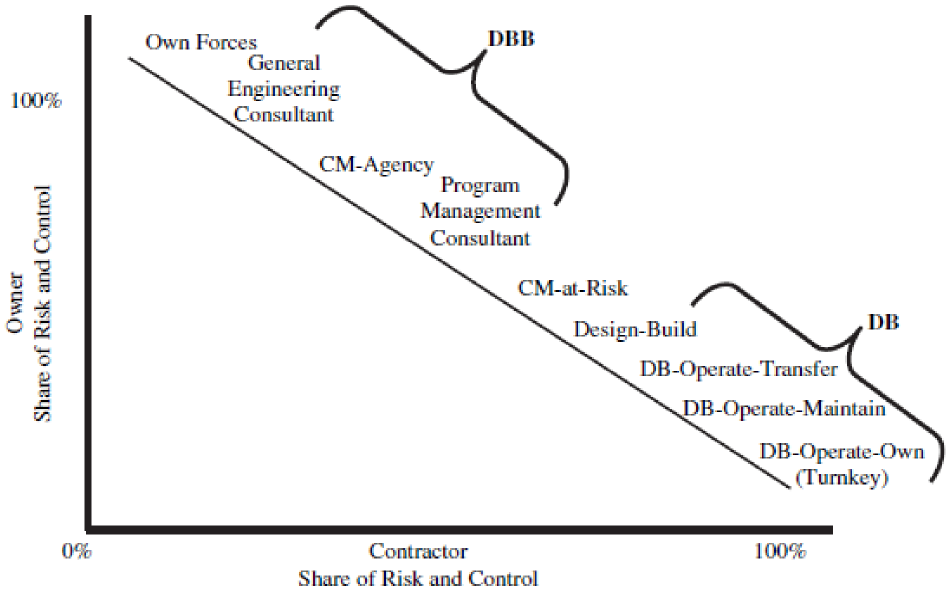


Figure 30. Risk sharing and control in alternative contracting strategies (FTA, 2006).

Table 30. Pavement-type selection in various alternative contracting/delivery methods.

Method	Definition	Pavement-Type Selection
Cost Plus Time Bidding	It involves consideration of the bid cost for the contract items as well as the associated cost of the project time to reduce project completion time and road user costs.	Agency makes the selection.
Flexible Notice-to-Proceed Dates	For small non-critical projects, the agency establishes the number of days for project completion and provides the contractor the flexibility to start work within a time period.	Agency makes the selection.
No Excuse Incentives	The contractor is given a “drop-dead date” for completion of a phase of work or the entire project that are time critical. Based on the early or delayed completion, the contractor will receive incentives or disincentives.	Agency makes the selection.
Incentive/Disincentive Provisions for Early Contract Completion	It specifies the time required for critical work and uses this provision for those critical projects where traffic delays and user discomfort are to be held to a minimum. It provides incentives to contractors for early completion.	Agency makes the selection.
Interim Completion Dates	It focuses on the early completion of a specific phase of a contract such as a ramp, an interchange or another component of a larger project that are time critical. Such projects usually involve high road user costs.	Agency makes the selection.
Lane Rental	The contractor is required to pay a rental fee for lane closure during a specific time period, which could be daily, hourly or fractions of an hour. The fee is based on the estimated cost of delay or inconvenience to the road user during the rental period.	Agency makes the selection.
Construction Manager at Risk	The agency procures the contractor services (construction manager / general contractor) for both preconstruction and construction services. It improves the integration of planning, design, and construction teams to optimize cost, schedule and quality.	Agency makes the selection.

Table 30. Pavement-type selection in various alternative contracting/delivery methods.

Method	Definition	Pavement-Type Selection
Multi-Parameter Bidding including Quality (A+B+Q Bidding)	In addition to cost (A) and time (B) components to complete the project, a level of quality or performance (Q)that would be achieved over a specified period of time to reduce project completion time and improve quality.	Agency makes the selection. Contractor involvement depends on the warranty period.
Materials and Workmanship Warranty (typically 2-4 years)	The contractor is responsible for correcting defects in pavement caused by elements within their control.	Agency makes the selection.
Short-term Performance Warranty (typically 5-10 years)	The contractor is responsible for material design, quality control, and pavement performance for warranty period.	Agency makes the selection.
Long-term Performance Warranty (typically more than 10 years)	The contractor is responsible for structural design, material design, quality control, and pavement performance for warranty period	Contractor makes the selection.
DB	The agency procures contractor services for both design and construction.	Either the agency makes the selection or the contractor follows agency-allowed process.
DBOM	It combines the design and construction responsibilities of design-build procurements with operations and maintenance.	Contractor makes the selection.
Design-Build-Warrant	It combines the conditions of a warranty clause with a design-build contract.	Agency makes the selection. Contractor involvement depends on the warranty period.
Design-Build-Finance-Operate	With this approach, the responsibilities for designing, building, financing and operating are bundled together and transferred to private sector partners.	Contractor makes the selection.
Long-term Lease	It involves the long term lease of existing, publicly-financed toll facilities to a private sector concessionaire for a prescribed concession period during which they have the right to collect tolls on the facility.	Contractor makes the selection.

In other words, the contractor's involvement in pavement-type selection should be commensurate with the amount of risks that contractor shares, which in turn, depends on the scope of contractor services and contract period.

In design-build projects, the agency procures the contractor services for both design and construction. Upon completion of the project, the agency assumes the responsibilities for maintaining the pavements at a desired performance level beyond the warranty period. The contractor's services typically do not extend to other phases of the pavement life cycle, such as M&R. While the agency may opt for a contractor-based pavement-type selection, the agency will manage post-construction risks better if it controls the selection process. The agency can control the selection process by stipulating certain pavement types, life cycle assumptions, and the LCCA framework. Therefore, an agency-based or agency-allowed process is considered appropriate for design-build projects.

In alternative contracting scenarios such as lane rental or cost plus bidding, the key project goals are to reduce road user costs and shorten project completion time. The contractor focuses on

better traffic maintenance strategies and resource management to achieve project objectives. The contractor does not take any risks related to the operational phase of the project. In such scenarios, the agency-based selection process is deemed appropriate.

Similarly, in warranty contracts, the duration of the warranty period largely defines the scope and responsibilities of the contractor. The contractor is responsible for only materials and workmanship issues for shorter periods (2 to 4 years). In short-term performance warranty contracts, the contractor is expected to ensure the desired level of pavement performance for about 5 to 10 years through better material designs. Under normal circumstances, the contractor is not expected to be involved in any major rehabilitation activities during the warranty period. Hence, the agency-based process is considered appropriate for such scenarios.

When the warranty period is 10 years or more, the contract scope will typically require the contractor's involvement in major rehabilitation activities. The contractor takes significantly higher risks to ensure pavement performance over a longer term, which may exceed the typical service lives of initial construction. The contractor may have to undertake a major rehabilitation effort during the warranty period, which involves significant financial risks. Greater contractor involvement in the selection process is considered appropriate, as it provides the contractor the preference to select the most appropriate and cost-effective strategy for meeting performance requirements. Stipulating the contractor's choice of pavement type may compromise one of the perceived benefits of the warranty approach. Similarly, the contractor undertakes greater responsibility in design-build operate and maintain and long lease projects. A contractor-based selection process is considered appropriate for such scenarios.

8.3 RISK ASSESSMENT IN CONTRACTOR-BASED TYPE SELECTION

In traditional design-bid-build delivery, the agency owns the entire responsibility and risk for any pavement selection or design-related issues. In alternative contracting projects, the agency is, at a minimum, still responsible for establishing the project goals, the project scope, design criteria, performance measurements, and basic configuration of the project. Therefore, it is essential for the agency to identify potential risks, particularly those risks related to design, at the inception stage and allocate them appropriately between the agency and the contractor. Typically, if the agency will have responsibility for O&M, they will specify the pavement types.

Furthermore, although the contractor (or a concessionaire) bears significantly greater financial risks for projects requiring their long-term involvement, as the owner of the facility, the agency holds the ultimate responsibility towards taxpayers and road users for the performance of the pavement. Table 31 indicates how the agency–contractor relationship typically changes in these scenarios. This table provides necessary backdrop to understand how these challenges can be managed effectively when risks are understood, their consequences measured, and they are allocated to the party that best manages them. To accomplish this objective, there is a need for a common language and a working relationship between the agency and the contractor, and contract provisions to best serve them. The contract provisions can be flexible to meet the needs of varying contracting types, project requirements, and risks, which sometimes can be unique to a specific project.

Table 31. Agency and contractor roles in different contracting scenarios.

Process	Design-Bid-Build	Alternate Bidding	Design-Build [1,2]	Long Term Performance Warranty[1]	Design-Build with O&M[1]
Identification of pavement alternatives					
Development of potential alternatives at agency level	Agency	Agency	Agency	Agency	Agency
Identification of feasible alternatives at project level	Agency	Agency	Agency & Contractor[2]	Agency & Contractor	Contractor
Development of a life cycle model for pavement alternatives					
Service life of initial pavement structure (includes pavement design)	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Service lives of future rehabilitation treatments	Agency	Agency	Agency	Contractor	Contractor
Timing and extent of M&R treatments	Agency	Agency	Agency	Contractor	Contractor
Estimation of life cycle costs					
Initial Construction	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Future M&R	Agency	Agency	Agency	Contractor	Contractor
Salvage	Agency	Agency	Agency	N/A	N/A
Remaining service life for hand-back	N/A	N/A	N/A	Contractor	Contractor
Supplementary	Agency	Agency	Agency & Contractor[2]	Agency & Contractor	Agency & Contractor
Work zone costs	Agency	Agency	Agency & Contractor[2]	Agency & Contractor	Agency & Contractor
Traffic operations[4]	Agency	Agency	Agency	Agency	Agency& Contractor
Economic analysis of pavement alternatives					
Develop expenditure stream diagrams	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Establish LCCA framework	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Compute life cycle costs	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Analyze/interpret results	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Re-evaluate strategies	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Economic and non-economic evaluation of pavement alternatives					
Evaluate pavement alternatives using economic factors	Agency	Agency	Agency & Contractor[2]	Contractor	Contractor
Evaluate pavement alternatives using non-economic factors	Agency	Agency	Agency & Contractor [3]	Agency & Contractor [3]	Agency & Contractor[3]
Weigh non-economic factors against economic analysis	Agency	Agency	Agency	Agency & Contractor [3]	Agency & Contractor[3]
Final selection	Agency	Contractor	Agency & Contractor[2]	Contractor	Contractor

(1) Agency may perform the pavement-type selection process independently for validating contractor-based analysis and internal purposes.
(2) Depends on the type of design-build contract.
(3) Contractor may not consider factors relating to environment, road users, and society.
(4) It may be difficult to develop consensus on calculating differential costs during normal traffic operations between pavement types. Note that the M&R strategies are developed for each alternative to maintain desired performance level.
N/A = Not applicable

In practice, the agency communicates the project goals, requirements, and deliverables to the contractor through contract provisions in the RFP. The contractor is obligated to provide the product and services specified in the contract provisions with certain technical, cost, time, and quality requirements.

As the selection process flows from the preliminary engineering phase through the selection of the final pavement type, three distinct milestones are recognized in this process:

- Advertising for bids – The agency's internal assessments and decisions culminate in the development of contract provisions. This is when the agency finally communicates its requirements to the potential contractor.
- Submission of bids – The contractor's internal assessments and the business decisions culminate in the development of bidding strategies (i.e. the contractor proposes a pavement-type alternative for a certain cost value in the submitted bid).
- Evaluation of contractor proposal – Upon the submission of bids, the agency finally accepts/rejects the contractor's proposal based on its conformance to contract provisions of the project.

Based on this relationship, the Guide for Pavement-Type Selection presents a process for the agency and the contractor to manage risks associated with the pavement-type selection. Figure 17 presents a flowchart of the risk management process.

8.3.1 Agency Risks

The most common alternative contracting methods involving contractor-based selection are design-build, design-build with O&M, and long-term performance warranty. The contracting method largely defines the contractor's scope in the project and the associated risks.

The agency conducts a comprehensive risk assessment in the preliminary engineering phase prior to establishing the contract provisions. Typical agency risks include reduced pavement performance, increased unplanned intervention, cost overruns, time delays, and associated indirect effects such as public dissatisfaction and increased work zone accidents. The agency also can perform an independent evaluation of economic and non-economic factors to address responsibilities toward to the taxpayers, road users, and the environment.

Table 32 presents a list of factors for the agency's risk assessment. The process includes identification of risks, categorizing the probability of occurrence, determining how significant the impact would be if the risk occurred, and properly allocating risks to the parties that best manage them.

Washington State has developed a risk allocation matrix that identifies a risks related to design, construction, changing site conditions, warranty, and other factors and assigns those risks appropriately between the agency and the contractor. Similarly, Colorado has developed a risk decision matrix that identifies potential issues related to various contract provisions and recommendations.

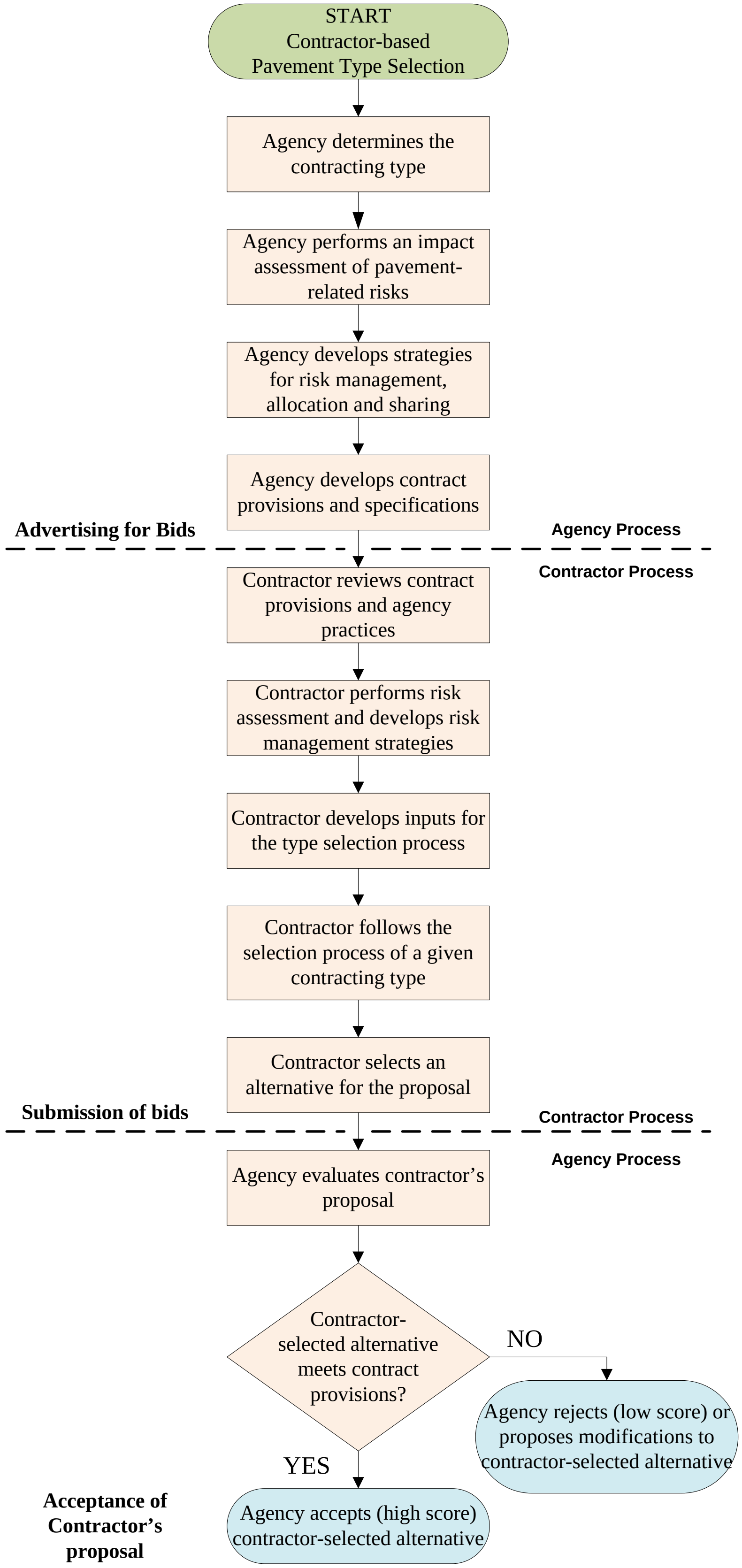


Figure 31. Overview of the contractor-based type selection process.

Table 32. Factors suggested for risk analysis.

Design-Build	Design-Build with Operations and Maintenance	Performance Warranty
• Initial costs • Supplementary costs • Work zone costs • Non-economic factors	• Agency's pool of alternatives • Performance criteria • Service life of initial pavement • Service life of structural rehabilitation • Type and timing of maintenance and functional rehabilitation • Initial costs • Commodity price inflation • Supplementary costs • Future maintenance costs • Future costs for rehabilitation • Future operational costs • Work zone costs • Non-economic factors • Inflation, discount factors and macroeconomic risks • Projected traffic volume • Projected revenue	• Agency's pool of alternatives • Performance criteria • Service life of initial pavement • Service life of structural rehabilitation • Type and timing of maintenance and functional rehabilitation • Initial costs • Commodity price inflation • Supplementary costs • Future maintenance costs • Future costs for rehabilitation • Future operational costs • Work zone costs • Non-economic factors • Inflation, discount factors and macroeconomic risks • Projected traffic volume • Additional costs for warranty requirements (for surety bonds as in additional bid price, $/sq.yd)

Note: In design-build scenarios, where the contractor is not responsible for O&M or long-term performance warranties, the contractor would follow the agency-specified process in developing life cycle strategies.

To leverage these risks, the agency uses contract provisions as control points to define the contractor's obligations. For example, an agency may use performance criteria to leverage risks associated with the pavement component of a proposed facility. The agency then specifies threshold values of performance parameters and scheduled monitoring to ensure a desired level of service. The contractor is obligated to undertake repair and rehabilitation work whenever the measured performance fails to meet the requirements, and failure to maintain the threshold performance may result in disincentives.

In addressing risks, the agency may be inclined to be more stringent in specifying the control points. Such stringent criteria may attract contractor bids with higher prices than the agency's estimate. In some cases, the contract provisions may not be adequate to cover all the agency risks, which can result in a significant loss to the agency. Therefore, in achieving the project goals, the agency-specified criteria should be robust, realistic, and achievable to attract reasonable bid prices from bidders. The agency should establish criteria for evaluating contractor-proposed pavement types and communicate them in the RFP or bid documents. In cases where low bid is the sole criterion for award, and the agency is assuming future risks, the agency should specify the alternatives that are suitable. Input from the PTSC may be helpful in establishing contract provisions and evaluation criteria pertinent to pavements.

The agency also may use risk-sharing mechanisms such as warranty ceiling or price adjustment clauses for inflation management to achieve a balance in risk allocation. These strategies may play a significant role in developing reasonable contract provisions and attract balanced bids from contractors. Examples of risk sharing measures include:

- Warranty ceiling – Under this clause, the agency and the contractor agree on warranty expiration by setting a cap on expenditures, years in service, and cumulative traffic. For example, the warranty is set to expire when the pavement reaches "x" number of years, "y" number of ESALs, or "z" dollars of total expenditures, whichever comes first (May et al., 2003). For instance, in the New Mexico Route 44 long-term performance warranty project, the agency and the contractor agreed that the warranty limits for the project were 20 years of service life, 4,000,000 ESALs, or $110 million of contractor expenditures. It is imperative to determine optimum ceiling criteria to balance between the agency's risks on warranty expiry and total warranty costs stemming out of macroeconomic uncertainties.
- Inflation management – Under this clause, the agency and the contractor agree on a maximum level of price inflation that the contractor would absorb on future M&R costs. This clause helps to offset the inflationary component in bid prices due to uncertainties in commodity prices over a longer term. Note that pavement materials have their own price history and forecasts.

<u>Technical Criteria in RFP</u>

The agency specifies a set of technical criteria that describes the requirements of the work. It includes the project scope, design, construction, and performance criteria. The project scope specifies the products and services which the contractor must provide under the contract. The agency may define the project scope using one the following provisions in the contract document: basic configuration, betterments and alternative technical concepts. The design and construction criteria are the requirements that the contractor must adhere to in the process of design and construction. The agency also may specify performance criteria that the contractor must meet or exceed (Molenaar et al., 2005).

The basic configuration defines fundamental parameters of the project which cannot be changed. However, the contractor has the flexibility to make adjustments in final design, while maintaining compliance with the contract requirements. Through the betterment provision, the agency may specify the minimum requirements in the RFP, allowing the bidders to propose improved configurations in their submittal. The agency also may allow innovative ideas through the provision of alternative technical concepts, where the contractor can propose innovative changes to agency's basic configuration, project scope, design, and construction criteria. The agency typically specifies the elements that are open to the alternative technical concepts.

8.3.2 Contractor Risks

As a private enterprise, the contractor's primary organizational objectives are to increase the probability of winning the bid, meet the contractual requirements, minimize losses, and maximize profits. The contractor's risks typically depend on the following factors:

- Construction risks (constructability and specifications).
- Location and site conditions (traffic, subgrade, working conditions, etc.).
- Performance and financial risks (initial costs, future needs, anticipated cost inflows, etc.).
- Realistic performance criteria.
- Chances of a successful bid.

- Incentive/disincentive structure.
- Agency's receptiveness to proposed strategies.
- Contractor's experience.
- Contractor's ability to control operations and subcontractors.

The contractor's perceived risks increase as the "unknowns" in the proposed project increase. Contractors tend to manage these perceived risks by building financial contingencies into their bid price. Similarly, if the project criteria are unrealistic (e.g., unreasonable quality limits), the contractor perceives higher risk, resulting in a higher proposed price. If the final bid price is too high, it is likely that the contractor will lose the contract.

The contractor's risk assessment process includes a careful review of the project criteria specified in the RFP or bid documents, identifying potential risks, categorizing the probability of occurrence, determining how significant the impact would be if the risk occurred, and developing strategies to mitigate the risks.

8.4 DEVELOPING INPUTS FOR CONTRACTOR-BASED SELECTION PROCESS

While the overall framework of agency-based pavement-type selection process is applicable, contractor-based pavement-type selection also needs to incorporate the impact of increased risks in determining the inputs for the process. These factors can be incorporated in the proposed framework of contractor-based selection under the evaluation of feasible alternatives using economic and non-economic factors.

The contractor may find it advantageous to begin by reviewing the agency's pavement-type selection practices, pavement design methodology, and pavement management data. The agency-based pavement-type selection process can provide a solid starting point. The agency-based selection process reflects local practices on inputs such as M&R and future impacts to traffic, and the agency is likely to evaluate contractors' technical proposals based on how well they address local conditions. In some alternative contracting projects, the agency may provide specific guidance in the RFP on pavement-type selection criteria, such as pavement life cycle strategies and design methodology.

The factors listed in Table 32, presented earlier in the discussion of agency risks, also is applicable for contractor risk analysis. The contractor should take a holistic view of the contract provisions, results of risk assessment, and the available risk sharing mechanisms into consideration in customizing the inputs.

The contractor risk assessment can be utilized in establishing statistical distribution of risk factors to characterize their variability or uncertainty. For example, the inflationary risks of commodity prices may help to set the standard deviation of future costs, while the assessment of incentives/disincentives for measured pavement performance may prompt the contractor to focus more on maintenance strategies and less on rehabilitation.

Statistical characterization of risk factors may be infeasible if sufficient data are unavailable. In such cases, the contractor can make heuristic adjustments by employing tools such as sensitivity

analysis and Monte-Carlo simulation. Contractors should make use of probabilistic risk assessment for determining inputs, which is similar to the probabilistic LCCA process.

8.5 AGENCY'S EVALUATION OF CONTRACTOR-BASED SELECTION

The agency evaluates the contractor's proposed pavement type for its conformance to contract provisions of the project, as charted in Figure 32. The agency can validate the assumptions and analysis criteria used in the contractor's selection process, as well as whether the contractor's selection meets the overall project goals. Once the contractor submits the preferred pavement type, the agency should check for compliance with its economic and non-economic goals.

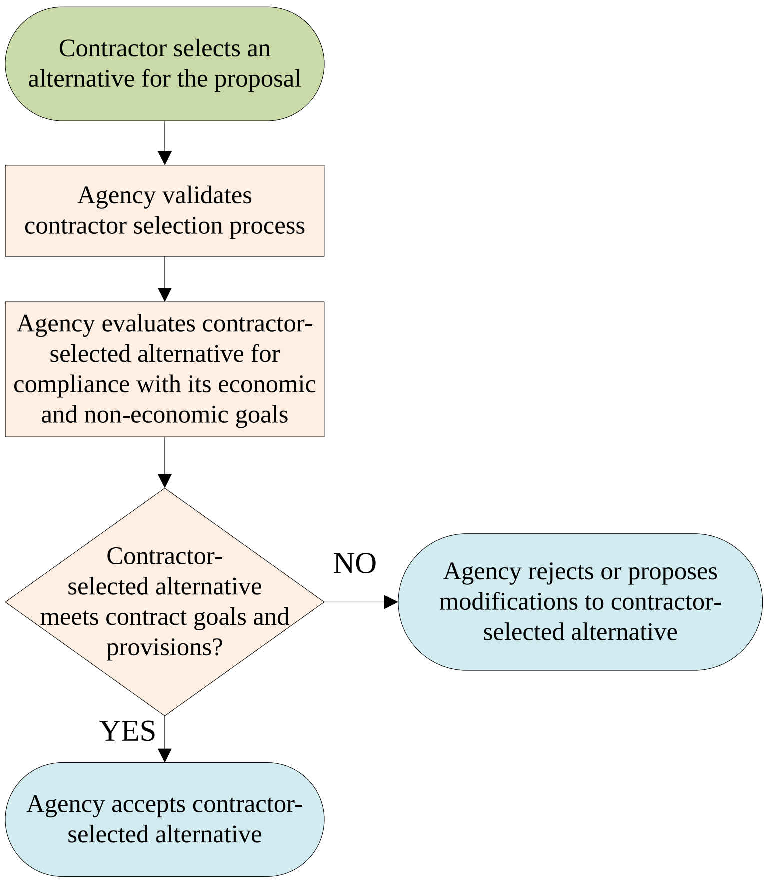


Figure 32. Contractor-based selection of most-preferred pavement type.

The agency can use the following criteria in evaluating the contractor-selected pavement type:

- Cost feasibility and reasonableness of alternatives.
- M&R schedule.
- Structural design.
- Innovative/new practices proposed.
- Quality management.
- Construction time and the impact of work zone to traffic.
- Constructability.

Based on the evaluation, the agency can accept or reject the contractor's proposed pavement type or initiate negotiations for further modifications. When the pavement portion is a relatively small part of the project, scoring on the pavement design will not be a determining factor in the award of the project. In such cases, and where low bid award is mandated by law, the agency should consider specifying the acceptable pavement designs in the RFP.

Proposal Evaluation and Award

Agencies typically use a two-step selection process for procurement in alternative contracting projects involving design-build or long-term contractor services. The first step of the selection process is the issuance of a Request for Qualifications (RFQ). Based on the design-build teams' responses to the RFQ, the agency prepares a shortlist of teams that pre-qualify for the second phase. The issuance of the RFP is the second step in the process, where the shortlisted teams submit their technical and price proposals in response to the RFP requirements. The agency evaluates the proposals, ranks them, and selects the most responsive bidder.

The agency's evaluation is based on the technical, schedule, organizational, and price aspects of the bidder's submittal. The key parameters used in the evaluation include cost, quality, design approach, qualifications, and time. There are different approaches in state agency practices on how to rank the proposals and how to select the most responsive bidder, either based on best value or low bid algorithms. Commonly used award algorithms are (Molenaar et al, 2005):

- Meets technical criteria–low-bid (award to the lowest responsive bid, if the criteria are met).
- Adjusted bid (award to the lowest price bid after adjusted with technical score).
- Adjusted score (award to the highest technical score bid after price adjustments).
- Weighted criteria (award to the bidder with maximum weighted score).
- Fixed price–best proposal (award to the best proposal within stipulated cost).

8.6 PAVEMENT-TYPE SELECTION IN ALTERNATIVE CONTRACTING PROJECTS

8.6.1 Design-Build Projects

With regard to pavement-type selection and pavement design in design-build contracts, variants exist among the States' practices. North Carolina and Indiana have specified both pavement type and thickness of pavement layers with no opportunity for the contractor to modify. Washington and Michigan have specified both the pavement type and minimum thickness requirements, while allowing the contractor to propose the final design. Utah and Maryland allowed the contractor to select both pavement type from the allowable or preferred list and conduct thickness design using the agency preferred pavement design standards. Missouri permitted the contractor to select pavement type and perform the pavement design. Florida left the decision to the project manager to either provide a completed pavement design to the contractor or to provide only the design criteria.

To summarize, based on current practices, an agency may define the contractor's role in one of the following ways:

- **Agency-specified**. The agency specifies the pavement type in the proposal and specifies either the final thickness of each pavement layer or the minimum thickness (or minimum compacted depth). The contractor is allowed to make necessary design adjustments for certain conditions (e.g., frost protection). In any event, the contractor must follow the agency-specified pavement type and thickness design.
- **Agency-preferred.** The agency specifies the preferred pavement types as well as any pavement types that are not allowed. The contractor must select a pavement type from the choice the agency provides. The agency may ask the contractor to perform thickness design for the selected pavement type in accordance with the standard procedures. For example, in the Intercounty Connector (ICC) project, Maryland allowed the bidders to select between a flexible and rigid pavement type; however, it restricted the use of continuously reinforced concrete pavement (CRCP) and composite pavements.
- **Agency-permitted**. The agency allows the contractor to select the pavement type and perform the thickness design. The agency requires the contractor to provide detailed documentation of the design inputs, a narrative on how the inputs were determined, the design methodology, and the outputs.

For design-build projects, most agencies specify a short warranty period of 1 year (Minnesota and Washington specify 3- and 5-year warranty periods, respectively). The shorter warranty generally is adequate to cover materials and workmanship issues. So, by and large, the agency assumes the responsibility for managing the risks in the post-construction period of the project.

Considering the short-term turnover period and limited contractor responsibility, agencies tend to stipulate the pavement types to be used in a project or specify the criteria to be followed in the selection process. For example, in the I-15 CORE project, Utah specified its preference for concrete pavement in high traffic-volume areas and all areas of mainline freeway reconstruction, while allowing the bidders to select a conventional unbonded concrete overlay or a HMA overlay with a stone matrix asphalt (SMA) on the surface. However, the agency specified the key inputs of the selection process, such as the minimum pavement thickness, the sequence of future M&R activities and the LCCA inputs for each allowable pavement type. In summary, the agency's control over the whole or critical steps of the selection process helps to ensure that the contractor builds a pavement that meets the agency's expectations.

When the agency specifies the pavement type, the agency performs the pavement-type selection using its own design methodology, life cycle strategies, and cost criteria. While specifying the final pavement type, the agency is suggested to allow incentives for contractor innovation and competition that would result in long-term cost savings. In the other scenarios, contractors can follow the agency-allowed process in pavement-type selection presented in Figure 33.

Typically, agencies take many non-economic factors into account in the pavement-type selection process. The non-economic factors also incorporate the heuristic knowledge the agency has gained through experience, such as performance trends, influence of climate, local materials, subgrade factors, and the effect of traffic pattern on certain pavement types. For example, the agency may have insight into potential long-term performance issues of certain aggregate mineralogy (e.g., stripping in HMA or alkali silica reactivity in concrete). This knowledge could be a decisive factor in selecting a pavement type.

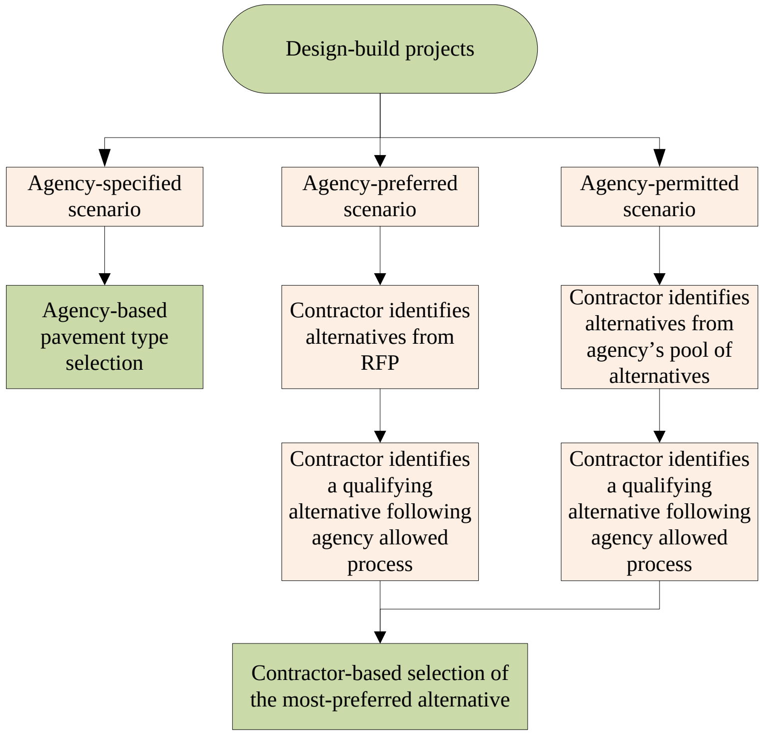


Figure 33. Pavement-type selection for design-build projects.

In a practical sense, irrespective of the selection scenarios discussed above, the pavement type in design-build projects is selected using the agency selection process. Even in the "agency-permitted" scenario, where the contractor has the flexibility to select the pavement type and perform thickness design, in reality, the contractor follows the agency's type selection process and thickness design procedures. Furthermore, the agency evaluates the technical proposals using its own practices as the yardstick. Considering these factors, an agency-allowed process is considered appropriate for all design-build projects.

8.6.2 Pavement-Type Selection in Design-Build Projects with O&M

These projects involve a greater role for the private sector through public private partnerships in areas such as project conceptualization, financial planning, project financing, O&M, toll collection, congestion pricing, and design and construction. Design-build projects with O&M typically are larger and more complex than traditional projects. Variants of design-build projects with O&M include:

- Design-build-operate-maintain.
- Design-build-finance-operate.
- Long-term lease.

Due to the complexity of these projects, there are several risk factors associated with finance, revenue, macroeconomics, and facility management that may have a direct or indirect bearing on

the pavement-related costs. These risks may have a "subjective" influence on the contractor's decision making. Examples of these risks include:

- Traffic volume below projections.
- Insufficient revenue from tolls.
- Excessive maintenance and operational costs.
- Increasing financing costs.
- Unpredictable commodity prices.
- Macroeconomic uncertainties related to inflation and discount rates.

Given the contractor's risks and responsibilities, agencies generally allow the contractors to select the preferred pavement type. However, minimum performance criteria are typically specified and there may be lane rental charges for lane closures. The contractor can follow the process presented in Figure 34.

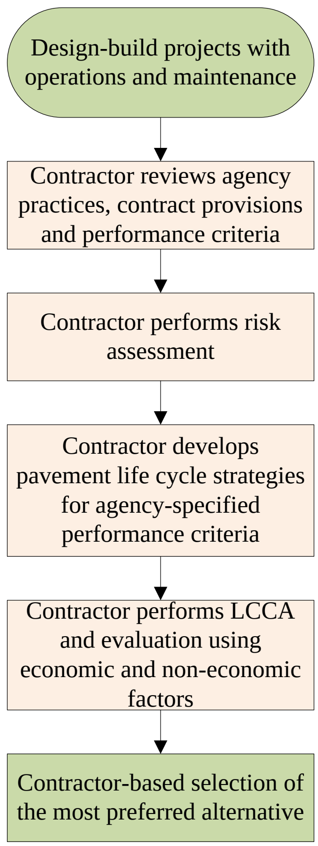


Figure 34. Pavement-type selection for design-build projects with O&M.

8.6.3 Pavement-Type Selection in Warranty Projects

Pavement warranties require significant decision making by both agencies and contractors, as they contribute additional risks and benefits to pavement life cycle costs. There are three types of warranties practiced in the highway industry: materials and workmanship, short-term performance, and long-term performance.

Materials and Workmanship Warranty

In projects involving materials and workmanship warranty, the contractor is responsible only for material properties and workmanship issues that contribute to poor pavement performance during the warranty period. Since the agency is responsible for pavement-type selection, pavement design, and LCCA, the agency-based process can be followed.

Short-term Performance Warranty

In short-term performance warranty projects, the agency is responsible for pavement-type selection and structural design requirements. Some agencies, however, may allow the contractor to select the pavement type in addition to design and construction aspects, and thereby allow for innovation. The contractor is responsible for material design, any improvements needed in materials and structural designs, better quality control, and performance issues during the warranty period. Short-term warranties are used in both traditional design-bid-build contracts and alternate contracts including design-build and multi-parameter bidding.

The agency specifies performance thresholds to monitor pavement performance during the warranty period. In short-term performance warranty projects, the agency-based pavement-type selection process can be followed (see Figure 35). In addition, the contractor may need to perform risk assessment to incorporate risk premiums in the bid price.

Long-term Performance Warranty

In long-term performance warranty projects, the contractor is responsible for performance issues and planned/unplanned maintenance activities over an extended period (typically, between 10 and 20 years). This type of warranty is used in both traditional and alternative contracting projects, where some projects may involve substantial financial investment from the contractor. However, the contractor generally is not given facility operations control.

In these projects, the contractor is responsible for pavement-type selection, structural design, materials selection and design, quality control, pavement maintenance, rehabilitation strategies, and performance. Contractor-based type selection is considered vital to long-term performance warranty projects, as it allows the contractor to select the most appropriate and cost-effective strategy for meeting performance requirements. The agency is responsible for establishing realistic performance thresholds, monitoring performance and, in some cases, sharing risks. Establishing realistic and achievable performance thresholds based on historical data is critical. Agencies use performance specifications for acceptance in these projects.

The contractor can follow the process presented in Figure 35.

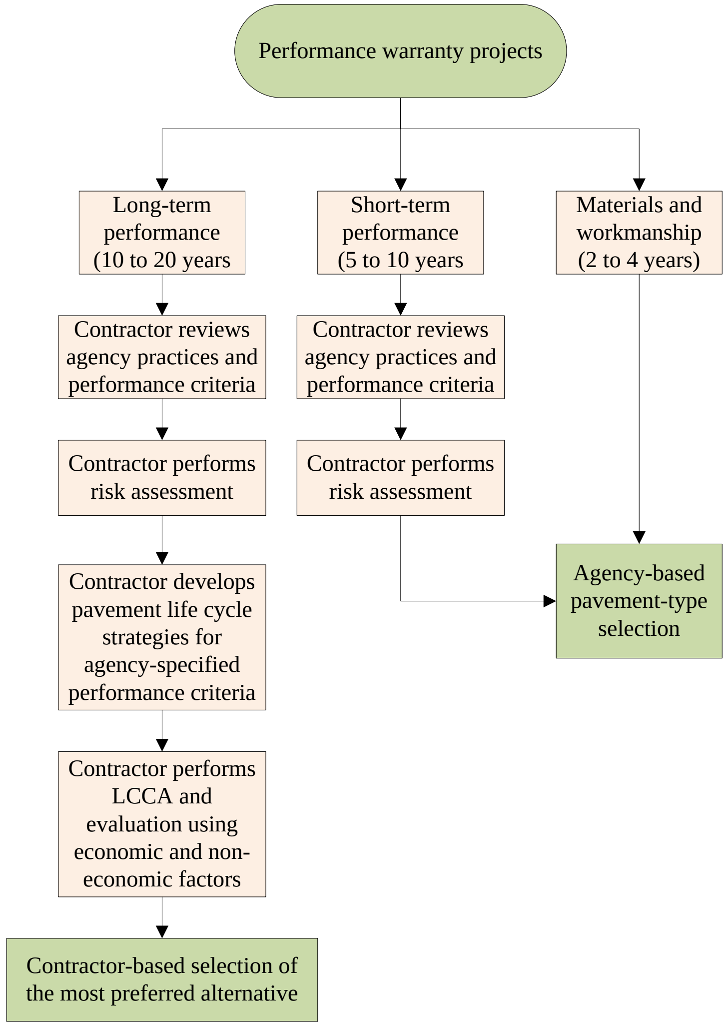


Figure 35. Pavement-type selection for performance warranty projects.

CHAPTER 9 – CASE STUDIES OF THE PAVEMENT TYPE-SELECTION PROCEDURE

Three case studies were conducted, each focusing on agency-based selection, alternate bidding and contractor-based selection. The case studies compare the proposed approach with the type selection practices and identify the reasons for differences between the two processes. The objectives of the case studies were to (1) demonstrate the application of the proposed pavement-type selection approach for "real world" highway projects, (2) compare the outcomes with the results and decisions made by the agency or the contractor in those projects, and (3) refine the proposed approach to address any identified deficiencies.

As outlined previously, the proposed approach is as follows:

1. Identify a pool of pavement-type alternatives.
2. Identify feasible alternatives for the project.
3. Develop life cycle strategies for each alternative.
   i. Determine the initial pavement structure for feasible alternatives.
   ii. Determine pavement performance and M&R activity timing.
4. Perform LCCA.
   i. Establish LCCA framework.
   ii. Estimate direct/agency costs.
   iii. Estimate indirect/user costs.
   iv. Develop expenditure stream diagrams.
   v. Compute life cycle costs.
5. Evaluate alternatives using economic factors.
6. Evaluate alternatives using non-economic factors.
7. Weigh economic and non-economic factors using the alternative preference screening matrix.
8. Make final pavement-type decision.

The Colorado DOT, Missouri DOT and the 407 Express Toll Route (407 ETR), Ontario, Canada, were selected for the case studies. A memorandum was prepared to outline our data gathering efforts for the two agencies, including worksheets, targeted questions, and discussion on key steps involved in the proposed pavement-type selection process. Once prepared, the memorandum was sent to the three agencies. They then selected a project for the case study and provided the project documentation containing the LCCA results and the final recommendations on the selected pavement type. The team reviewed the participants' selection processes and the project documents, and then conducted an interview with the personnel from both agencies.

9.1 CASE STUDY 1: AGENCY-BASED PAVEMENT-TYPE SELECTION

9.1.1 Introduction

The Colorado DOT has a comprehensive and well documented pavement-type selection process. The agency uses both deterministic and probabilistic approaches in computing life cycle costs and takes economic and non-economic factors into consideration in selecting the most-preferred pavement type for a project.

The project selected for this case study was the reconstruction of Interstate 25 in Weld County, between State Highway 119 and State Highway 66. The project scope included the addition of a driving lane in each direction to a four-lane divided highway and vertical profile changes. The length of the project was 5.38 miles. The roadway is classified as a rural interstate highway with an historic AADT of 52,100 (estimated in 2004) with 13.9 percent truck traffic.

9.1.2 Identify a Pool of Pavement-Type Alternatives

The pavement types that Colorado has approved for pavement-type selection in both new or reconstruction projects and rehabilitation projects are as follows:

- Conventional asphalt concrete (AC) pavement.
- Full-depth AC pavement.
- AC with stabilized base.
- AC overlay of rigid pavement.
- AC recycled pavement – including cold in-place recycling, hot in-place recycling, full-depth reclamation.
- Jointed plain concrete pavement (JPCP).
- Thin whitetopping.
- Unbonded concrete overlays.
- JPCP overlay of AC pavements.

9.1.3 Identification of Project-Specific Feasible Alternatives

Colorado DOT conducted a project scoping study to identify feasible pavement-type alternatives for this project from the broader pool of alternatives listed above. Since this project was a widening job, the agency evaluated the impact of roadway geometry features such as changes in vertical profile, overhead clearances, and on-grade structures. The agency also evaluated the past performance and material properties of the existing pavement.

Based on this evaluation, the DOT identified two feasible alternatives for use in LCCA that are specific to this project:

- Conventional AC pavement.
- JPCP.

Other alternatives in the list were eliminated since they would not have met the project's long-term goals and vertical alignment constraint.

The agency then submitted a pavement justification report to the pavement-type selection committee outlining the reasons for including specific alternatives in the selection process.

9.1.4 Developing Alternative Pavement Strategies

To develop the life cycle strategies for the alternatives considered in this project, Colorado DOT first performed the structural design of the alternatives, estimated their service lives, and assigned the timing sequence of future maintenance and rehabilitation activities.

Determining Initial Pavement Structure

Colorado DOT first developed structural designs for the flexible and rigid pavement alternatives using the AASHTOWare DARWin software version 3.1 and the 1998 rigid design supplement to the AASHTO 1993 Guide, respectively. The cross-sectional designs of the feasible alternatives are shown schematically in Figure 36.

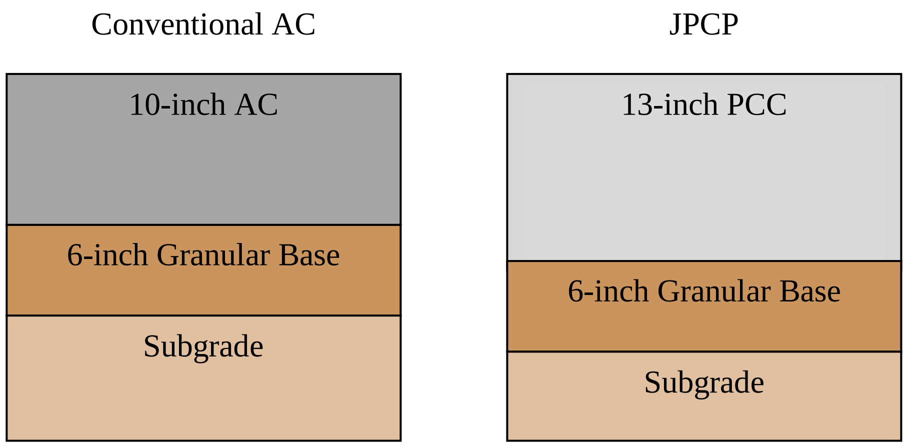


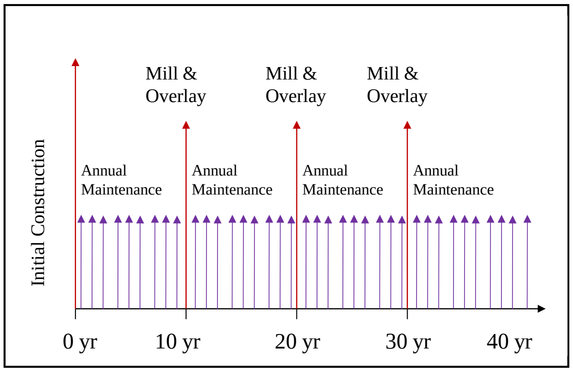
Figure 36. CDOT I-25 case study: structural designs of pavement alternatives.

Determining Pavement Performance and M&R Activity Timing

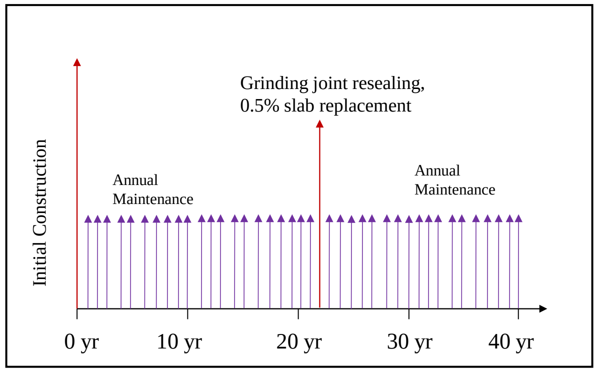
The agency identified the timings and extents of anticipated M&R treatments using a pre-defined strategy. Colorado defines M&R strategies for different pavement types based on the performance trend analysis of the statewide pavement condition data and experience based estimates. The recommended rehabilitation sequences and the life cycle models of the two pavement types are presented in Table 33 and Figure 37, respectively.

Table 33. CDOT I-25 case study: M&R strategies of pavement alternatives.

Conventional AC	• Mill and 2-inch AC overlays at years 10, 20 and 30 • Annual maintenance
JPCP	• 50 percent full width diamond grinding; ½ percent slab replacement in the travel lanes; and joint resealing at year 22 • Annual maintenance



a. Conventional AC Pavement



b. JPCP

Figure 37. CDOT I-25 case study: life cycle models of pavement alternatives.

9.1.5 Perform LCCA

A detailed documentation of the Colorado DOT's LCCA process is published in the agency's *Pavement Design Manual* (CDOT, 2011). Only the basic LCCA inputs pertinent to the pavement-type selection process are discussed in this section.

<u>CDOT's LCCA Framework</u>

The agency requires the LCCA of feasible alternatives for all new or reconstruction projects with more than $2,000,000 initial pavement material cost. Colorado's LCCA procedure requires the computation of NPV over an analysis period of 40 years at a discount rate of 4 percent.

The agency takes both direct agency costs and indirect user costs into account; however, the user costs are considered for M&R activities but not for initial construction. The agency costs include initial construction costs, supplemental costs, rehabilitation costs, and maintenance costs. The supplemental costs include 10 percent preliminary engineering costs, 15 percent traffic control costs, and 18.1 percent construction engineering costs. Although the DOT takes salvage value in account, no salvage value was assigned to either alternative at the end of analysis period.

User costs were computed using the WORKZONE-RUC program. Colorado DOT computes user costs based on its workzone traffic management policy of a maximum queuing time of 30 minutes or queue length of 5 miles. The agency and the user cost components considered in the LCCA are listed in Table 34.

Table 34. Colorado DOT's agency and user cost items.

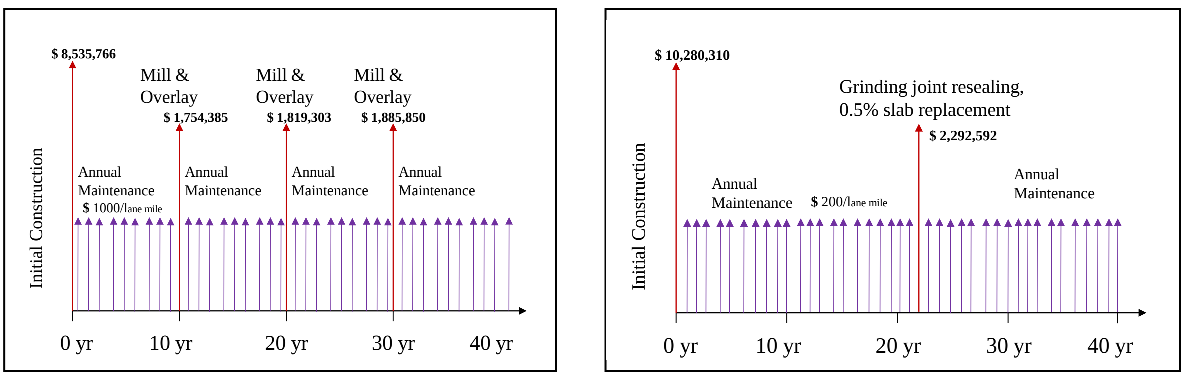
Agency Costs	**User Costs**
Construction costs	WZ speed change VOC
Engineering costs	WZ speed change delay
Design costs	WZ reduced speed delay
Maintenance costs	Queue stopping delay
Traffic control costs	Queue stopping VOC
Salvage value	Queue added travel time
	Queue idle time

Colorado uses DARWin and RealCost for deterministic and probabilistic analyses, respectively. In the probabilistic analysis, a triangle distribution is used for computing discount rate and agency construction costs, whereas a log normal distribution is used for computing service life of alternatives. The agency accepts the probabilistic estimations at the 75th percentile level.

Expenditure Stream Diagrams and Life Cycle Costs

The expenditure stream diagrams for both conventional AC and JPCP are shown in Figure 38. Note that the figure shows only the undiscounted, deterministic inputs of various initial and future costs. The life cycle costs obtained from deterministic and probabilistic analyses are summarized in Table 35 and Table 36, respectively. The differences in NPV between the two alternatives, as determined using deterministic and probabilistic analyses, were 1.0 percent and 4.1 percent, respectively.

In Colorado's practice, the designer makes a decision to eliminate an alternative or consider them as equivalents based on their difference in life cycle costs. Colorado specifies a minimum difference criterion of 10 percent to be used in determining the preferred alternative to another on the basis of life cycle costs. A cost comparison between two alternatives that yields results within 10 percent certainly would be considered to have equivalent designs. In this case, the cost difference between the two alternatives is less than 5 percent; therefore, the two alternatives were deemed equivalent.



a. Conventional AC Pavement b. JPCP

Figure 38. CDOT I-25 case study: expenditure stream diagrams.

Table 35. CDOT I-25 case study: results of deterministic LCCA.

Activity	Conventional AC Pavement		JPCP	
	Year	Discounted Costs	Year	Discounted Costs
Original construction	0	$ 17,331,546	0	$ 20,651,193
Rehabilitation 1	10	$ 2,532,543,38	22	$ 1,967,884
Rehabilitation 2	20	$ 1,770,151		
Rehabilitation 3	30	$ 1,236,885		
NPV		$ 22,851,126		$ 22,619,078
Difference in NPV	1.02%			

Table 36. CDOT I-25case study: results probabilistic LCCA.

Statistics	Conventional AC		JPCP	
	Agency Costs	User Costs	Agency Costs	User Costs
Mean	$21,148,480	$760,910	$21,705,260	$985,780
Percentile (75%)	$23,123,510	$1,107,220	$23,805,650	$1,409,150
Total life cycle costs at 75th percentile	$24,230,735.00		$25,214,793.00	
Difference	4.06%			

When the cost analysis does not show a clear indication of the preferred alternative, Colorado's policies require the designer to refer the process to the PTSC for critical review of the LCCA and further evaluation of alternatives using secondary factors. These secondary factors may include both economic and non-economic factors. The PTSC then selects decision factors consistent with the corridor project goals and evaluates them. Once the decision factors are evaluated and ranked, the PTSC members complete the rating sheet independently or collectively, so that the final results represent a group decision.

In this project, Colorado DOT's project goals were to minimize future M&R costs, while none of the non-economic factors were evaluated. The future rehabilitation costs were the only evaluation criterion used in selecting the preferred alternative. The decision to use financial goal as the only secondary factor in this project is compatible with the general principle of the proposed approach that the inclusion and the importance of other factors, economic or non-economic, vary from project to project and depends on the goals the agency pursues.

On the other hand, if Colorado were to use the proposed approach, the agency would make a decision on the preferred alternatives based on the evaluation using economic and non-economic factors upon computation of the life cycle costs.

9.1.6 Conclusions

Based on the goal of minimizing future rehabilitation costs, the JPCP type was selected. This case study demonstrates the application of the proposed pavement-type selection approach in real-world projects with no deviations in expected outcomes when compared with the agency's original approach.

9.2 CASE STUDY 2: ALTERNATE PAVEMENT TYPE BIDDING

9.2.1 Introduction

Missouri DOT (MoDOT), in cooperation with FHWA and the paving industry, developed guidelines for pavement design and pavement-type selection, culminating in the publication of *Pavement Design and Type Selection Process* (MoDOT, 2004). One of the key recommendations in this guide is to use alternate bidding to obtain more competitive prices for roadway projects. The report includes additional guidelines for the successful implementation of alternate bidding.

The project selected for this case study was the reconstruction of Route 32 near Bearcreek in Cedar County. The project scope was to improve the connectivity of Route 32 between east of Route A to east of Route RA. The scope included the mainline paving for a length of 1.856 miles with either PCC or AC, constructed on a prepared subgrade in accordance with the MoDOT standard specifications.

9.2.2 Identify a Pool of Pavement-Type Alternatives

MoDOT has approved the following pavement types for use in new, reconstruction, and rehabilitation projects:

- Conventional AC (greater than 4 inches) over granular base
- New JPCP (doweled)
- Unbonded JPCP overlay
- HMA overlay on rubblized PCC
- Conventional HMA overlay

Besides conventional AC pavements, MoDOT also uses small percentages of Superpave HMA and stone matrix asphalt (SMA) overlays. In addition, the agency considers the use of perpetual AC pavement, ultrathin whitetopping, and continuously reinforced concrete pavement (CRCP). Jointed reinforced concrete pavement (JRCP), a pavement type widely used in Missouri until 1993, is no longer used.

9.2.3 Identification of Project-Specific Feasible Alternatives

MoDOT routinely uses conventional HMA and JPCP for both new and reconstructed pavements. Since this project was a reconstruction job, the agency selected these pavement types as candidates for alternate bidding.

9.2.4 Developing Alternative Pavement Strategies

MoDOT provided the pavement design thicknesses for the mainline on this project: 8 inches of AC or 7 inches of JPCP. These thicknesses were determined using the MEPDG by applying equivalent distress threshold criteria and design criteria. The agency's limiting distress criteria for design selection are as follows:

- AC Pavement:
    - ¼-inch mix rutting at the end of 20 years
    - 2 percent fatigue cracking at the end of 30 years
- JPCP:
    - 3/16-inch faulting at the end of 25 years
    - 1.5 percent cracking at the end of 25 years

MoDOT then utilized pre-defined strategies to determine the expected service life of the initial structure and rehabilitation treatments. Based on pavement performance and survival data, the

agency has established an expected service life of 20 years for AC and 25 years for JPCP. The rehabilitation treatments recommended for the two pavement types are presented in Table 37. The pavement life cycle models for the AC and JPCP alternatives are presented in Figure 39 and Figure 40, respectively.

Table 37. MoDOT Route 32 case study: M&R strategies of pavement alternatives.

Conventional AC	• Mill 1 ¾ in and replace in kind, traveled way only (24 ft) at year 20. • Mill 1 ¾ in and replace in kind on entire pavement width, including shoulders, at year 33.
JPCP	• Diamond grind traveled way (24 ft wide) and perform full depth pavement repair (assume 1.5 percent of traveled way) at year 25.

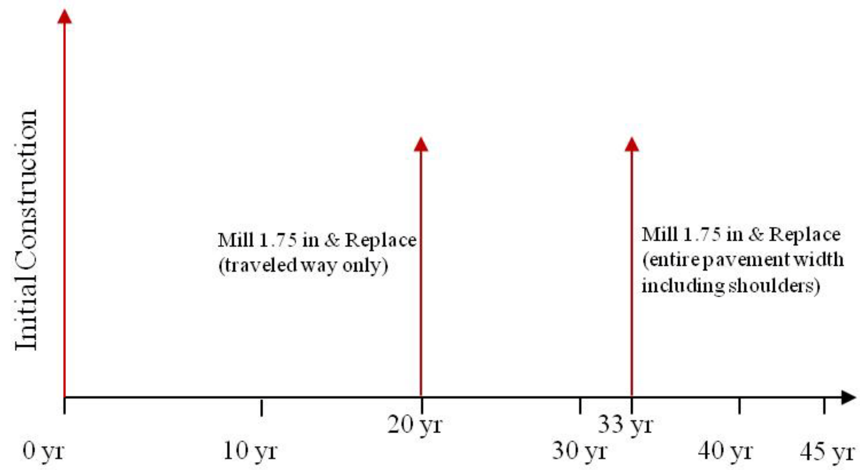


Figure 39. MoDOT Route 32 case study: life cycle model of the AC alternative.

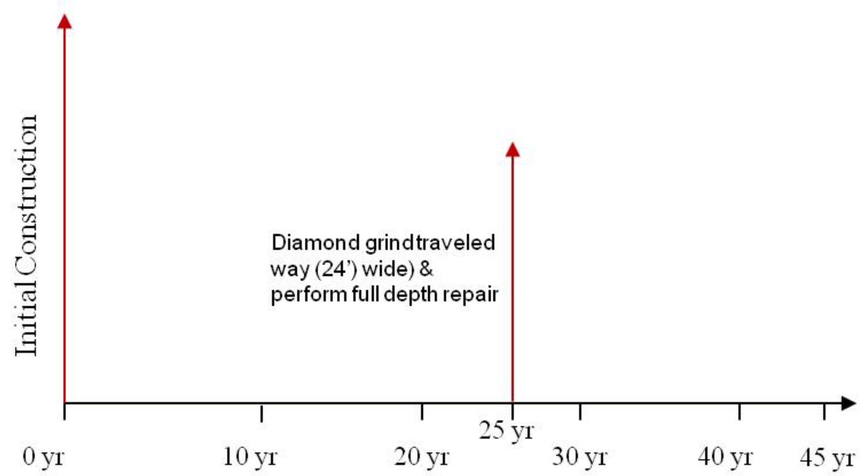


Figure 40. MoDOT Route 32 case study: life cycle model of the JPCP alternative.

9.2.5 Perform LCCA

MoDOT's LCCA process is documented in the *Pavement Design and Type Selection Process* document. MoDOT uses a cost analysis spreadsheet to compute life cycle costs. The agency's LCCA procedure requires the deterministic computation of NPV over an analysis period of 45 years at a real discount rate specified in the OMB circular A-94 (2.8 percent in 2008).

Agency Costs

MoDOT considers only the agency costs associated with initial construction and rehabilitation activities. Maintenance costs are also not currently included, as the agency believes that the costs have kept the same relative proportion between JPCP and asphalt pavement types. Similarly, the agency does not take salvage values into account, as the assumptions behind the salvage value calculations, the agency believes, are largely hypothetical and unknown.

The agency takes both direct construction costs and indirect project costs into account for agency costs. Such costs include incidental construction, preliminary engineering (design) and construction engineering (inspection and materials testing), mobilization, and miscellaneous (traffic control) costs.

MoDOT uses estimated unit costs for expected pay item quantities of future rehabilitation activities. Unit costs are obtained from local suppliers and quarries and used on a per-job basis. When the commodity prices are volatile, no price adjustment factors are applied to agency costs and the structural designs will remain unchanged.

User Costs

MoDOT does not include user costs in the LCCA.

Life Cycle Costs

MoDOT is one of the 12 state DOTs that keeps the engineer's estimate confidential even after the contract is awarded; thus, the initial construction costs for the Route 32 project were not available. The agency determined the bid adjustment factor to account for the difference in discounted future costs of the two alternatives. The bid adjustment factor was first published in the bid advertisement documents and was later utilized in determining the lowest bidder. The bid adjustment factor computed for this project is presented in Table 35.

Table 38. MoDOT Route 32 case study: results of deterministic LCCA.

Activity	**AC Pavement**		**JPCP**	
	Year	**Discounted Costs**	**Year**	**Discounted Costs**
Original construction	0	Not Available	0	Not Available
Rehabilitation 1	20	$91,964	25	$48,601
Rehabilitation 2	33	$75,789		
Bid Adjustment Factor			$119,152	

Economic and Non-economic Factors

Since MoDOT used "standard" alternatives in this project, a project-level evaluation using economic and non-economic factors was not performed.

Contract Award

Upon letting, three contractors submitted bids on this project. Two bids were received for the AC alternate, and one was received for the JPCP alternate. The bid adjustment factor was then added to the lowest AC bid and compared with the JPCP bid (see Table 39).

Of the three bids, the lowest bid amount (after adjustment) was for AC pavement; the JPCP bid was 9.1 percent higher than the lowest bid amount. Therefore, the AC pavement contract was awarded to the lowest bidder. The bid adjustment factor did not determine the winning bid.

Table 39. MoDOT Route 32 case study: bidding results.

Bidder	Alternate	Bid amount	Bid amount after adjustment	Percent Difference
Bidder A	AC	$1,524,308	$1,643,508	0
Bidder B	JPCP	$1,792,421	$1,792,421	9.1
Bidder C	AC	$1,754,209	$1,873,409	14.0

9.2.6 Conclusions

MoDOT's pavement-type selection practice follows the approach developed in NCHRP Project 10-75 in all respects except the evaluation of proposed alternatives using economic and non-economic factors at the project level. As discussed, since MoDOT considers only a few pavement types, and the alternatives used in this project are used routinely, the agency would not have found the need for project-level evaluation.

9.3 CASE STUDY 2: CONTRACTOR-BASED PAVEMENT-TYPE SELECTION

9.3.1 Introduction

The project selected for this case study was the construction of the Highway 407 in Toronto, Ontario, Canada, between mileposts 0 and 67. The highway is a toll road managed by a private consortium, 407 ETR. This project involved the construction of 69 km of 4- and 6-lane highways on a new alignment. The length of the project was 63 miles. The roadway is classified as a rural divided freeway highway with a design ESAL of 100 million and 8 percent truck traffic.

The central section of the 407 ETR toll highway originally was constructed as a design-build project for the Ontario Ministry of Transportation. There were two primary bidders for the project. The winning team completed extensive life cycle costing using a 50-year analysis period and a 7 percent interest rate. The philosophy of the team was to build a high-quality, low-maintenance pavement using the most current technological advances. This resulted in an exposed concrete pavement being put forth. The second bidder put forward a relatively thin

flexible pavement design with frequent structural overlays. In reviewing the life cycle designs for the two bids, the Ministry was not interested in the frequent overlay design due to the significant disruption that this would cause for traffic, and the team putting forward the higher quality pavement was selected.

In 2000, the toll highway was sold to the private sector in a public private partnership deal. The concession period was 99 years. As a part of this deal, the concessionaire agreed to extend the highway immediately, 15.5 miles to the west and 9.3 miles to the east. The purchase price for the highway was significant, and the philosophy of the concessionaire was different from that of the original design-build contractor. While the performance of the exposed concrete pavement was very good, the cost to extend the highway in concrete was deemed too expensive. Further, as the purchase and on-going operation of the highway was to be financed by tolls, the concessionaire elected to part from life cycle cost as a key decision factor and design flexible pavements with a 10-year initial life. The feeling was that they could be overlaid after 10 years and, in the meantime, they could recoup some of the costs through highway tolls.

9.3.2 Develop Potential Pavement-Type Alternatives

The pavement types that were considered for pavement-type selection are listed as follows:

- JPCP with an open graded drainage layer.
- AC with an open graded drainage layer.
- AC with a dense graded base layer.
- Micro-surfacing.
- NovaChip.
- CPR (dowel bar retrofit, cross stitching, slab replacement).

9.3.3 Identification of Project-Specific Feasible Alternatives

Within the broad group of pavement types, 407 ETR identified JPCP and conventional AC pavement as feasible alternatives for this project.

9.3.4 Developing Alternative Pavement Strategies

In this step, the feasible alternatives were assigned an initial structure and the probable M&R activities covering the selected analysis period.

The cross-sectional designs of the feasible alternatives for the Highway 407 are shown schematically in Figure 41.

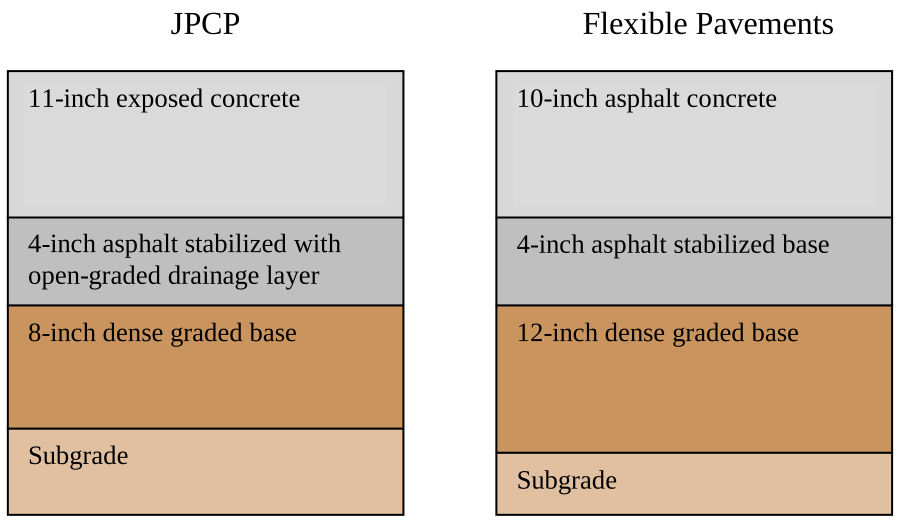


Figure 41. Highway 407 case study: structural designs of pavement alternatives.

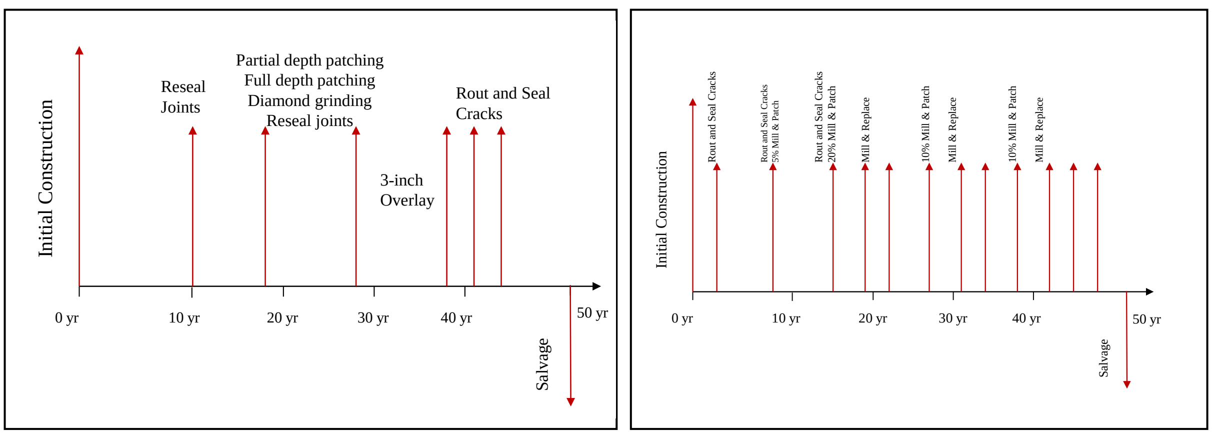
The recommended rehabilitation sequences for the pavement types considered in the project are presented in Table 40 and Figure 42. 407 ETR has developed these strategies by combining performance trend analysis of pavement condition data with experience and the innovative strategies. Note that 407 ETR makes extensive use of pavement preservation and preventive maintenance treatments such as slab repairs, cross-stitching, and dowel bar retrofit. 407 ETR also is very active in trying new and innovative treatments to expand their potential use in maintaining the highway.

Table 40. Highway 407 case study: M&R strategies of pavement alternatives.

Year	JPCP	Flexible Pavement
3		Route and seal cracks
9		Route and seal cracks
9		5 percent mill and patch
10	Reseal joints	
15		Route and seal cracks
15		20 percent mill and patch
18	Partial depth patching	
18	Full depth patching	
18	Diamond grinding	
18	Reseal joints	
19		Mill 3 inches, replace 3 inches
22		Route and seal cracks
27		Route and seal cracks
27		10 percent mill and patch
28	Partial depth patching	
28	Full depth patching	
28	Diamond grinding	
28	Reseal joints	

Table 40. Highway 407 case study: M&R strategies of pavement alternatives.

Year	JPCP	Flexible Pavement
31		Mill 3 inches replace 3 inches
34		Rout and seal cracks
38	Overlay 3 inches asphalt concrete	
38		Rout and seal cracks
38		10 percent mill and patch
41	Rout and seal cracks	
42		Mill 3 inches and replace 3 inches
44	Rout and seal cracks	
45		Rout and seal cracks
48		Rout and seal cracks



a. JPCP b. Flexible Pavement

Figure 42. Highway 407 case study: M&R strategies of pavement alternatives.

9.3.5 Perform LCCA

407 ETR's LCCA Framework

407 ETR's LCCA procedure involves the computation of NPV over an analysis period of 99 years at a discount rate of 4 percent. As a private organization with a 99-year lease, 407 ETR completes long-term capital and maintenance plans to value the highway infrastructure for leader reasons. Their LCCA procedure takes only direct agency costs into account; user costs are not considered. In this case study, only the results of deterministic LCCA are presented.

Life Cycle Costs

The life cycle costs of the two alternatives, as estimated from the deterministic analysis, are summarized in Table 41.

Table 41. Highway 407 case study: results of deterministic LCCA.

Cost Item	JPCP	Flexible Pavement
Initial Construction Costs	$ 1,930,940	$ 1,841,620
Total M&R Costs –undiscounted	$ 972,604	$ 1,741,563
Total M&R Costs–discounted	$ 240,116	$ 453,683
Total User Delay Costs	$ 0	$ 0
Net Present Value	$ 2,167,723	$ 2,286,169
Difference	5.5%	
Note: Costs provided are for a typical 1 km, 6-lane section of roadway. They include pavement lanes only cost and do not include median barrier, shoulders, drainage systems, etc. The drainage systems are the same for both the flexible and rigid pavements. Salvage value of Alternative 1 year 38 and Alternative 2 year 42 overlay included as a negative cost.		

9.3.6 Evaluation of Economic and Non-economic Factors

The difference in NPV between the two alternatives was 5.5 percent. These alternatives were deemed equivalent. As recommended in the proposed approach, the equivalent alternatives were evaluated using economic and non-economic factors to select the preferred pavement strategy alternative. 407 ETR was asked to use the alternative preference screening matrix tool to determine the impact of the individual economic and non-economic factors on the decision to select one pavement type or another. Table 42 shows the completed worksheet for the screening matrix. The calculated rating scores for JPCP and flexible pavement were 80 and 39.2 percent, respectively. The scores indicate that there are significant differences between the two pavement types and that JPCP may be much better suited than the flexible pavement. Therefore, based on the rating scores, the JPCP was selected.

9.3.7 Conclusions

This case study demonstrates the application of the proposed pavement-type selection approach in projects where the contractor makes the pavement-type selection. In the contractor-based decision making scenario, the contractor generally follows the agency's pavement-type selection procedures and the LCCA. However, when the LCCA is being applied for multi-decade projects such as this one, users are cautioned to consider the inherent limitations of the LCCA and the validity of LCCA inputs over multiple decades. In such situations, designers should use shorter analysis periods (e.g., 40 years) and exercise engineering judgment.

9.3.8 General Notes – Contractor Pavement-Type Selection

ARA interviewed several contractors who are involved in bidding both design-build and public private partnership contracts throughout Canada and the United States. A summary of the salient points from these discussions is provided below:

- None of the contractors completed their own internal life cycle costing. All of them rely on specialty pavement consultants to do this.

Table 42. Highway 407: Evaluation of alternatives using the screening matrix.

Factor	Factor Weight	JPCP		Flexible	
		Rating	Weighted Score	Rating	Weighted Score
Group A. Cost considerations					
Initial Cost	50	High	50.0	High	50.0
Life cycle Cost	30	High	30.0	Low	6.0
User Costs	0	Low	0.0	High	0.0
Future Rehabilitation Costs	20	High	20.0	Low	4.0
Group A unweighted total	**100**		***100.0***		***60.0***
Group B. Construction/ materials considerations					
Roadway/Lane Geometrics	20	No difference	0.0	No difference	0.0
Continuity of Adjacent Pavements	10	High	10.0	Low	2.0
Continuity of Adjacent Lanes	40	High	40.0	Low	8.0
Availability of Local Materials and Experience	10	No difference	0.0	No difference	0.0
Traffic During Construction	20	No difference	0.0	No difference	0.0
Group B unweighted total l	**100**		***50.0***		***10.0***
Group C. Other considerations					
Safety Considerations	50	High	50.0	Medium	30.0
Maintenance Capability	30	High	30.0	Medium	18.0
Future Needs	20	High	20.0	Low	4.0
Group C unweighted total	**100**		***100.0***		***52.0***
Sub Totals	**Group Weights**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**
A. Cost Considerations	50	100.0	50.0	60.0	30.0
B. Construction/Materials Considerations	40	50.0	20.0	10	4.0
C. Other Considerations	10	100.0	10.0	52	5.2
Grand total	**100**		**80.0**		**39.2**

Note: All values in percent.

- Pavement life cycle costing for large public private partnership projects typically feeds into an overall cost model for the project and is used by the lenders to evaluate cash flow needs.
- For design-build projects, the goal is to build what the owner wants and expects, and the life cycle costing is used to validate the specific pavement type and maintenance and operations plan. For many design-build projects, it was felt that the owner's documentation and contract requirements restricted the pavement type to one or another design.

- Contractors would like a more open process that would permit more innovation, but it is recognized that it would be difficult to evaluate some innovations, and there is a reluctance to suggest something radically new for fear of the whole bid being rejected.
- Secondary and tertiary factors for pavement-type selection generally are ignored by contractors unless there is a specific requirement to address them as part of the bid.
- Future costs (maintenance and operations) generally are not considered in design-build bids unless required by the owner, and then the contractor's goal is to make them reasonable to ensure that the bid is not rejected.
- Initial cost and risk are the most important factors for a contractor in choosing one pavement type over another. Major risk items almost always come down to time of construction. For other sites, they typically have a good understanding of risk and price it accordingly. Rehabilitation projects under traffic and difficult working conditions (e.g., small sites, heavy traffic, poor subgrade soils, nighttime construction, weather issues) are priced as high-risk items for the contractor. Several contractors own both asphalt and concrete operations, and they indicated that they would select to build either flexible or rigid pavement depending on location and site conditions.
- Contractor experience and control of operations was cited as a major decision in determining the pavement type. If the contractor did not have the experience to build one pavement type or another, they were very nervous that the operation was not fully under their control, which could lead to problems and higher costs.

REFERENCES

Ahlvers, D. "MODOT Alternate Pavement Approach," Presentation to the AASHTO Subcommittee on Construction, 2009. http://www.transportation.org/sites/construction/docs/Ahlvers%20Alternate%20Pavement%20Approach.pdf. (As of December 2, 2009)

Air Force Civil Engineer Support Agency (AFSECA), *Historical Air Force Construction Cost Handbook*, Directorate of Technical Support, Air Force Civil Engineer Support Agency, Tyndall Air Force Base, Florida, 2007.

American Association of State Highway and Transportation Officials (AASHTO). AASHTO Guide for Design of Pavement Structures. AASHTO, Washington, D.C, 1993.

American Association of State Highway Transportation Officials (AASHTO), AASHTO Survey on Design-Build Projects, AASHTO, Washington, D.C,2007.

American Association of State Highway Officials (AASHO), The Informational Guide on Project Procedures, Prepared by the Special Committee of Project Procedures, AASHO, Washington, D.C,1960.

Applied Research Associates (ARA), Inc. Mechanistic-Empirical Pavement Design Guide (Appendix C-Life Cycle Cost Analysis). NCHRP Project 1-37A. Washington, D.C., 2004.

Colorado Department of Transportation (CDOT), *Pavement Design Manual* (Chapter 10), Colorado DOT, Denver, Colorado, 2011.

Federal Highway Administration (FHWA), Federal Aid Policy Guide, 23 CFR 626, dated April 8, 1999, FHWA, Washington, D.C., 1999. http://www.fhwa.dot.gov/legsregs/directives/fapg/cfr06261.htm (As of December 20, 2010)

Federal Highway Administration (FHWA), "Life-Cycle Cost Analysis, RealCost User Manual," Office of Asset Management, FHWA, Washington, D.C., 2004.

Federal Highway Administration (FHWA), "Clarification of FHWA Policy for Bidding Alternate Pavement Type on the National Highway System," Memorandum dated November 13, 2008, Office of Pavement Technology, FHWA, Washington, D.C., 2008. http://www.fhwa.dot.gov/pavement/081113.cfm. (As of December 20, 2010)

Federal Highway Administration (FHWA), Special Experimental Projects No. 14 - Alternative Contracting, Office of Program Administration (Contract Administration), FHWA, Washington, D.C., 2009. http://www.fhwa.dot.gov/programadmin/contracts/sep_a.cfm (As of December 20, 2010).

Federal Highway Administration (FHWA), Best-Value Alternative Bidding (A-D) Evaluation, Federal Highway Administration, Office of Program Administration (Contract Administration), FHWA Washington, D.C., 2008. http://www.fhwa.dot.gov/programadmin/contracts/sep14iaeval2008.cfm (As of December 20, 2010).

Federal Highway Administration, Public-Private Partnerships, Office of Innovative Program Delivery, FHWA Washington, D.C., undated website. http://www.fhwa.dot.gov/ipd/p3/index.htm (As of December 20, 2010).

Federal Transit Administration (FTA), Construction Project Management Handbook, FTA, Washington, D.C., 2006. http://www.fta.dot.gov/documents/Construct_Proj_Mangmnt_CD.pdf (As of December 20, 2010).

Final Design-Build Rule for SAFETEA-LU Section 1503, Federal Highway Administration, 2007. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2007_register&docid=fr14au07-13. (As of December 2, 2009)

Gisi, A.J., Special experimental project (Sep-14): Alternate Surfacing Bidding, Report No. FHWA-KS-09-1, Kansas Department of transportation, Topeka, Kansas, 2009. http://www.fhwa.dot.gov/programadmin/contracts/sep14ks2009.pdf (As of December 20, 2010).

Maryland State Highway Administration (MDSHA). 2005. “Pavement Type Selection Team Final Report-Revised,” MDSHA, Baltimore, Maryland.

May, R.W., W.A. Palmer and M.E. Valerio, "New Mexico 44:A Case History of Long-Term Warranted Performance," Association of Asphalt Paving Technologists, Lexington, KY, 2003.

Missouri DOT Pavement Design and Type Selection Process, An Independent Peer Review by The Transtec Group, Inc. Missouri Department of Transportation, Jefferson City, 2005. http://www.modot.mo.gov/newsandinfo/documents/Alt_Bid_Peer_Review_Report_Final.pdf. (As of December 20, 2010)

Molenaar, K., Gransberg, D., Scott,S., Downs, D. and Ellis, R. "Recommended AASHTO Design-Build Procurement Guide", Final Report, NCHRP Project No. 20-7/Task 172, National Cooperative Highway Research Project, Transportation Research Board, Washington, D.C., 2005.

Oie, C., Ellis, P., Benefield, J. and Yakowenko, J. “Price/Supply Issues, Alternate Bidding Issues, Practices for Increasing Competition,” Presentation, AASHTO Subcommittee on Construction - Contract Administration Section , January 2009.
http://construction.transportation.org/?siteid=58&pageid=2888
http://construction.transportation.org/Documents/pricesupplyalternatebidissuesjan2009summary.ppt (As of December 20, 2010).

Pennsylvania Department of Transportation (PennDOT), Alternate Bidding Policy, Revision to Section 11.6, Pavement Policy Manual, PennDOT, Harrisburg, dated February 26, 2009. http://www.pa.pavement.com/documents/SOL/090226_SOL%20465-09-03_Alternate%20Bidding%20Policy%20Revised.pdf. (As of December 20, 2010)

Temple, W.H., Zhang, Z., Lambert, J. and Zeringue, K.M. "Agency Process for Alternate Design and Alternate Bid of Pavements," Transportation Research Record No. 1981, Transportation Research Board, Washington, DC, 2004.

Walls III, J. and M.R. Smith, *Life–Cycle Cost Analysis in Pavement Design, Interim Technical Bulletin*, Report No. FHWA-SA-98-079, Federal Highway Administration (FHWA), Washington, D.C., 1998.

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Appendix A – **STATE PAVEMENT-TYPE SELECTION PROCESSES**

1. Alabama Department of Transportation

Alabama's procedure is illustrated in Figure A1.

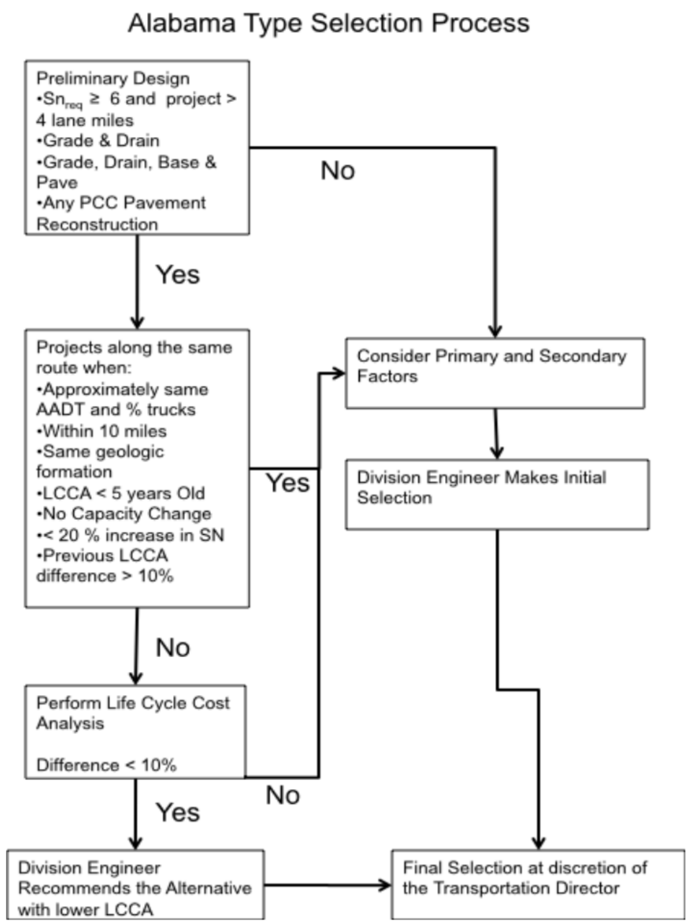

Figure A1. Alabama's pavement-type selection process.

2. Arizona Department of Transportation

Arizona does not have a formal process for pavement-type selection. However, guidelines are provided in their *Preliminary Engineering and Design Manual*. Factors which they consider include:

- Continuity of pavement type.
- Location and local conditions.
- Conservation of natural resources.
- Anticipated construction problems.
- Life cycle cost.

Normally, the pavement design that satisfies the structural requirements and represents the least cost should be selected. In practice, most Arizona pavements, except those on urban freeways, are constructed using HMA. Urban freeways are constructed using PCC overlaid with a rubberized asphalt surface layer for tire pavement noise reduction. A pavement design summary is prepared and reviewed by the district and other appropriate sections. Final approval is given by the Assistant State Engineer for materials.

3. Arkansas State Highway and Transportation Department

Arkansas' procedure is illustrated in Figure A2.

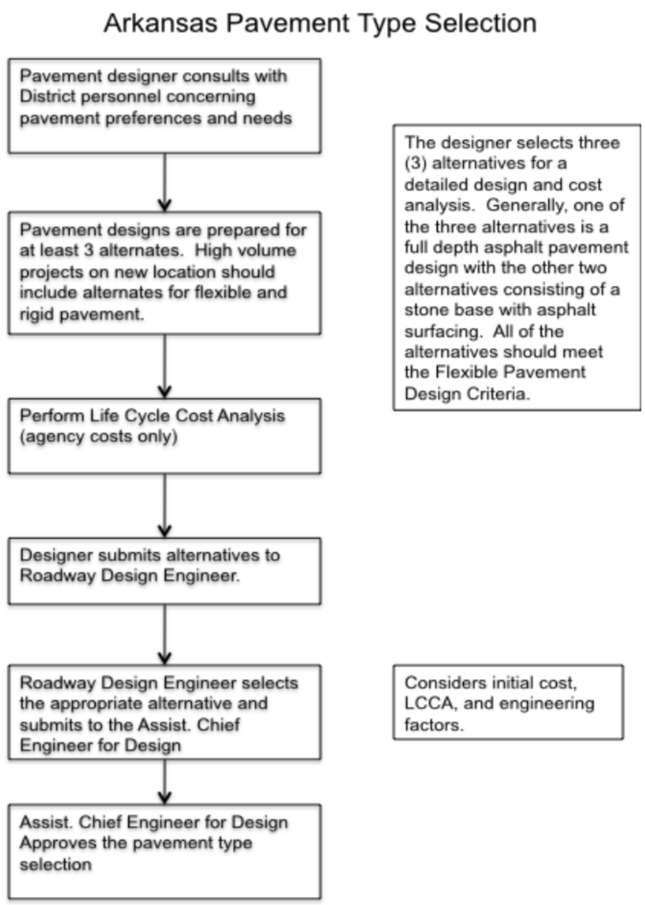

Figure A2. Arkansas' pavement-type selection process.

4. Colorado Department of Transportation

Colorado's procedure is illustrated in Figure A3.

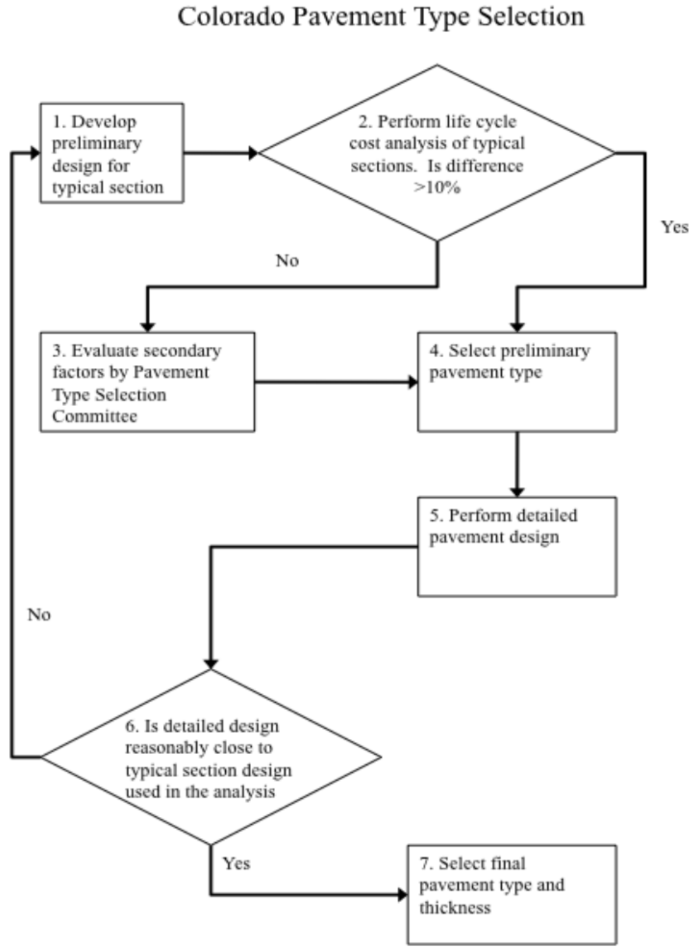

Figure A3. Colorado's pavement-type selection process.

5. Delaware Department of Transportation

Delaware's procedure is illustrated in Figure A4.

6. Idaho Transportation Department

Idaho's procedure is illustrated in Figure A5.

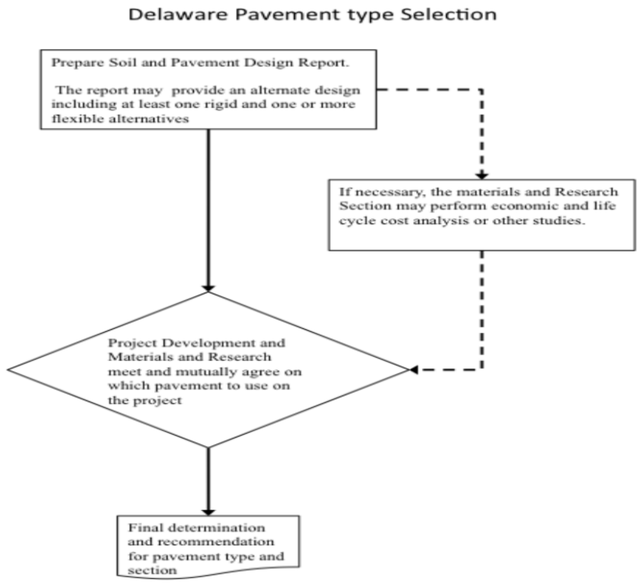

Figure A4. Delaware's pavement-type selection process.

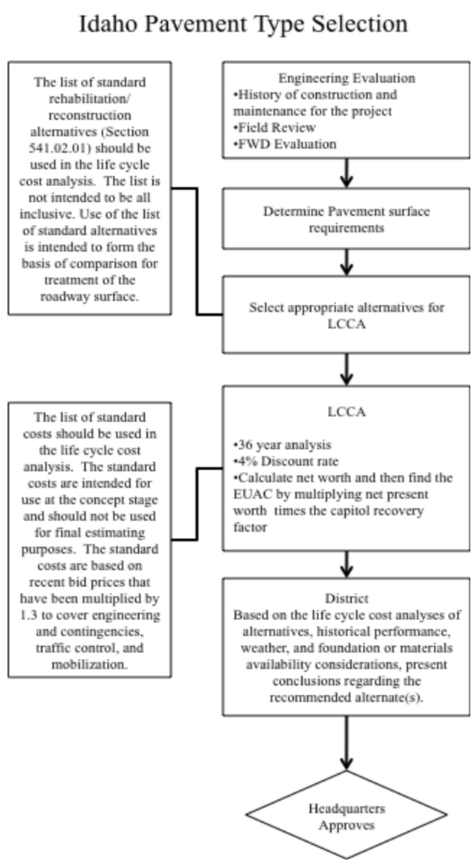

Figure A5. Idaho's pavement-type selection process.

7. Illinois Department of Transportation

Illinois's procedure is illustrated in Figure A6.

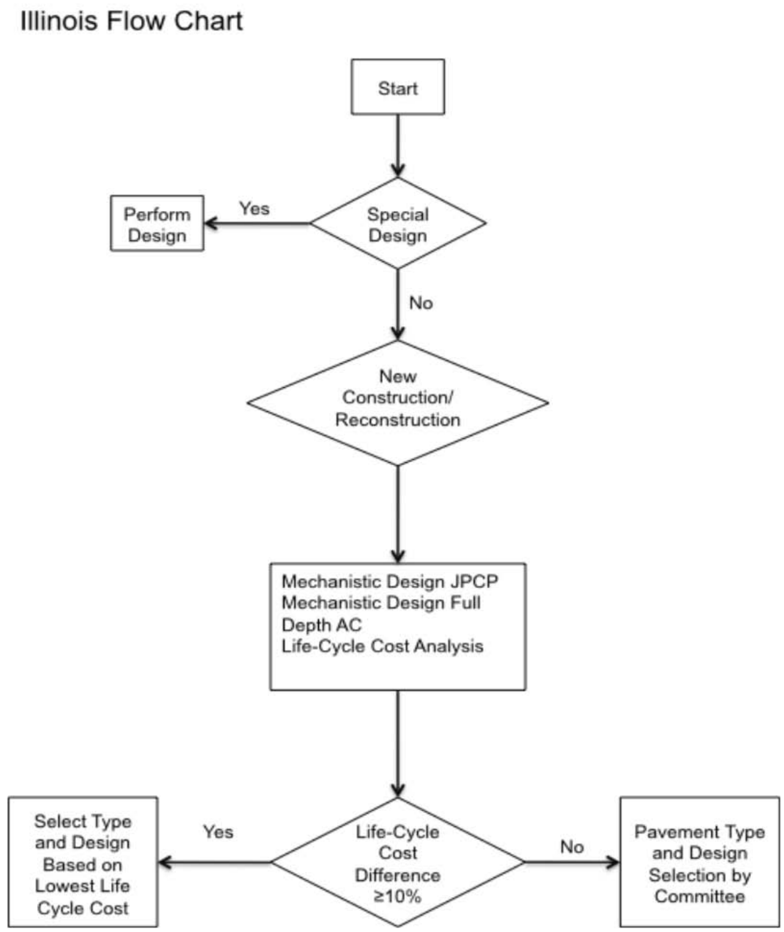

Figure A6. Illinois' pavement-type selection process.

8. Indiana Department of Transportation

In Indiana, pavement-type selection is performed 1 to 2 years before construction, at the time the final geotechnical engineering report is prepared. Pavement-type selection is based on specific project considerations that include project budget, the geotechnical engineering report, the project design traffic, and square yards of pavement and shoulders that will be constructed. The pavement type is selected by a panel composed of:

- Planning and Operations Deputy Commissioner.
- Business and Asset Deputy Commissioner.
- Production Management Director.
- Pavement Engineering Manager.
- The Pavement Design Engineer and the Directors of the ACPA-Indiana Chapter and The Asphalt Pavement Association of Indiana are non-voting members of the panel.

The selection panel meets quarterly. The Pavement Design Engineer prepares a listing of all projects for the previous 2 years and the planned projects for the next 3 years.

Indiana’s procedure is illustrated in Figure A7.

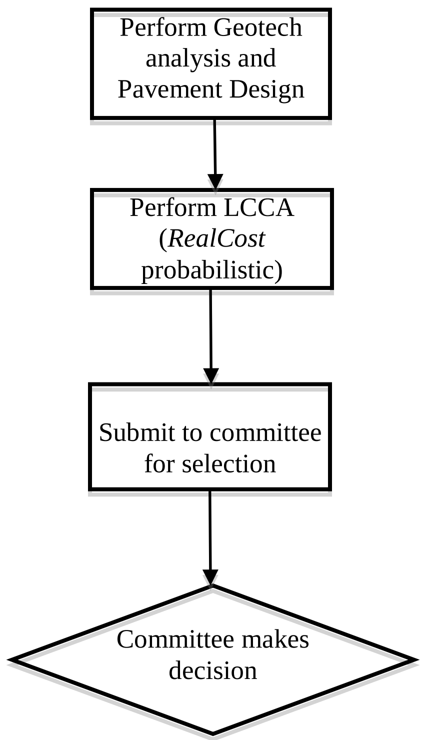

Figure A7. Indiana’s pavement-type selection process.

9. Kansas Department of Transportation

Kansas’ pavement-type selection process involves the following steps:

1. Develop a report that defines the scope of the project and discusses the history of the pavement for rehabilitation projects. Perform structural and functional investigation. Develop alternate strategies.
2. Perform structural design. The design life is 10 years for HMA and 20 years for PCC.
3. Develop a cost estimate for each alternative using actual bid tabs from prior projects which are adjusted for size and location. Use these cost data to perform an LCCA with a 40-year analysis period.
4. Submit the data developed to the surface selection committee composed of the Bureau Chiefs of Design, Construction, Materials, District Engineer, and Operations Director.
5. Submit final selection to the Deputy Secretary for Engineering and State Transportation Engineer for approval.

Louisiana Department of Transportation and Development

The pavement-type selection process is initiated within the Road Design Section by requesting that the District Administrator complete a project information checklist. The completed checklist, traffic data, and a request for the subgrade soil survey are sent to the Pavement and Geotechnical Design Administrator, who is responsible for the preparation of the pavement structural design. When AC is specified for the pavement structure, the Pavement and Geotechnical Section typically will furnish the asphalt types.

The process for pavement-type selection will produce information needed to accomplish this task based on input from the following: Road Design, District Administrators, Planning, Materials and Testing, Pavement Design, Pavement Management, Headquarters Construction, Headquarters Maintenance, and the Louisiana Transportation Research Center (LTRC).

The following is a description of activities:

1. Projects will be forwarded to the Road Design Engineer for design upon programming.
2. Road Design will transmit a request for information to the appropriate District Administrator
3. The District Administrator will complete the project information checklist and transmit back to Road Design with a copy to the Chair of the Pavement Structure Review Committee.
4. Road Design will request section thickness designs from the Pavement Design Engineer. Alternate designs will be provided where practical and feasible.
5. The Project Manager will request traffic data from the Office of Planning and Programming and notify the Pavement and Geotechnical Design Group to initiate soils classification testing.
6. The Pavement and Geotechnical Design Group will request soil data, roadway borings, subgrade soil survey, pH, and resistivity information and muck limits and depths from the District Lab.
7. The Pavement Engineer will make the appropriate comparative designs and recommend typical sections to the Chief Engineer.
8. The Pavement Design Engineer will then conduct an LCCA, prepare a project information packet, and transmit the information packet to the Pavement Structure Review Committee Chairman.
9. The Pavement Structure Review Committee will then evaluate the information included in the packet and make a recommendation to the Chief Engineer.

10. Maine Department of Transportation

Maine has no type selection process, since they build only HMA pavements.

11. Maryland State highway Administration

Maryland’s procedure is illustrated in Figure A8.

Under the Maryland LCCA process, it is the total life cycle cost values (80th percentile) that are used to determine if further steps are necessary in the pavement-type selection process. After calculating these total life cycle costs, the percentage difference between two costs is computed. The specific decision criteria for continuing with a pavement-type selection process are the following:

- If the total life cycle costs of different pavement-type alternatives are within 10 percent at the 80 percent probability level, the pavement-type selection process will continue.
- If the total life cycle costs are more than 10 percent different at the 80 percent probability level, the pavement type with the lowest life cycle cost will be selected.

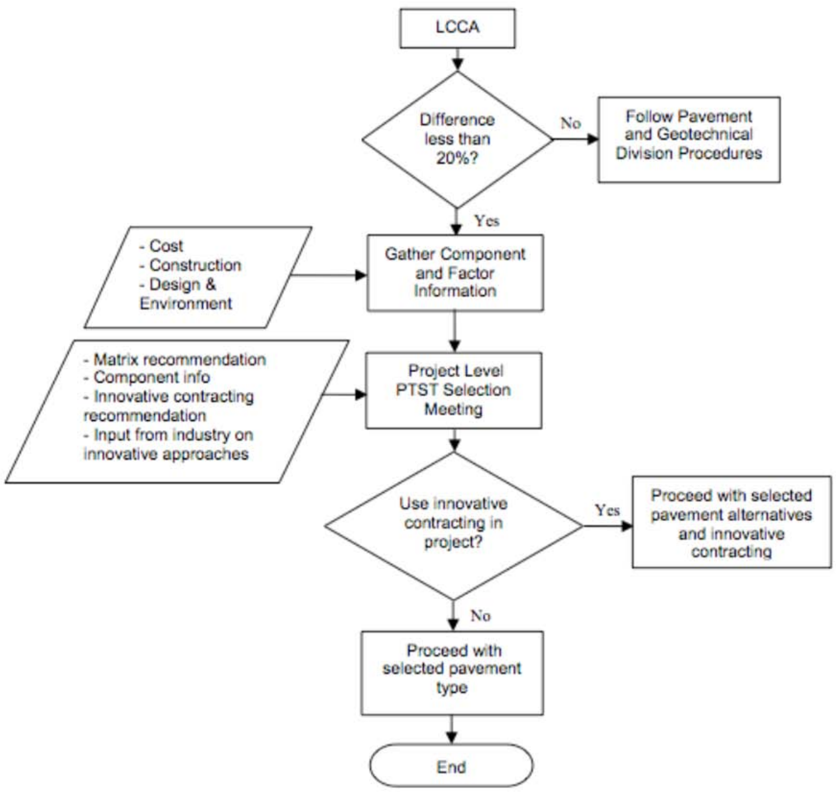

Figure A8. Maryland's pavement-type selection process.

12. Michigan Department of Transportation

Michigan's procedure is illustrated in Figure A9.

By statute, Michigan must develop and implement an LCCA for each project for which total pavement costs exceed $1,000,000 funded in whole, or in part, with State funds. The DOT must design and award paving projects utilizing material having the lowest life cycle cost. All pavement designs must ensure that State funds are utilized as efficiently as possible.

"Life cycle cost" is defined as the total of the cost of the initial project plus all anticipated costs

for subsequent maintenance, repair, or resurfacing over the life of the pavement. LCCA must compare equivalent designs and must be based on Michigan's actual historic project maintenance, repair, and resurfacing schedules and costs, as recorded by the pavement management system, and must include estimates of user costs throughout the entire pavement life.

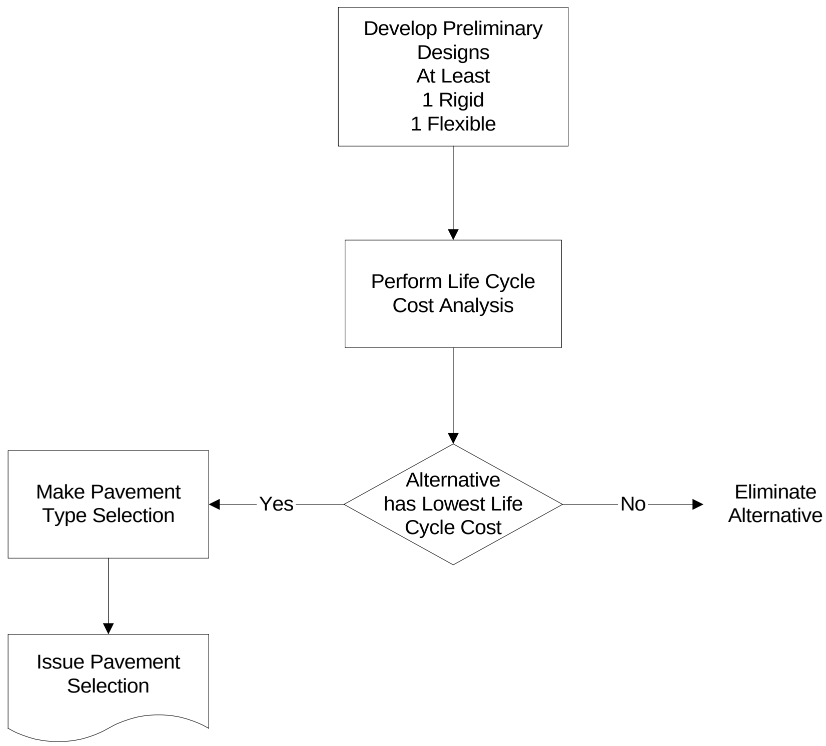

Figure A9. Michigan's pavement-type selection process.

13. Minnesota Department of Transportation

Minnesota's procedure is illustrated in Figure A10.

14. Missouri Department of Transportation

Missouri's procedure is illustrated in Figure A11.

15. Montana Department of Transportation

Montana does not have a formal policy for pavement-type selection since they historically have built only flexible pavements. However, due to recent asphalt price escalation, they are performing informal pavement-type selection. Typically, pavement-type selection is initiated by the pavement design engineer or design project manager at the preliminary field review. The projects considered are those where rigid pavement appears to be cost competitive or there is heavy and/or stop-and-go traffic. LCCA using agency costs only are computed when a type selection is initiated. Final approval is given by the District Administrator.

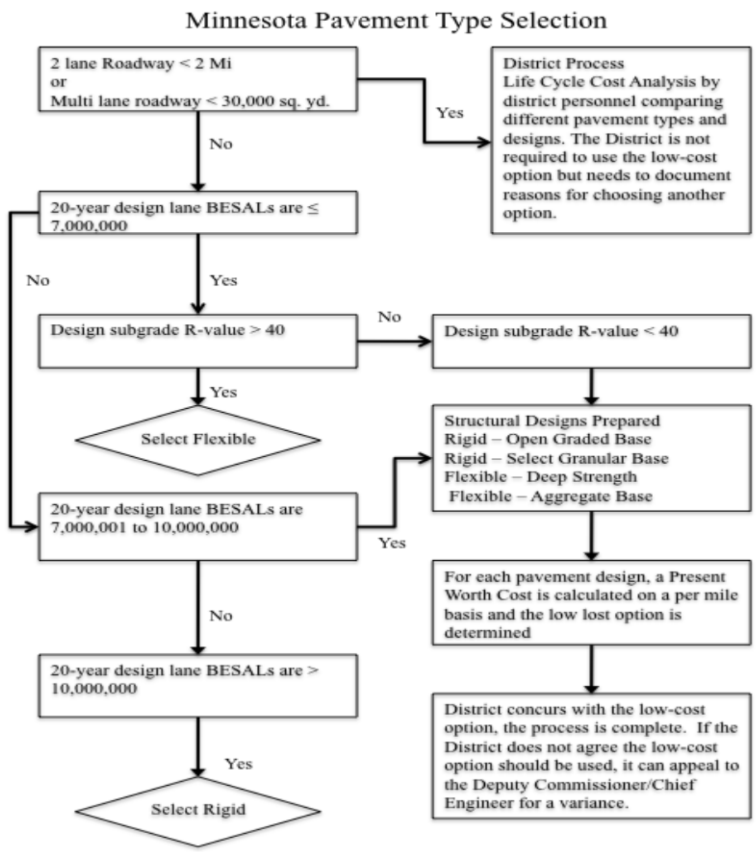

Figure A10. Minnesota's pavement-type selection process.

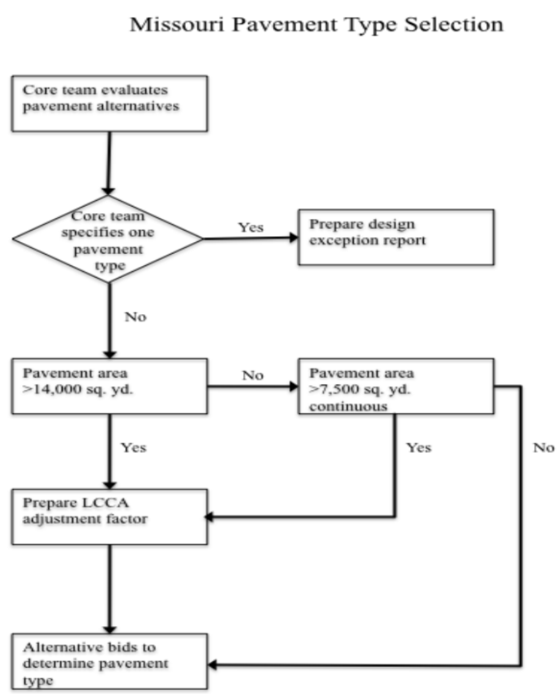

Figure A11. Missouri's pavement-type selection process.

16. Nebraska Department of Roads

Nebraska does not have a formal procedure. The decision is still based on funding, constructability, traffic, and life cycles. If there are no overriding factors and the alternatives are within 15 percent of each other, then they are considered equal. The pavement design engineer makes the pavement determination, working with the District Engineers who manage funding and work forces for their regions of the state.

17. Nevada Department of Transportation

On the interstate in Las Vegas, PCC is used for new construction. For rural Las Vegas, HMA is used. For Northern Nevada, HMA generally is used. The Nevada DOT Director and the Principal Materials Engineer are responsible for type selection. While an LCCA may be made, it is not always considered in the final selection, which "is mostly a political decision."

18. New Hampshire Department of Transportation

New Hampshire has no pavement-type selection process, as they build only flexible pavements.

19. New Mexico Department of Transportation

New Mexico's pavement-type selection procedure is fairly informal. Selection is made by a team from the district and pavement design. The DOT indicates use of LCCA with user delay costs. PCC is used primarily in the Albuquerque area and only recently has been considered outside of the Albuquerque area.

20. North Carolina Department of Transportation

Pavement-type selection procedures have not been received.

21. North Dakota Department of Transportation

North Dakota's pavement-type selection is based on initial cost, roadway/lane geometrics, functional class, and traffic level and composition. LCCA is not used. The Chief Engineer makes final approval. No documentation of the procedure was provided, and none was available on the web. The DOT indicated that the same procedure has been followed for 30 years.

22. Ohio Department of Transportation

Ohio's type selection procedure is illustrated in Figure A12.

23. Pennsylvania Department of Transportation

Pennsylvania's procedure is illustrated in Figure A13.

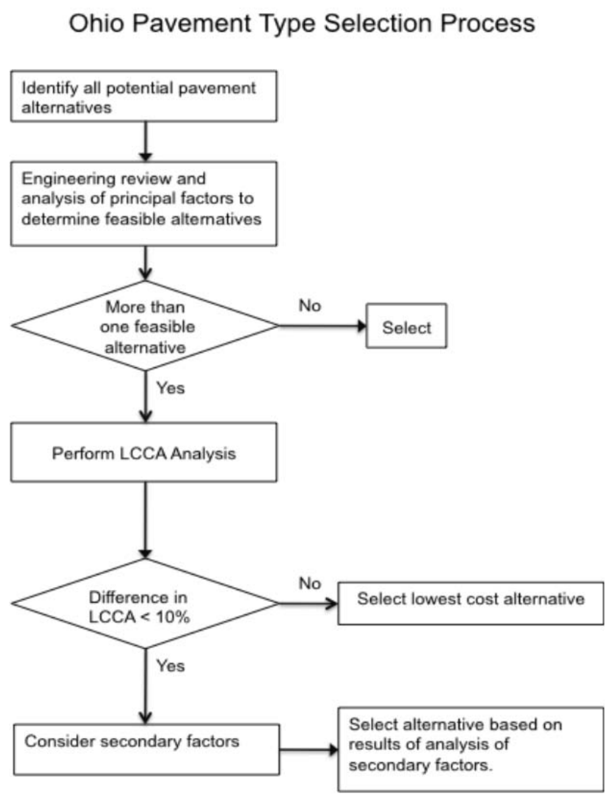

Figure A12. Ohio's pavement-type selection process.

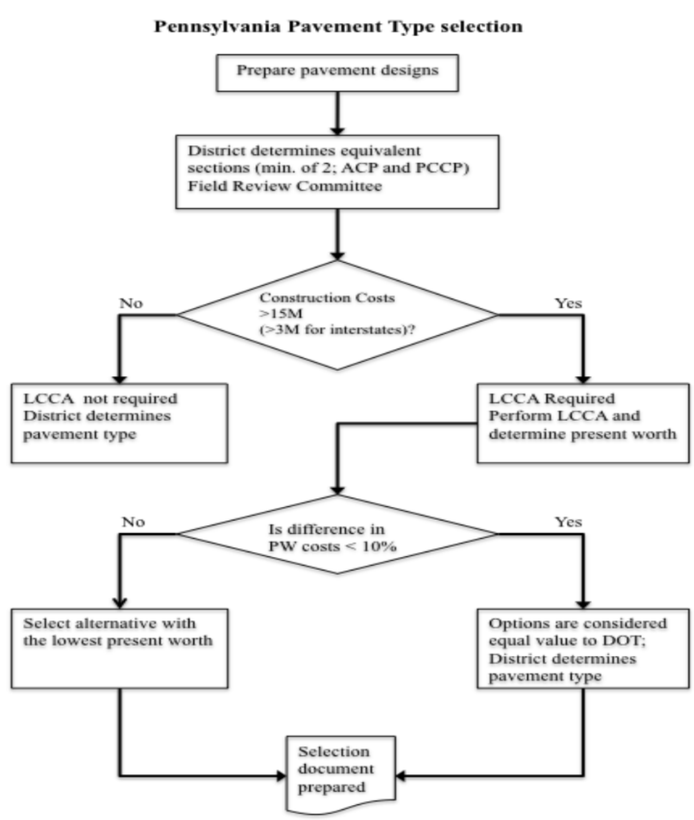

Figure A13. Pennsylvania's pavement-type selection process.

24. South Carolina Department of Transportation

South Carolina's procedure is illustrated in Figure A14.

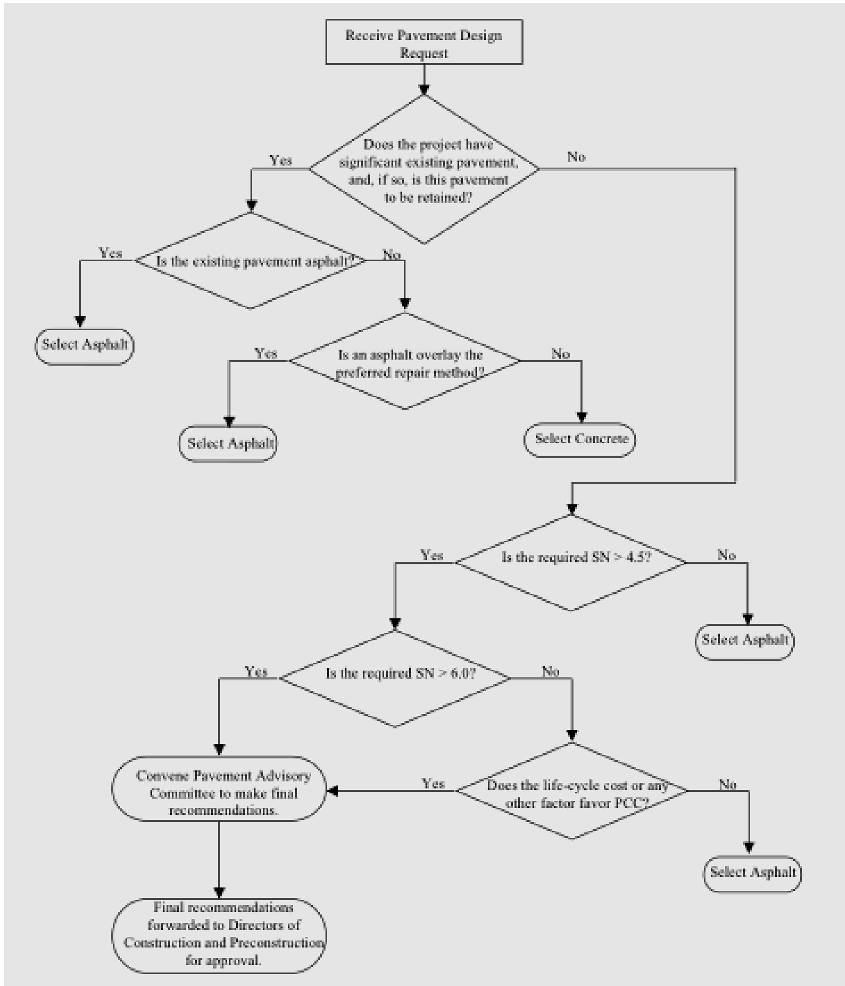

Figure A14. South Carolina's pavement-type selection process.

25. South Dakota Department of Transportation

South Dakota's procedure is illustrated in Figure A15.

26. Tennessee Department of Transportation

Tennessee provided the following response:

> Pavement-type selection is not used on "all" new construction, reconstruction, or rehabilitation. Generally, it is conducted on high type facilities (i.e., interstates, freeways, 4 lane highways). The Department is currently working to solidify new policies concerning pavement-type selection.

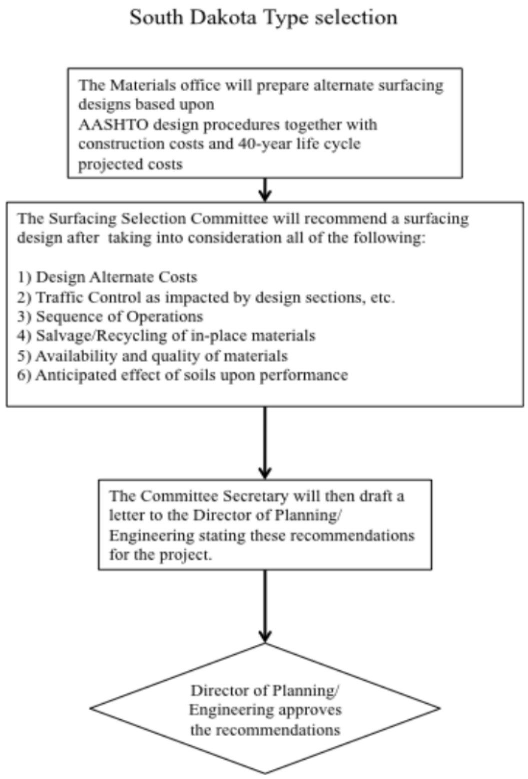

Figure A15. South Dakota's pavement-type selection process.

The response would indicate that the Chief Engineer is involved in the approval of the final selection. When a type selection is to be made, an LCCA is performed. Documentation was not provided, and none was available on the web. The response form indicated none was available.

27. Texas Department of Transportation

The following excerpt from Section 4 of Texas DOT's *Pavement Design Guide* summarizes the principal factors used in pavement-type selection in Texas:

> Selecting a pavement type is an important decision. Like other aspects of pavement design, the 1993 American Association of State Highway and Transportation Officials (AASHTO) Guide states, "The selection of pavement type is not an exact science but one in which the highway engineer must make a judgment on many varying factors.…" Appendix B of the AASHTO Guide provides a list of principal and secondary factors to consider in the selection process.
>
> **Ultimately, the decision is at the District's discretion**. Some principal factors for consideration may include:
>
> - Traffic (volume, percent heavy trucks, degree of congestion resulting from subsequent rehabilitation efforts).
> - Soils characteristics (shrink-swell potential, bearing capacity).
> - Climate/weather (amount of rainfall, icing potential).

- Construction considerations (staged, urgency of quick completion, detour requirements, anticipated future widening).
- Recycling (using material from existing structure or other sources).
- Cost comparison (life cycle cost analysis [LCCA] is preferred, but initial costs may dictate).

Secondary factors may include:

- Performance of similar pavements in the area (similar structures with similar traffic history).
- Adjacent existing pavement sections (continuity of cross section).
- Conservation of materials and energy.
- Availability of local materials or contractor capabilities.
- Traffic safety (reflectivity properties under highway lighting, surface drainage, maintenance of skid properties).
- Traffic noise mitigation (added).
- Incorporation of experimental features (unique to one pavement type).
- Stimulation of competition between major paving industries.
- Local preference.

28. Utah Department of Transportation

The Region Pavement Management Engineer will determine the pavement type at the project level, with assistance from the Asset/Pavement Management Group and the Region Project Managers. Pavement-type determination consists of three steps.

The first step is to determine if specific corridors will be rigid or flexible pavement and conform to the corridor designations. The Asset Management group champions this process by working closely with region pavement managers and central materials to select pavement types for Utah. Pavement-type selection is based on an overall corridor analysis including LCCA, maintenance consistency, and geographic constraints. A general LCCA is applied that includes initial construction, rehabilitation, user costs, and maintenance. Maps and documents are then published for use in pavement design. Pavement type will remain unchanged once determined by corridor unless a safety issue or minimal (temporary) performance period requirement (preservation-type) is presented. Not all pavements and corridors will be identified as one or the other. These will continue on in the process.

1. Corridor criteria for concrete roads – high truck traffic.
   a. Truck volumes ≥ 3,000 AADTT.
   b. Traffic counts – High ADT.
   c. Truck speeds – Slow moving trucks industrial area.
   d. Consistency – Maintenance and pavement.
   e. Life cycle costs – User impacts costs and maintenance impacts in areas where it is most critical to get in, get out, and stay out.
   f. Subgrade conditions.

g. Construction materials.
h. Context-sensitive solution – Areas where colored concrete and heat effects can be beneficial such as urban areas.
i. Most interstates through the Wasatch Front.
j. Most major collectors.

2. Asphalt Roads, bad subgrade and low truck traffic – For individual Roads.
   k. Local roads – Mainly cars.
   l. Rural roads.
   m. Rural Interstate with unstable sub grade, lack of suitable PCC aggregates, canyons, steep grades, high elevations for snow removal issues.
   n. Remote locations.
   o. Climate data – Canyon areas where concrete will not be used (safety).

29. Vermont Agency of Transportation

While Vermont indicated that a type selection is performed, the process is biased to HMA and, as a result, no PCC pavements are constructed. Documentation was not provided and is not available on the web.

30. Washington State Department of Transportation

Washington's procedure is outlined in Section 4 of the *WSDOT Pavement Guide* (WSDOT, 2005). Key excerpts are presented below, and the process is illustrated in Figure A16. Figure A17 shows an example of the formal type selection memorandum used.

> 4.4 ENGINEERING ANALYSIS
>
> After completing the pavement design analysis and the life cycle cost analysis, the engineering analysis is conducted when there are two viable alternatives. Finding the HMA and PCC alternatives to be approximately equivalent, the Region must provide their engineering analysis supporting the pavement-type selection. The fact that these are not easily quantified does not lesson their importance; in fact these factors may be the overriding reason for making the final pavement-type selection. These decision factors should be carefully reviewed and considered, by WSDOT engineers most knowledgeable of the corridor and the surrounding environment.
>
> When offering the engineering analysis for pavement-type selection, the Region must not use reasoning or examples that have already been taken into account within the pavement design analysis or the life cycle cost analysis. Examples of reasoning that should not be presented in the engineering analysis include:
>
> 1. Availability of funds for the more expensive pavement type.
> 2. Supporting the choice for pavement type based on ESALs or ADT (already accounted for in the life cycle cost analysis).

3. Supporting the choice for pavement type based on user delay (already accounted for in the life cycle cost analysis).

The Region should include the engineering reasons that drive the selection of one pavement type over another, given that their life cycle costs are approximately equivalent. Additional considerations, though not inclusive or exclusive, are found in APPENDIX 4. Not all factors will come into play on every project, nor will all factors have equal weight or importance on each project. Many of the factors are synergistic, combining or subtracting, depending on the selection and many of the factors are interrelated. Staff intimately familiar with the design goals of the entire project, or entire corridor, should make the engineering analysis evaluations.

4.5 SUBMITTAL PROCESS

The pavement-type selection, including all applicable subsections (pavement design analysis, cost estimate and life cycle cost analysis, and engineering analysis) shall be submitted electronically to the Pavement Design Engineer at the HQ Materials Laboratory. The pavement-type selection analysis shall be reviewed and distributed to the Pavement-Type Selection Committee (APPENDIX 5) for approval. The report submittal shall include detailed explanation of the various applicable items, as those outlined above, that supports the selection of the recommended pavement type.

WSDOT Pavement Guide - Volume 1

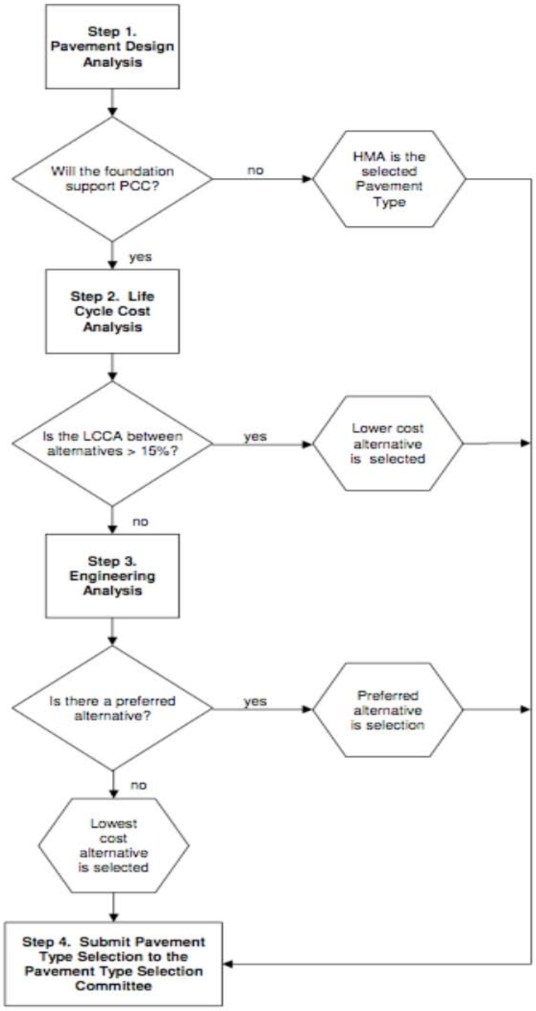

Figure 1. Pavement Type Selection Flow chart

May 2005

Figure A16. Washington's pavement-type selection process.

Washington State
Department of Transportation

Memorandum

PAVEMENT TYPE SELECTION

SR-3
Luoto Road to SR-305
MP 48.90 to MP 53.00

The Pavement Type Selection Committee has completed its review of the pavement type selection for the project SR-3 Luoto Road to SR-305, MP 48.90 to MP 53.00.

The project consists of constructing the final two lanes of the ultimate four-lane facility from Luoto Road to SR-305.

The pavement design analysis resulted in both pavement types (HMA and PCC) being viable. In the life cycle cost analysis, one PCC alternative was compared to one HMA alternative. In the life cycle cost analysis of the two alternatives, there is a cost advantage in the use of HMA over PCC of greater than 15 percent. The Committee approves the use of HMA on this project.

The Pavement Type Selection Committee

Don Nelson ______________________ Director, Environmental and Engineering	Harold Peterfeso ______________________ State Design Engineer
John Conrad ______________________ Assistant Secretary Engineering and Regional Operations	Greg Selstead ______________________ Director of Project Control and Reporting
Tom Baker ______________________ State Materials Engineer	Randy Hain ______________________ Olympic Region Administrator

LMP:bg

Figure A17. Example of Washington's formal pavement-type selection memorandum.

31. West Virginia Department of Transportation

West Virginia's procedure is illustrated in Figure A18.

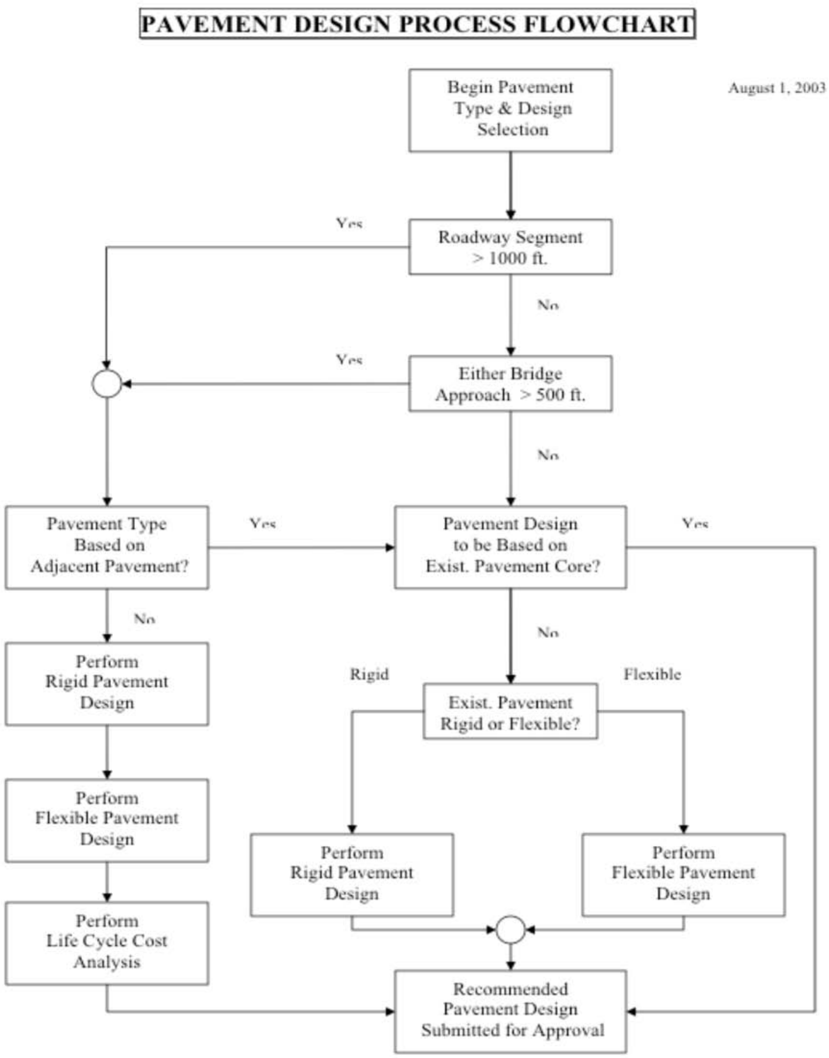

Figure A18. West Virginia's pavement-type selection process.

32. Wisconsin Department of Transportation

Wisconsin's procedure is illustrated in Figure A19.

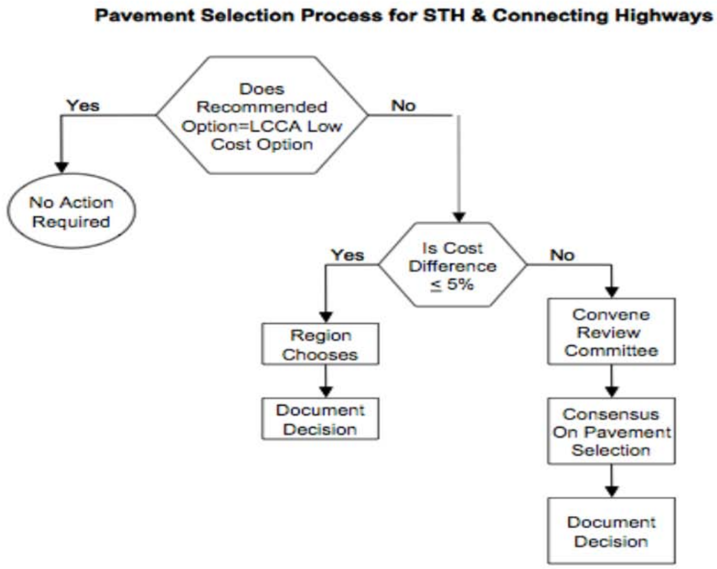

Figure A19. Wisconsin's pavement-type selection process.

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APPENDIX B – CASE STUDIES OF ALTERNATIVE CONTRACTING AND DESIGN-BUILD PROJECTS

Alternative Contracting

Missouri Department of Transportation

Missouri has been a pioneer in implementing alternate bidding in its paving projects. Through July 2009, Missouri has used alternate pavement-type bidding in 124 projects including both full-depth and rehabilitation projects. The agency uses alternate bidding for projects over two lane miles and applies a life cycle cost adjustment factor (C) for bid adjustment. The life cycle cost adjustment factor considers future cold milling and overlay of the surface layer of asphalt at 20- and 33-year intervals and diamond grinding of the concrete surface at 25 years. For projects less than 2 lane miles, the agency lets with pavement options with no LCCA factor. Missouri performs LCCA primarily for determining the C factor, rather than for pavement-type selection. Using LCCA and current market unit prices, Missouri determines the life cycle cost adjustment factor as follows:

Adjustment factor (C) = PV (future HMA rehab) – PV (future PCC rehab)

Missouri has reported significant savings in paving costs through alternate bidding over the past few years. Their price summaries indicate that the 3-year average asphalt price (per ton) and concrete price (per CY) for alternate paving projects are 5.1 and 8.6 percent, respectively, lower than those for non-alternate bidding projects (Ahlvers, 2005). An independent peer review on Missouri's pavement design and type selection process indicated that the agency has developed a balanced, innovative program that could serve as a national model for other highway agencies throughout the nation and beyond (MoDOT, 2005).

Louisiana Department of Transportation and Development

Louisiana uses (A+B+C) model for evaluating alternate bidding projects. In addition to the contract price (A), the agency uses adjustment factors for future M& R costs (C) and project completion time (B). It uses a predetermined value ($ per day), adjusted for traffic volume, as incentives/disincentives, to account for user delay costs associated with difference in project completion time between two alternatives. The agency follows the LCCA methodology recommended in the FHWA's interim technical bulletin. The sequence of future M&R activities is based on the agency's pavement performance history. Based on the LCCA results, the pavement types are considered reasonable and compete as alternatives, when their life cycle cost difference is less than a 20 percent threshold.

Pennsylvania Department of Transportation

Pennsylvania applies alternate bidding for the following projects:

- Projects that require an LCCA (all projects with an estimated cost over 15 million and all Interstate projects over 3 million).
- New construction, reconstruction projects, and major rehabilitation projects that do not require an LCCA.

Using LCCA, Pennsylvania determines the life cycle adjustment factor (C) based on the present value of the future maintenance (PV_{maint}) and user delay costs (PV_{user}) for both alternatives, as shown below:

$$C = PV_{maint} + PV_{user}$$

The M&R sequences for alternatives are established in accordance with the guidelines provided in Publication 242, *Pavement Policy Manual*. The alternate pavement designs are deemed equivalent when their life cycle cost difference is less than 10 percent threshold, provided the non-economic factors are satisfied.

Kentucky Transportation Cabinet

In bid evaluation, Kentucky uses an adjustment value (C) determined based on future agency costs using LCCA. The agency uses separate M&R sequences for interstates (including parkways) and all other routes. When alternative pavement designs have life cycle cost difference within 10 percent and there are no overriding engineering factors favoring one alternate, the agency may elect to take alternate bids. The (A+B+C) model is employed in bid evaluation if the calculated user costs during initial construction exceed $2,000,000 for either alternate. The user delay costs for project completion time (B factor) is added with the initial costs and the future M&R costs, and the lowest bid total determines the successful bidder.

Other State Agencies

Other agencies, including Indiana, Idaho, Montana, Kansas, Alabama, Ohio, and Colorado DOTs, have implemented alternate bidding in their paving projects. These agencies generally follow their own pavement-type selection process and thickness design procedures in developing pavement-type alternatives. LCCA is an integral part of their alternative selection process. The results of LCCA are used to establish the equivalency of the pavement-type alternatives and determine the bid adjustment factor (C) to account the difference in future M&R costs between them. Most state DOTs adhere to the 10 percent threshold as recommended by the FHWA for the National Highway System; however, Louisiana and Washington State DOTs use 20 and 15 percent thresholds, respectively, for accommodating pavement types in their alternate bids.

The bid evaluation model appears to change with agency practices. Some States use the (A+B+C) model to factor in the difference in user delay costs (B factor) associated with the project completion time between the alternatives, whereas other States apply an adjustment factor only for future M&R costs to the contract price. Similar, the key LCCA inputs, such as the analysis period and discount rates, differ with state agency practices.

Best-Value Alternative Bidding (A-D)

Iowa Department of Transportation developed projects for letting using the best–value alternative bidding technique. The descriptions of the projects are presented as follows:
Sioux County, May 2008 – The first project for which bids were taken was Sioux County, STP–E–7055(617)—8V–84, a trail project. Because of fluctuating HMA binder prices, the agency wanted to include both PCC and HMA alternatives in the bid. The PCC alternative appeared to have a longer life than the HMA, so the best-value alternative bidding was an ideal solution to allow contractors to bid either option and expand the number of bidders on the project. Bids for this project were received on May 20. A predetermined alternative differential of $75,000 was included in the proposal for the PCC alternative. Six bids, two HMA and four PCC, were received. A PCC contractor submitted the lowest overall bid, so the alternative differential did not affect which contractor was recommended for award.

Audubon County, June 2008 – The second best-value alternative bidding project was in the June 17, 2008, letting. This project was a trail in Audubon County where the contractor was given an option to bid either a PCC trail or a HMA trail. Like the Sioux County trail, the designer felt that a PCC trail would have a longer life than the HMA. Five contractors bid the project. Four bid the PCC alternate, and one bid the HMA alternate. The HMA contractor submitted the lowest dollar bid ($357,386), but the contract was awarded to a PCC contractor who submitted the best bid considered, based on longer pavement life ($348,599).

Warren County, August 2008 – The third best-value alternative bidding projects was in the August 19, 2008, letting. This project was a resurfacing of a Warren County Road. One contractor bid the PCC alternate, and two contractors bid the HMA alternate. One of the HMA contractors submitted the lowest dollar bid ($1,081,454) and was awarded because their bid was lower than the PCC contractor bid considering the alternative differential ($1,098,641).

Example
In the following example, the contracting agency is willing to pay $200,000 additional to have a better value alternative section X2 built over the baseline configuration X1 (see Table B1). In addition, the contracting authority is willing to pay an additional $400,000 to have a better value alternative section alternative Y2 built over another baseline section Y1.Although bidder AAAA submitted the lowest bid total (A), bidder BBBB will be selected as the low bidder considering the lowest overall (A-D) total.

Table B1. Illustration of best-value alternative bidding.

Bidder	$ bid on non-alternative Sections Items	Alt Bid	X Bid	Alt Bid	Y Bid	Bid Total for Proposal (A)	Sum of Alternative Differentials (D)	Basis for Award (A-D)
AAAA	$1,000,000	X1*	$200,000	Y1*	$200,000	$1,400,000	$ 0	$1,400,000
BBBB	$1,050,000	X2	$250,000	Y1*	$250,000	$1,550,000	$200,000 (for X2)	$1,350,000
CCCC	$1,300,000	X2	$300,000	Y2	$400,000	$2,000,000	$600,000 (for X2 & Y2)	$1,400,000
DDDD	$1,250,000	X1*	$300,000	Y2	$300,000	$1,850,000	$400,000 (for Y2)	$1,450,000

(*) baseline configuration.

Design-Build Projects

<u>120th Avenue Connection , Colorado Department of Transportation</u>

Evaluation Method: Best Value- Adjusted Score (Numerical Score)

Background: The Colorado DOT, in partnership with the City and County of Broomfield, proposed to extend 120th Avenue from Wadsworth Parkway, across US 36 to approximately 120th Avenue and Teller Street, including an intersection with US 287. The portions of the proposed roadway are owned separately by the DOT and the City and County of Broomfield, and are mentioned herein as DOT and non-DOT sections, respectively.

Excerpts from the Proposal

- Colorado DOT specifies the pavement type for various roadway sections in the RFP. The agency specifies PCC for mainlines and intersections, HMA on ABC for the non-DOT sections, and SMA on the bridge decks.
- In addition to pavement type, the DOT also specifies minimum pavement thickness requirements for various roadway sections. Available in the RFP package, the DOT issued a pavement design report that provides initial recommendations for PCC mainlines, PCC intersections, and SMA on bridge decks. The pavement design procedure includes both deterministic and probabilistic LCCA of pavement alternates over a 40-year analysis period.
- The contractor is responsible for joint design for PCC and thickness design for HMA with ABC for non-DOT sections. The contractor also is responsible for designing detour/temporary pavements.
- Any contractor-based pavement designs should be performed in accordance with the 2009 Colorado DOT Pavement Design Manual, the AASHTOWare DARWin method (for flexible pavements), and the 1998 AASHTO Supplement (for rigid pavements). The contractor submits all pavement designs to DOT for approval and/or acceptance.
- Colorado DOT conducted geotechnical investigations in the project area that includes laboratory testing and borings. The investigation report, included in the RFP package, provides necessary inputs for pavement design such as R-values, California Bearing Ratio (CBR), depth to ground water table and soil classification information. The contractor is responsible for any supplemental subsurface investigations necessary for this project and submits a report to the DOT for approval.
- The RFP included modifications to applicable sections of Colorado's *Standard Specifications for Road and Bridge Construction*. It also included project special provisions that provided guidelines for HMA and SMA mixture designs. The design of pavement materials follows the modified Standard Specifications and any additional guidelines issued in the RFP.
- The regular QA procedures, as set forth in modified Standard Specifications, are used for quality compliance of materials and workmanship.
- There is a 1-year warranty on all elements of the project. The warranty type basically covers materials and workmanship.

Excerpts from Design-Build Manual

Pavement Design

Pavement design data should consist of condition reports, existing sub-grade information, or supplemental as-built plans. End result designs, or performance provisions, should be developed based on “life cycle-cost” and future traffic forecasts. Temporary or detour pavements should be based on existing traffic data and existing or proposed sub-grade conditions. The risks of maintenance of temporary and detour pavements should be placed completely on the Design-Build Contractor. All shoulders for final configuration alignments should be designed with the same criteria as the final end-result condition to provide safety and maximum potential for future use. When desired the use of flexible or rigid pavements should be specified.

Alternative Configuration Concepts, or ACCs

Proposers are encouraged to recommend alternatives to the Basic Configuration, Temporary Configuration, Additional Requested Elements (AREs), and changes to the Quality Management, Geotechnical and Pavement (excluding pavement types), Earthwork, Drainage, Roadways, Structures, Maintenance of Traffic, Public Information, Modifications to the Standard Specifications Category B requirements, and Architectural Requirements (Book 4) that are equal or better in quality or effect (as determined by CDOT in its sole discretion). These recommendations are categorized as "Alternative Configuration Concepts" or "ACCs." Other RFP sections are not subject to the ACC process.

Evaluation of Proposals

There are two established standard methods for evaluating proposals. The Numeric Proposal Evaluation process where proposals are given a numeric score used for ranking. And, the Adjectival Proposal Evaluation process where categorizes of acceptance are described and used for rank. Both of these approaches are presented in the Resource Section of this Manual. Regardless of the approach used the entire Evaluation Board must be brought together for training in the evaluation process.

The New I-64 Project, Missouri Department of Transportation

Evaluation Method: Fixed Price-Best Value (Numerical Score & Pass/Fail)

Background: This project is the reconstruction of I-64 roadway section from west of Spoede Road in St. Louis County to east of Kings Highway Boulevard in the City of St. Louis. This project involves reconstruction of bridges and pavements.

Excerpts from the Proposal

- The contractor provides the pavement design for mainlines including auxiliary lanes, shoulders and ramps for both reconstructed areas and rehabilitated areas, and their

locations. Any pavement reconstruction on arterials or local streets should match the existing pavement type.

- The contractor provides the documentation of the pavement design method that includes all design inputs that were used to arrive at the pavement selections, including a narrative on how the inputs were determined. The documentation also includes the following pavement design outputs:
    - Design life.
    - Rehabilitation cycles for the design life provided.
    - Pavement typical sections.
    - Pavement and base thickness.
    - Distress predictions including rutting and fatigue cracking for asphalt pavements and faulting and slab cracking for concrete pavements.
    - Minimum friction number (FN) and maximum IRI measurement that will be obtained on the final wearing surface.
- The contractor provides the documentation for each proposed pavement type for reconstructed and rehabilitated areas on mainline lanes, including auxiliary lanes, shoulders, and ramps.
- Missouri DOT evaluates the pavement design proposals using the criteria that provide a long pavement life with minimal rehabilitation cycles, greater skid resistance, greater smoothness, and lower structural distresses.
- The agency provides traffic volume forecasts necessary for pavement design.
- The contractor submits a quality manual that outlines all quality control (QC) and QA undertaken for project execution. The quality manual also includes the standards, methods or procedures, frequencies of product control, QA inspection, sampling, and testing. The DOT conducts quality oversight or audit, which includes checking on a sampling basis.
- The contractor provides a 1-year warranty on pavements.
- Missouri DOT included geotechnical data and reports in the RFP package. However, the contractor is responsible for collection of any supplemental investigations deemed necessary to complete the analyses, design, and construction. The contractor submits the geotechnical report to the DOT before the beginning of construction.

I-15 CORE Corridor Expansion, Utah Department of Transportation

Evaluation Method: Fixed-Price Best-Value (Numerical Score & Pass/Fail)

Background: This project is the reconstruction of I-15 from American Fork Main Street interchange to the Provo Center Street interchange for a length of approximately 14 miles.

Excerpts from the Proposal

- Utah has selected to use a fixed-price, best-design procurement and selection process.
- Utah prefers concrete pavement in high traffic-volume areas and all areas of mainline freeway reconstruction. However, it allows contractors to select PCC, whitetopping, or HMA overlay pavement types. Utah specifies the use of an SMA wearing course on HMA overlays.

- If whitetopping is used, Utah requires mainline sections to be designed as conventional unbonded PCC pavement incorporating the existing pavement as a stabilized base; if the existing pavement is profile milled, Utah specifies that the minimum thickness of the remaining HMA layer shall be 5 inches.
- Rigid pavements should be designed for a minimum service life of 30 years. Flexible pavements should be designed for a minimum service life of 20 years. The pavement design should consider climatic conditions, drainage, and performance concerns at intersections and ramp ends.
- Utah provides the minimum pavement thickness requirements for both PCC and HMA pavements in mainline sections, ramps, and cross-streets.
- The contractor performs the pavement design in accordance with a list of standards provided in the RFP that includes the 1993 AASHTO *Guide for Design of Pavement Structures* and the Utah *Pavement Management and Pavement Design Manual*.
- The LCCA should be performed for both flexible and rigid pavements by incorporating M&R cycles with new pavement design. Utah requires the use of Utah *Pavement Management and Pavement Design Manual* for user costs, as well as specifies the discount rate and M&R schedule (for both PCC and HMA) for use in deterministic LCCA.
- The contractor provides a pavement design report to Utah. The report should address design details, inputs for all pavement sections, site-specific conditions, proposed treatments for areas such as joints, and distresses on existing pavements. The submittal does not require Utah approval.
- The pavement design should be performed by a Utah-licensed professional engineer who has a minimum of 10 years of experience in pavement design, including experience with interstate highways and projects of similar size and type.
- Utah includes a geotechnical report in the RFP that includes deep boring, photographs of the cores, soil laboratory tests, and the in-place CBR values of the existing base and subgrade soils. It also includes a boring summary in the RFP with the location, thickness of asphalt, base, and subgrade layers, and depth to ground water table.
- Utah values pavements that meet high quality and durability standards that will minimize maintenance needs throughout their respective design lives. They encourage the use of existing pavement and fill materials within the corridor by incorporating those materials into the newly reconstructed roadway.
- Utah encourages the contractor to recommend alternatives that are equal or better in quality.
- The contractor provides warranty on material and workmanship for a period of 1 year.

T.H. 169 – St. Peter, Minnesota Department of Transportation

Evaluation Method: Best Value- Adjusted Bid (Numerical Score)

Background: This project is located within the city limits of St. Peter in Nicollet County. This project is the reconstruction of 1.5-mile roadway section on T.H.169 from T.H.22 intersection to Union Street intersection. This project involves milling and overlaying of existing pavement.

Excerpts from the Proposal

- The contractor conducts necessary geotechnical investigations necessary of this project, which includes laboratory tests.
- Minnesota specifies the pavement types and minimum thicknesses. This includes both flexible and rigid pavements. Minnesota also specifies the type, size, and spacing of dowel bars and tiebars for PCC pavements, and PG binder grade and aggregate class for HMA pavements.
- Minnesota provides an option to the contractor to decrease the concrete thickness to a minimum of 7 inches and make up with Class 6 material in the parking lanes between the pedestrian bump-outs.
- The contractor designs adjacent local streets and roads to comply with local municipality/road authority requirements.
- Minnesota Specifications are used for the PCC pavement and HMA mill and overlay.
- For PCC mix design, the contractor has an option to design one in accordance with their own modifications to Minnesota DOT Special Provisions or to request concrete mix designs or adjustments for trial from the DOT Concrete Engineering Unit.
- The contractor provides a 3-year warranty on pavements.
- The RFP evaluation is based on the best value or the lowest adjusted bid price. The adjusted score is determined by dividing the bid price by their technical proposal score. Minnesota uses a "two-phase" procedure involving an RFQ followed by a RFP.
- The contractor submits a quality management plan, which includes a quality manual, for meeting design and construction requirements. The QC and QA activities are carried out by the contractor as outlined in the quality manual, which includes materials control, inspection, sampling, and testing. Minnesota DOT performs construction quality verification as well as independent assurance sampling and testing.

Excerpts from the Policy Guide

Project Selection

Mn/DOT's design-build program is currently tailored to large construction projects, but can be modified for smaller projects.
For projects being considered for design-build, contact Mn/DOT's Design-build director as soon as possible. The district and the design-build director will need to coordinate efforts to define the scope of work and begin the design-build team selection process. The selection of the design-build team often requires an extensive Request for Qualifications (RFQ) and Request for Proposal (RFP).

Good Candidates

- Projects that need to be "fast-tracked" for public safety or political reasons
- Projects that allow for innovation in the design and construction efforts
- Projects with funding "sun-set" dates where traditional bid-build delivery may not be able to achieve these dates
- Projects where in-house staffing cannot meet the project demands
- Emergency projects with tight time constraints.

Evaluation

- MnDOT also uses the low bid approach in design-build projects, suchas on I-35 (Contract No. S96264), TH 14 (Contract No. S01185), and TH 100 (Contract No. S02019).

9 Mile Road over I-75 Bridge Replacement, Michigan Department of Transportation

Evaluation: Low Price Bid (Pass/Fail)

Background: Design and construction including the removal of remaining portions of the 9 Mile Bridge over I-75 and reconstruction of a new structure at 9 Mile Road over I-75, concrete pavement reconstruction of approximately 0.50 mi of northbound and southbound I-75, substructure work on the center pier at John R Road, and all other related work to design and construct the project, Oakland County.

Excerpts from the Proposal

- Michigan DOT specified the pavement type and minimum required pavement sections for the project.
- Michigan DOT specified that certain alternatives are unacceptable for pavement design:
    - Change in surface type of the pavement.
    - Alternatives that have the depth of non-frost susceptible material lower than the depth specified in the DOT-provided pavement design.
    - Alternatives that have total pavement thickness lower than the DOT-specified total minimum thickness (or structural requirements)
- Michigan DOT provided HMA/PCC alternatives for temporary pavements (for the purpose of traffic maintenance) but specified the minimum thickness.
- Michigan DOT provided soil and roadway boring logs and pavement cores for the project in the RFP exhibits.

This project includes a 5-year materials and workmanship pavement warranty.

Interstate 405, Washington State Department of Transportation

Evaluation Method: Adjusted Score (Total score = Technical score*10^7/Cost)
*****Has Pavement Evaluation Criteria

Excerpts from the Proposal

- Washington State DOT specifies the pavement type, service life, and the minimum compacted depth to be used for various segments. It has attached a report titled "I-405: I-5 to SR 169 Widening Project Pavement" that includes the results of the Washington State DOT review of the existing roadway section.
- The contractor produces the pavement design in accordance with the criteria provided by Washington State DOT (see Table B2).
- Washington State DOT provided design traffic, in terms of ESALs, for pavement design.

- The contractor should make adjustments to the minimum pavement thickness, specified by Washington State DOT, to accommodate climatic conditions such as frost depth.
- The contractor should perform the pavement design in accordance with Washington State DOT specified standards that includes Washington State DOT Pavement Guide and 1993 AASHTO Guide.
- Washington State DOT also specifies the assumptions for rehabilitation and maintenance treatments (e.g., 15-year interval for the wearing course).
- The contractor should submit a draft pavement design report for review and comments, followed by a final report.
- Washington State DOT performs all acceptance testing for QA.
- Washington State DOT requires a general warranty for a period of 2 years. The contractor provides a warranty bond for 5 years; however, after 3 years, the warranty bond will be reduced for the remainder of the period.
- Washington State DOT also specifies the required actions for correcting defects during the warranty period.

Excerpts from Design Build Guidelines

[WSDOT] Provides a full pavement report to the contractor for all roadways within the project limits, including all shoulders.

If the Department performs preliminary geotechnical engineering evaluations or analyses, reference these as conclusions in the design criteria, not as recommendations to the design builder.

WSDOT should do the time consuming base data collection whenever possible. After the initial project scope, WSDOT should perform a preliminary geotechnical investigation. After the geotechnical investigation is completed, obtain field data in the approximate location of the project's major features. Perform preliminary geotechnical engineering analyses, as necessary, to address feasibility issues and to define project design criteria such as foundation type constraints.

***The Resurfacing Report**, will address the pavement section design. The Resurfacing Report's use should be flexible depending on the project type. On **Improvement** projects, where the pavement section is not dependent on existing subgrade, WSDOT would prefer to use a warranty and the report would provide design criteria, a reference pavement section design for proposal evaluation, and warranty provisions.*

*On **Preservation** projects, the actual design is best determined by WSDOT due to the liability associated with the condition of the existing subgrade. In either case, use the report as an internal backup reference document for WSDOT evaluation of proposals and/or designs. Place information from the report within this section of the Scope of Work or reference it for use by the Proposers in proposal preparation.*

416 Pavement Design
The pavement design and construction for mainline, collectors/distributors, auxiliary lanes shall, at a minimum, provide for a [40] year service life. The Contractor shall design a pavement section that provides for surface and subsurface drainage giving full consideration to frost effect and the elimination of trapped water. Pavement design and construction for

ramps, frontage roads, cross streets, and local streets shall, at a minimum, be designed to provide a [20] year service life. The pavement design shall be in accordance with the AASHTO Guide for the Design of Pavement Structures, [1993] and the WSDOT Pavement Guide– Volume 1, and for the conditions listed below.

The following elements of the proposal will be evaluated to determine the score for the Pavement component of the Technical Solutions major factor:

Table B2. WSDOT evaluation criteria for pavements in I-405 project.

Criteria	**Points Possible**
A. **Site investigation approach** - Appropriate and validated technology for the characterization of subgrade soils and/or the existing pavement structure. For pavement rehabilitation, methodology used to establish existing pavement condition and identification of site location for pavement repair and remedial action.	20
B. **Design/Rehabilitation Approach** - Appropriate use of local and national standards, guides, manuals, and design methodology, coupled with sound pavement engineering and experience.	20
C. **Material Selection** - appropriate use of materials that have locally proven to result in long-term pavement performance.	20
D. **Constructability** - Pavement section and all associated components is designed such that constructability is ensured.	20
E. **Pavement QA/QC Approach** - Methodology used to ensure pavement sections are constructed as designed and minimization of defects that may result during construction such that long-term performance is not jeopardized.	20
Total	100

TIP Project R-2404A (Windsor Bypass), North Carolina Department of Transportation

Evaluation Method: Best Value- Adjusted Bid (Numerical Score)

Background: TIP Project R-2404A (Windsor Bypass) is a 4-lane freeway on new location from US 13-17 to East of SR 1503 (Davis Road), in Bertie County.

Excerpts from the Proposal

- The DOT provides the final pavement designs. A catalog of pavement designs as provided in the RFP is shown in Table B3:

Table B3. NCDOT catalog of pavement designs for Windsor Bypass project.

LINE	**Surface**	**Intermediate**	**Base***	**ABC**
L-line, new construction	3.0” S9.5C	3.0” I19.0C	5.5” B25.0C	-----
L-line, widening of existing road	3.0” S9.5C	3.0” I19.0C	5.5” B25.0C	-----
Y1 (US 17 & NC 308)	3.0” S9.5B	2.5” I19.0B	4.0” B25.0B	-----
Y1A (US 13 Bus.)	3.0” S9.5B	-----	4.0” B25.0B	-----
SR1	3.0” S9.5B	-----	4.0” B25.0B	-----
Y2	3.0” S9.5B	-----	4.0” B25.0B	-----
Y3	3.0” S9.5B	-----	5.5” B25.0B	-----
Y4 (US 13)	3.0” S9.5C	3.0” I19.0C	4.0” B25.0C	-----

Table B3. NCDOT catalog of pavement designs for Windsor Bypass project.

LINE	Surface	Intermediate	Base*	ABC
Ramp A and Ramp D @ Y4	3.0” S9.5C	3.0” I19.0C	4.0” B25.0C	-----
Ramp B @ Y4	3.0” S9.5C	3.0” I19.0C	4.0” B25.0C	-----
Loop D @ Y4	3.0” S9.5C	4.0” I19.0C	4.0” B25.0C	-----
Y5 and Y7	3.0” S9.5B	-----	4.0” B25.0B	-----
Y6	3.0” S9.5B	-----	5.5” B25.0B	-----
Ramp A and Ramp D @ Y6	3.0” S9.5B	-----	4.5” B25.0B	-----
Loop A and Ramp C @ Y6	3.0” S9.5B	-----	4.5” B25.0B	-----

* For L-line, new construction, the Design-Build Team may use an alternate with an aggregate base course (ABC). The ABC Alternate consists of 3.0” S9.5C, 4.0” I19.0C, and 10.0” ABC.

- The contractor is responsible for the design of temporary pavements such as detour pavements. The temporary pavements should be designed in accordance with the North Carolina DOT Pavement Design Procedure. The contractor submits the pavement design report for review.
- The North Carolina DOT Pavement Design Procedure is based on the AASHTO Interim Guide for Design of Pavement Structures, 1972 (Chapter III Revised, 1981) for the design of flexible and rigid pavements. An LCCA is performed for evaluating the pavement alternates over a 30-year analysis period.
- The contractor provides 12-month guarantee for materials and workmanship. There is an extra quality credit for providing warranty extension. The maximum credit assigned for warranty extension varies with projects.
- The RFP specified the use of 2002 Standard Specifications with revised sections for construction requirements, materials design, quality compliance, and acceptance of work.

Excerpts from Design-Build Manual

<u>Applicable Projects</u>

Typically, Design-Build projects may be considered if they fall within in at least one of the following broad categories:

1. Projects where design and construction need to be expedited for the public good.
2. Emergency Projects.
3. Projects with complex constructability or traffic phasing issues.
4. Projects affording opportunities for innovation.
5. Unusual projects that do not lend themselves to normal design-bid-build procedures.

   The type of project may also be an integral factor in its selection as a Design-Build Project. The following types of projects are particularly suitable to the Design-Build process:

1. New location projects
2. Large interstate widening or rehabilitation projects
3. Projects with heavy traffic volume
4. Large or unique bridge projects

   The project must be identified and included in the TIP.

<u>Intercounty Connector Contract A, Maryland State Highway Administration</u>

Evaluation Method: Best Value **–** Low Bid (Pass/Fail & Adjectival Ratings**)**

Background: The Intercounty Connector (ICC) links existing and proposed development areas between the I-270/I-370 and I-95/US 1 corridors within central and eastern Montgomery County and northwestern Prince George's County. ICC Contract A included the design and construction of approximately 7.2 miles of six-lane highway extending from I-270 / I-370 to approximately 600 feet east of MD 97.

Excerpts from the Proposal

- The contractor may elect to use either flexible or rigid pavement sections. However, Maryland restricts the use of CRCP or composite pavements.
- The pavement design should meet the requirements set forth in the Pavement Performance Specification, included in the RFP. The contractor should perform the pavement designs using 1993 AASHTO Guide and Maryland Pavement Design Guide.
- Maryland provides traffic data, criteria for both rigid and flexible pavement design, and criteria for rehabilitation of existing pavements. The criteria are consistent with the input requirements of 1993 AASHTO Guide. The structural layer coefficients for pavement design should be consistent with those specified in the Maryland Pavement Design Guide.
- Maryland specifies the maximum resilient modulus for base materials. They specify minimum thickness for flexible and rigid pavements other than the ICC mainline and shoulders.
- The contractor submits an interim pavement design report for review and comment that includes the testing and review of pavement investigations, pavement analysis and design inputs, cross-sections, rehabilitation techniques, subgrade improvement, Falling Weight Deflectometer (FWD) testing program guidelines, drainage design, material specifications, innovative construction techniques, and so on. The contractor then submits a final pavement design report that includes the as-built plans and details.
- Maryland specifies the performance criteria for acceptance that includes ride quality and skid resistance. Final acceptance will include structural evaluation based on QC testing, verification testing, and the final inspection.
- Procurement includes a two-step process: RFQ and RFP.
- Instructions to the proposer read as follows:

  A8.1.3 Pavement Design

  The Proposer shall prepare and submit the following information in Volume 5 of the Technical Proposal:

  A) Material selection criteria to be used to ensure pavement performance parameters are met with an emphasis on roadway safet ;

  B) Conceptual pavement designs for major roadway elements including any subgrade improvements and pavement drainage being considering; and

  C) The rehabilitation, reconstruction and base-widening strategy for the existing I-370 pavement, including the details for tie in for the ICC mainline.

- The evaluation of proposals will be based on both technical and cost factors. The technical evaluation factors are:
    1. Environmental.
    2. Key personnel, experience, and financial capability.
    3. Management approach.
    4. Technical solutions.
    5. Project support.

The pavement design will be evaluated based on how well the proposer understands and addresses in design solutions the pavement material, subgrade, tie-in, and safety needs of the project.

<u>Interstate 70 –Marion County, Indiana Department of Transportation</u>

Evaluation Method: Best value – Low Bid (Lowest bidder with technical score > 80)
** This bid was cancelled as no bid was below the engineer's estimate.*

Background: This project (Contract # 28690) involves the pavement replacement of I-70 from 0.54 miles east of the Sherman Drive overpass to just east of I-465 for a total project length of 3.61 miles. This project is located in Marion County, east of Indianapolis.

Excerpts from the Proposal

- Indiana DOT specifies the pavement type and thickness in the contract. Samples are provided below:
  This project will reconstruct I-70 from station 742+50 Line "I-70" to 108+00 Line "S-I-70-AA". New 16 inch QC/QA PCCP on 9" Subbase for PCCP on 12" Compacted Aggregate, No. 53, Base on Type I Subgrade Treatment shall be constructed for all of the I-70 lanes and shoulders. All new QC/QA PCCP shall have D-1 Contraction Joints (18'-0"spacing). PCCP coring and profilograph in accordance with 501 shall be required.

  Reconstruction of the Emerson Avenue ramps will extend as necessary to accomplish the required widening and profile grade adjustment of the reconstructed pavement for I-70. New 16 inch QC/QA-HMA pavement on Type I Subgrade Treatment shall be constructed for all ramp lanes and shoulders beyond the gore nose of I-70 to the end of the ramp reconstruction. Full Depth PCCP Patching shall be constructed as directed by the Engineer and Profiling PCCP shall be completed for all ramp lanes at Emerson Avenue beyond the end of the ramp reconstruction to the ramp terminus. HMA profilograph in accordance with 401 shall be required.

  Reconstruction of the Shadeland Avenue collector distributor lanes and ramps will extend as necessary to accomplish the required widening and profile grade adjustment of the reconstructed pavement for I-70. New 17.5 inch QC/QA-HMA pavement on Type I Subgrade Treatment shall be constructed for all CD/ramp lanes and shoulders beyond the gore nose of I-70 to the end of the CD/ramp reconstruction.

3.0 inch HMA milling and new 4.5 inch QC/QA-HMA overlay shall be constructed for all collector distributor lanes and ramp lanes, along with new 1.5” QC/QA-HMA overlay for all shoulders, at Shadeland Avenue and I-465 beyond the end of the CD/ramp reconstruction to the CD/ramp terminus as shown on the plans. HMA profilograph in accordance with 401 shall be required.

- Indiana DOT includes a geotechnical evaluation report in the RFP package. The contractor performs any additional geotechnical investigations for the proposed work.
- The contractor conducts all construction activities in accordance with Indiana DOT’s Standard Specifications, supplemental specifications, special provisions, and scope of services.

M-115, Clare County - Highways for LIFE (HfL) Pilot Program, Michigan Department of Transportation

Evaluation: Best Value Selection / Performance Contracting

Background: The Michigan M115 project includes reconstruction of approximately 5.5 miles of roadway and replacement of two bridges. The project includes 5.56 miles of HMA cold milling and two course overlay with asphalt stabilized crack relief layer, joint repair, drainage, intersection upgrade, and guardrail upgrading.

Excerpts from the Proposal

- Michigan DOT specifies the pavement type as “hot mix asphalt cold milling and two course overlay with asphalt stabilized crack relief layer.” In the event of the contractor opting for reconstruction of this pavement section, Michigan DOT specifies the pavement type as HMA and minimum thicknesses for different pavement layers.
- Michigan DOT issues a special provision tabulating the structural coefficients for pavement layers based on 1993 AASHTO Guide. Although this special provision is for informational purposes only, these coefficients would be used to evaluate the equivalency of alternate pavement designs.
- The contractor performs the pavement design in accordance with Michigan DOT’s recommended design methods.
- This project includes a 5-year pavement performance warranty.
- This project is a pilot performance contracting project. The technical proposal requires the bidders to propose plans in achieving the following six goals:
  Goal #1 - Opening to Traffic before the Baseline date.
  Goal #2 - Construction & Cleanup Completion before a specified date.
  Goal #3 - Pavement Performance that includes:
  Initial Pavement Acceptance,
  Pavement Performance Warranty
  Ride Quality
  Goal #4 – Worker Safety during Construction – injuries no more than 4.
  Goal #5 - Work Zone Crashes- preconstruction crashes no more than 4.
  Goal #6 - Motorist Delay - no more than 10 min. beyond its normal travel time.

- Michigan DOT specifies the allowable threshold values of performance parameters for warranty requirements. Michigan DOT would conduct pavement evaluations by dividing project into segments of 528 feet (See Table B4).
- The contractor is responsible for correcting defects in the pavement during the warranty period. Michigan DOT recommends action strategies for correcting defects (See Table B5).
- Michigan DOT specifies the acceptable range of Ride Quality Index and corrective action limit in the RFP for the contractor to meet ride quality requirements. The contractor is also eligible for incentives for providing better ride quality as specified in the RFP.

Table B4. Warranty requirements.

Condition Parameter	**Threshold Limits Per Segment**	**Max. Defective Segments Per Driving Lane-Mile** [(a)]
Longitudinal Crack	30 percent of segment length (528 ft)	1
Longitudinal Joint Crack	10 percent of segment length (528 ft)	1
De-bonding	5 percent of segment length (528 ft)	1
Raveling	8 percent of segment length (528 ft)	1
Flushing	4 percent of segment length (528 ft)	1
Rutting [(c)]	ave. rut depth = 0.25 inch [(b)]	1
Transverse Crack	15 Cracks of segment length (1 mile)	1

a. The maximum allowable number of defective segments per driving lane is determined by multiplying by the length of the specific driving lane in miles.
b. The rut depth threshold applies to each wheel path independently.
c. The pavement surface will be evaluated for the presence of rutting on each driving lane throughout the warranty period. The pavement surface will be measured beginning at the POB and every 132 feet thereafter to determine average rut depth to quantify rutting for a particular segment. Rut measurements will be done using a straight rigid device that is a minimum of 7 feet long and of sufficient stiffness that it will not deflect from its own weight, or a wire under sufficient tension to prevent sag when extended 7 feet. Measurements will be taken by placing this “straightedge” across the pavement surface perpendicular to the direction of travel. The straightedge shall contact the surface on at least two bearing points with one located on either side of the rut. The straightedge is properly located when sliding the straightedge along its axis does not change the location of the contact points. Rut depth is then measured at the point of greatest perpendicular distance from the bottom of the straightedge to the pavement surface.

Table B5. Corrective actions.

Condition Parameter	**Recommended Action**
Longitudinal Joint	Crack Cut and Seal
Longitudinal Crack	Cut and Seal
Transverse Crack	Mill and Resurface [(b)]
De-bonding	Mill and Resurface
Raveling	Mill and Resurface
Flushing	Mill and Resurface
Rutting	Mill & Resurface [(a)]

a. Recommended action is dependent on the depth of the rut susceptible material.
b. Mill and resurface limits shall be such that the transverse cracks within the segment are removed.

<u>SR 562 Resurfacing Project, Hamilton County, Ohio Department of Transportation</u>

Evaluation Method: Low Bid

Excerpts from the Proposal

- Ohio DOT provides the pavement type and thickness for this project. T he pavement thickness catalog is shown in Table B6:

Table B6. ODOT pavement design for SR 562 project.

Cincinnati Portion	**Norwood Portion**	**Ramps at the IR 75**
5.5” Asphalt (1986)	3” Asphalt (1993)	2.5” Asphalt (1986)
9” Reinforced Concrete	9” Reinforced Concrete	9” Reinforced Concrete
6” Subbase Material	6” Subbase Material	6” Subbase Material

- Ohio DOT provides initial soil exploration data. The contractor collects any additional geotechnical information. The contractor analyzes the subgrade according to Ohio DOT Geotechnical Bulletin 1 (GB1): Plan Subgrades.
- Ohio DOT provides concrete mix design requirements.
- Although warranties are not applied for this project, the scope manual indicates that warranty could be project-specific.

<u>Florida Department of Transportation Design-Build Guidelines</u>

Florida DOT uses two approaches in executing design-build projects.

Adjusted Score Design Build - the contract award is based on the lowest adjusted score, which is determined by dividing the price proposal by the technical proposal score. Suitable candidates for adjusted score design-build projects are:

- Intersection improvement.
- Interstate widening.
- Rural widening.
- Urban construction/reconstruction with major utilities, major subsoil, right of way, or other major unknowns (requires prior approval from the State Construction Office).
- Mill and resurfacing (requires prior approval from the State Construction Office).

Low Bid Design Build- the contract award is based on the lowest responsive bid. Resurfacing projects generally are selected for low bid design-build contracting.

> For Low Bid resurfacing designs, a topographic survey and pavement cross-sections, or cross-slope and profile data, a minimum milling depth and whether an ARMI layer is required should be included in the criteria. The Pavement Coring and Evaluation report will be provided with the criteria. In addition to this project specific criteria<u>, all</u>

standard requirements of the Department's pavement design manuals are to be followed.

FDOT may or may not ask the contractor to perform the pavement design. The guidelines reads:

The PM (Project Manager) must also determine if the Department is going to provide the pavement borings and pavement design or if the Firm will accomplish this.

If sufficient data is available, the Department can provide the complete pavement design package as part of the Design Criteria. If the Department does not provide the pavement design, project specific pavement design criteria will be provided as part of the Design Criteria Package to assure a reasonable pavement design is provided by all competing Design/Build teams.

As part of the RFP for all Design/Build projects, Districts shall include the typical section criteria and the minimum pavement design. The typical section design will identify the minimum lane widths, shoulder widths, median widths, cross slope and front slope requirements. The typical section criteria developed by the Department shall not be modified by the Design Build firm. Any requests to modify the typical section criteria by a Design/Build Firm will need to be approved by the Department and FHWA (as applicable) at the pre-bid meeting or prior to the information cut-off date. The minimum pavement design will typically include the minimum design period, minimum ESAL's, minimum design reliability factors, roadbed resilient modulus, minimum structural asphalt thickness, cross slope and the need for modified binder. For resurfacing design, include the minimum milling depth and whether an ARMI layer is required. The pavement coring and evaluation should be provided with the criteria.

It is evident that the DOT may elect to perform pavement designs on its own or ask the contractor to perform the pavement design. In any event, the Florida DOT Pavement-Type Selection Manual will be followed.

Highway 104 Cobiquid Pass, Nova Scotia

This project involved the construction of a new toll highway alignment. All trucks are required to use this new alignment, with non-commercial vehicles permitted to use the old alignment. At the time, the Province had constructed only one section of highway as a concrete pavement. They elected to permit the contractor to design the pavement structure. The specifications required that the contractor provide the mainline, ramp, and crossing road pavement structures are a part of their bid. The pavements had to be design by a professional engineer with at least 10 years of experience. The contract documents suggested that if the Province did not approve of the pavement structure, the bid would be declared non-compliant. All teams submitting elected to provide a flexible pavement structure. The highway has relatively low traffic levels (7,800 AADT – 2009) and typically sandy type subgrades. The cost of the thickness of the minimum concrete section that could be provided was substantially higher than a comparable flexible pavement design. Prior to the award of the contract, the Province held in-depth discussions with the preferred bidder. Technical committees for each major business area—pavements, structures, maintenance, etc.—were set up with representatives from the owner and

bidder. Once agreements on procedures and specifications to be followed were agreed to by each committee, the project was awarded.

<u>Highway 407 Electronic Toll Road (ETR), Ontario</u>

This project involved the construction of 69 km of 4 and 6 lane highway on a new alignment. While the project started out as a Design-Build Operate and Maintain, it changed to a Design-Build after the submission of the bids. The contractor was permitted to build whatever pavement structure they wanted, and life cycle costing was required based on a 35iyear performance period. The criteria for the pavement designs and maintenance plan were pass/fail. If the government did not approve the submitted pavement designs and maintenance plans, then the bid could be declared non-compliant. The winning bid was a long-life exposed concrete. One of the bidders proposed a thin pavement section with frequent overlays as the pavement aged/traffic increased. This was not current agency practice or desired for a toll highway that would be "under construction" every 5 years. The agency also specified that the bidders use the current standard agency construction and material specifications. The agency then set up and administered a third party to police the design and construction.

<u>California Department of Transportation (Caltrans)</u>

Caltrans specifies that bidder must follow a detailed list of requirements to build a cost-effective pavement, but the designers must participate in a roadway pavement concept meeting after award of the contract to get Caltrans' approval of the pavement designs. The contractor must incorporate the comments and suggestions from the meeting.

<u>North Texas Tollway Authority</u>

The North Texas Tollway Authority has developed their own mechanistic pavement design manual which must be followed for their designs.

<u>Texas Turnpike</u>

Texas requires the designer to complete a detailed geotechnical investigation and provide all appropriate pavement design parameters. The agency also requires the use of the Texas DOT pavement design manual. For rigid pavements, s only CRCP is acceptable for mainline pavements. Shoulders and ramps need to be the same as the mainline. Texas specifies all pavement design inputs and method of design (AASHTO 1993). Flexible must be designed using the DOT's FPS-19W (mechanistic) design and checked using the Texas triaxial class design method.

<u>New Mexico</u>

Only agency-approved pavement design engineers may perform the design. Technical design reference standards are outlined in their infrastructure design directive that provides all design guidelines, input parameters, etc.

<u>Green Lane Regional Municipality of York, Ontario</u>

This project involved the construction of a new four-lane municipal roadway including major storm sewer works. The project permitted contractor pavement design, indicating that the pavement design "had to be completed by a pavement engineer with at least 10 years of experience using a recognized design procedure." The owner's feeling was that if they specified the use of a "pavement design expert," they would get the pavement that they expected. The owner also specified that the bidders specify the pavement performance expectations (bidder develop the acceptance criteria). The project was built and immediately had performance issues. A third party reviewed the project and found that the pavement structure had insufficient asphalt concrete thickness to achieve the expected design life.

<u>New Brunswick</u>

The bidder must provide a pavement design plan including the design methodology and its application along with a summary of the pavement design parameters and design factors. They specify three possible pavement design methodologies. They highlight the variability of soil types and ask for a discussion on how this will be addressed. The technical submission will receive a compliance or non-compliance response by the evaluation team.

<u>Alberta</u>

The agency provides the pavement designs.

<u>Manitoba</u>

The agency provides the pavement designs.

Long-term Performance Warranty Projects

New Mexico Route 44 – 20-year Performance Warranty

The New Mexico State Highway and Transportation Department awarded a 20-year performance warranty contract to Mesa PDC, a private firm, under which the contractor provides design, construction management, and performance warranty services for US Route 550/NM Route 44 from San Ysidro to Bloomfield. The contractor's services also include project and quality management, bid package preparation, inspection, and testing and measurement services. Since New Mexico legislation does not allow design-build projects, the Mesa PDC is not involved in construction.

The total cost of the project was $323.83 million, which included $46.82 million for project design and construction management, $215.0 million for construction, and $60.0 million for pavement performance warranties. For the pavement, this equates to approximately $6,400 nominal per lane-mile per year. As part of the warranty agreement, Mesa PDC accepted up to 3.5 percent inflation risk on future maintenance and rehabilitation costs. The pavement warranty is limited to 20 years of service life, 4,000,000 ESALs, or $110 million of total Mesa PDC

expenditures. Therefore, beyond the $60 million payments from the agency, Mesa PDC is at risk for an additional $50 million in pavement expenditures, if necessary to meet the terms of the warranty. The pavement warranty is treated separate from structures warranty contracts.

Per the contract provisions for the pavement warranty, Mesa PDC will repair or replace any portions of the project that fail to meet specific objective performance measurement criteria. The pavement performance requirements establish minimum acceptable criteria for various road conditions including smoothness, rutting, cracking, bleeding, raveling, delamination, potholes, and depressions. The structures performance criterion establishes minimum acceptable criteria for various bridge, drainage, and erosion conditions. The pavement sections are inspected annually by PDC sub-consultants to locate and identify areas that do not meet the performance criteria. PDC then prepares an annual maintenance plan summarizing the findings of the inspections and outlining a plan for maintenance and repairs for the next construction season. Deficiencies identified during the annual inspections are repaired, bringing the problem areas back into compliance with the performance criteria.

The contract provisions required LCCA of several feasible alternatives. The contractor did not consider user delay costs in the LCCA. Under this warranty project, the contractor is responsible for the long-term risks, and therefore, develops inputs and assumptions for economic analysis, develops unit costs, estimates initial and future costs, and performs the type selection process. The contractor's economic analysis of pavement-type alternatives considered in the selection process is presented in Table B7. Based on the life cycle costs, the MESA PDC proposed the flexible pavement type with a polymer-modified asphalt binder.

Table B7. Summary of LCCA for New Mexico SR 44 project.

Type of Design	**Mainline Pavement Type**	**Initial Construction Costs ($000)**	**Total Maint. Costs ($000)**	**Total NPV Costs ($000)**	**EUAC Payment**
Discount Rate : 2%					
Mesa[1]	AC (9 in.)	$96,993	$70,122	$151,060	$9,238
Conventional	AC (8 in.)	$94,229	$101,380	$173,881	$10,634
AASHTO	PCC (9 in.)[2]	$142,640	$59,947	$187,386	$11,460
AASHTO	PCC (9 in.)[3]	$160,092	$54,261	$200,880	$12,285
Overlay/Widen[4]	AC (9 in.)	$86,597	$107,769	$169,124	$10,343
Discount Rate : 4%					
Mesa[1]	AC (9 in.)	$96,993	$70,122	$139,068	$10,233
Conventional	AC (8 in.)	$94,229	$101,380	$157,555	$11,593
AASHTO	PCC (9 in.)[2]	$142,640	$59,947	$176,371	$12,978
AASHTO	PCC (9 in.)[3]	$160,092	$54,261	$191,060	$14,059
Overlay/Widen[4]	AC (9 in.)	$86,597	$107,769	$150,594	$11,081
Discount Rate : 6%					
Mesa[1]	AC (9 in.)	$96,993	$70,122	$130,029	$11,337
Conventional	AC (8 in.)	$94,229	$101,380	$145,142	$12,654
AASHTO	PCC (9 in.)[2]	$142,640	$59,947	$168,313	$14,674

Table B7. Summary of LCCA for New Mexico SR 44 project.

Type of Design	Mainline Pavement Type	Initial Construction Costs ($000)	Total Maint. Costs ($000)	Total NPV Costs ($000)	EUAC Payment
AASHTO	PCC (9 in.)[3]	$160,092	$54,261	$183,833	$16,027
Overlay/Widen[4]	AC (9 in.)	$86,597	$107,769	$136,822	$11,929

[1] Mesa pavement type is the conventional flexible pavement of 9 inches thick with a polymer-modified asphalt binder.
[2] Mainline PCC pavement with AC shoulder.
[3] Mainline PCC pavement with PCC shoulder.
[4] Mill and overlay two existing mainline lanes and new inside & outside shoulders.

APPENDIX C – ALTERNATIVE PREFERENCE SCREENING MATRIX EXAMPLE

This appendix illustrates the application of the alternative preference screening matrix for pavement-type selection. In the example presented, three qualifying pavement-type alternatives are analyzed using the screening matrix for various evaluation scenarios.

NEED STATEMENT

Assume that an agency has identified three pavement-type alternatives using the process outlined in this guide. Alternative 1 is similar to Alternative 3, except that Alternative 3 includes some superior material and technological components. Also assume that the surface types in adjacent pavement sections of the proposed project are the same as for Alternative 2. For each alternative, the available information includes the LCCA outputs and the results of economic and non-economic evaluation.

Table C lists the cost estimates for the three alternatives obtained from the LCCA procedure, with future costs adjusted to their present values. As the life cycle costs are within 10 percent of one another, all three alternatives are qualified as cost-effective strategies for further evaluation.

Table C1. Results of LCCA.

Cost Factor	Alternative 1	Alternative 2	Alternative 3
Initial costs	$3,100	$3,800	$3,500
Present value of future rehabilitation costs	$792	$338	$723
Present value of future maintenance costs	$120	$58	$84
Present value of user costs	$171	$126	$158
Present value of total agency costs	$4,012	$4,196	$4,307
Present value of total costs	$4,183	$4,322	$4,465

Note: All costs are presented in thousands of dollars per lane mile.

Table C2 lists the economic and non-economic factors that the agency identified as important to its goals and project requirements. The economic evaluation of the alternatives establishes their financial viability, while the non-economic evaluation validates that these alternatives meet at least the minimum project requirements, as well as the agency goals and expectations.

In this example, three hypothetical evaluation scenarios for pavement-type selection are considered, each of which reflects emphasis on different agency goals and project needs, as outlined in Table C3. For each of these scenarios, the user must select the most preferred pavement type from the alternatives outlined above. Regardless of the scenario, the pavement-type selection aspects, such as the qualifying pavement-type alternatives, cost estimates, and evaluation criteria, should remain the same.

Table C2. Factors considered in the economic and non-economic evaluation.

Economic Factors	Non-economic Factors	
• Initial costs • Life cycle costs • User costs • Future M&R costs	• Roadway/lane geometrics • Continuity of adjacent pavements • Continuity of adjacent lanes • Availability of local materials and experience • Traffic during construction	• Noise • Subgrade soils • Local preference • Safety considerations • Conservation of materials/energy • Stimulation of competition • Maintenance capability • Future needs • Experimental features

Table C3. Agency goals and evaluation scenarios.

Scenario	Agency Goals
1	• To select a cost-effective pavement type with lower initial costs that meets the agency's financial goals and non-economic criteria
2	• To select a cost-effective pavement type that meets the agency's financial goals and non-economic criteria • To minimize future costs (maintenance, rehabilitation and road user costs) • To select a pavement type compatible with those of adjacent sections
3	• To select a cost-effective pavement type with lower initial costs that meets the agency's financial goals and non-economic criteria • To place additional emphasis on noise mitigation and safety features • May experiment with a new technology if feasible

STEP 1: IDENTIFICATION AND GROUPING EVALUATION FACTORS

First, the evaluation factors identified in Table C2 are grouped as cost considerations, construction/ materials considerations, and other considerations (see Table C4):

Table C4. Grouping of economic and non-economic factors.

Cost Considerations	Construction/ Materials Considerations	Other Considerations
• Initial costs • Life cycle costs • User costs • Future M&R costs	• Roadway/lane geometrics • Continuity of adjacent pavements • Continuity of adjacent lanes • Availability of local materials and experience • Traffic during construction	• Noise • Subgrade soils • Local preference • Safety considerations • Conservation of materials/energy • Stimulation of competition • Maintenance capability • Future needs • Experimental features

STEP 2: ASSIGNMENT OF GROUP AND INDIVIDUAL FACTOR WEIGHTS

In this step, the evaluation factors and groups are assigned appropriate weights to address the scenarios outlined in Table C3. The importance of evaluation factors changes with varying

scenario goals, and so do their weights. Table C5 presents the factors that may require additional emphasis (i.e., higher weights) in each scenario.

Table C5. Weighting scenarios and agency goals.

Scenario	Additional Emphasis in Weighting
1	• Initial costs • Life cycle cost (NPV)
2	• Life cycle cost (NPV) • Future rehabilitation costs • Future maintenance costs • Future user costs • Continuity of adjacent pavements
3	• Initial cost • Life cycle cost (NPV) • Future rehabilitation costs • Future maintenance costs • Noise • Safety considerations • Experimental features

In Scenario 1, the agency goal is to select an alternative with overall cost-effectiveness and lower initial costs; therefore, additional emphasis is placed on both life cycle and initial costs. In Scenario 2, the agency priorities include not only the overall cost-effectiveness of an alternative but also the anticipated M&R and future user costs. In addition to cost considerations, the agency emphasizes continuity issues related to surface types of adjacent pavement sections. In Scenario 3, in addition to considering life cycle costs, the agency considers implementing a new technology that is expected to provide better noise mitigation performance and safety features. Considering the varying agency priorities, the weights to each group are assigned as shown in, Table C6.

Table C6. Weighting scenarios and group weights (percent).

Scenario	Cost Considerations	Construction/ Materials Considerations	Other Considerations
1	60	20	20
2	60	35	5
3	60	5	35

The cost considerations are heavily weighed at 60 percent in all the three scenarios, while the construction/materials considerations and other considerations are given additional importance in Scenario 2 and Scenario 3, respectively.

Table C7 presents the distribution of weights assigned to individual factors within each group for the three scenarios. The table also illustrates the relative importance of individual factors across groups in the overall evaluation of the matrix. The factor weights across groups were calculated by multiplying individual factor weights within each group by their corresponding group weights provided in Table 4 of Chapter 6.

Table C7. Weighing scenarios and individual factor weights.

Group	Factor	Distribution of Factor Weights within a Group			Distribution of Factor Weights across Groups*		
		Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Cost considerations	Initial costs	30	20	30	18	12	18
	Life cycle costs	50	30	50	30	18	30
	User costs	5	10	5	3	6	3
	Future rehabilitation costs	10	25	10	6	15	6
	Future maintenance costs	5	15	5	3	9	3
	Group total	***100***	***100***	***100***	***60***	***60***	***60***
Construction / materials considerations	Roadway/lane geometrics	0	0	0	0	0	0
	Continuity of adjacent pavements	30	60	30	6	21	2
	Continuity of adjacent lanes	0	0	0	0	0	0
	Availability of local materials and experience	30	10	30	6	4	2
	Traffic during construction	40	30	40	8	11	2
	Group total	***100***	***100***	***100***	***20***	***35***	***5***
Other considerations	Noise	10	10	25	2	1	9
	Subgrade soils	20	20	0	4	1	0
	Local preference	10	10	15	2	1	5
	Safety considerations	15	15	25	3	1	9
	Conservation of materials/ energy	10	10	10	2	1	4
	Stimulation of competition	25	25	0	5	1	0
	Maintenance capability	10	10	0	2	1	0
	Future needs	0	0	0	0	0	0
	Experimental features	0	0	25	0	0	9
	Group total	***100***	***100***	***100***	***20***	***5***	***35***

Note: All values in percent.

STEP 3: PREFERENCE RATING OF INDIVIDUAL FACTORS

This step entails preference rating of individual factors for each alternative based on their relative advantages and disadvantages. A comparative evaluation is presented in Table C8 and Table C9.

Table C8 lists the differences in cost estimates of the alternatives, as percentages, for various economic factors. The cost difference is calculated as the difference from the lowest estimate for this factor among the three alternatives. As noted in this table, Alternative 1 has the lowest

initial costs, direct agency costs, and life cycle costs among the alternatives; Alternative 2 has the lowest future M&R costs and user costs; Alternative 3 generally ranks between Alternatives 1 and 2, except in the area of life cycle costs.

Table C9 compares the relative advantages and disadvantages of the alternatives in terms of non-economic factors. Alternative 2 has advantages over the others in terms of continuity of adjacent pavement but is at a disadvantage regarding subgrade conditions and recycling potential. Alternative 3 is similar to Alternative 1 in many aspects, but it offers better noise mitigation properties and safety features (such as skid resistance and reflectivity) than Alternatives 1 and 2.

Next, we assign preference ratings to evaluation factors based on the advantages that a given alternative offers. In this example, the rating criteria and rating scheme presented in Chapter 5 are used. Alternative 1 has the lowest initial cost among the alternatives (see Table A8); the initial costs of Alternative 2 and Alternative 3 are higher by more than 10 percent. Using the rating criteria, Alternative 1 is rated “high” and the other alternatives are rated “low” for the initial cost factor.

Table C8. Comparative evaluation of alternatives against economic factors.

Economic Factors	**Alternative 1**	**Alternative 2**	**Alternative 3**
Initial costs	--	23	13
Present value of future rehabilitation costs	135	--	114
Present value of future maintenance costs	107	--	45
Present value of user costs	35	--	25
Present value of initial and future direct costs	--	5	7
Net present value of Initial and future costs	--	3	7

Note: Note: All values in percent.

Table C9. Comparative evaluation of alternatives against non-economic factors.

Non-economic Factors	**Alternative 1**	**Alternative 2**	**Alternative 3**
Roadway/lane geometrics	No issues	No issues	No issues
Continuity of adjacent pavements	Different but no issues	Same as adjacent pavements	Different but no issues
Continuity of adjacent lanes	No issues	No issues	No issues
Availability of local materials and experience	No issues	No issues	No issues
Traffic during construction	Easy to accommodate	Somewhat difficult to accommodate	Easy to accommodate
Noise	Moderate noise levels	Increased noise levels	Lower noise levels
Local preference	No preference	No preference	Some preference
Safety considerations	Good skid resistance but poor reflectivity	Good reflectivity but poor skid resistance	Better reflectivity and skid resistance
Conservation of materials/ energy	More recycling possibilities	Little recycling possibilities	More recycling possibilities
Stimulation of competition	Competition is encouraged	Competition is encouraged	Competition is encouraged

Table C9. Comparative evaluation of alternatives against non-economic factors.

Non-economic Factors	Alternative 1	Alternative 2	Alternative 3
Subgrade soils	No major issues	Some issues	No major issues
Maintenance capability	Common experience	Common experience	Common experience
Future needs	Easy to accommodate	Easy to accommodate	Easy to accommodate
Experimental features	Common technology	Common technology	No local experience

Next, we assign preference ratings to evaluation factors based on the advantages that a given alternative offers. In this example, the rating criteria and rating scheme presented in Chapter 6 are used. Alternative 1 has the lowest initial cost among the alternatives (see Table C8); the initial costs of Alternatives 2 and 3 are higher by more than 10 percent. Using the rating criteria, Alternative 1 is rated "high" and the other alternatives are rated "low" for the initial cost factor.

Table C10 presents the complete set of preference ratings for the alternatives and evaluation factors considered in this example. This set of ratings is common to the three scenarios considered.

Table C10. Preference ratings for alternatives.

Group	Factor	Alternative 1	Alternative 2	Alternative 3
Cost considerations	Initial costs	High	Low	Low
	Life cycle costs	High	High	High
	User costs	Low	High	Low
	Future rehabilitation costs	Low	High	Low
	Future maintenance costs	Low	High	Low
Construction/ Materials considerations	Roadway/lane geometrics	No difference	No difference	No difference
	Continuity of adjacent pavements	Medium-high	High	Medium-high
	Continuity of adjacent lanes	No difference	No difference	No difference
	Availability of local materials and experience	No difference	No difference	No difference
	Traffic during construction	Medium-high	Medium	Medium-high
Other considerations	Noise	Medium	Low-medium	High
	Subgrade soils	Medium-high	Medium	Medium-high
	Local preference	Medium	Medium	High
	Safety considerations	Medium	Medium	High
	Conservation of materials/ energy	Medium-high	Low-medium	Medium-high
	Stimulation of competition	High	High	High
	Maintenance capability	No difference	No difference	No difference
	Future needs	No difference	No difference	No difference
	Experimental features	Low	Low	High

STEP 4: SCORING PAVEMENT-TYPE ALTERNATIVES

First, the ratings are converted to numerical scores. Next, for each alternative, the unweighted numerical scores are adjusted to weighted scores using the weights tabulated in Table C7. The sum of the weighted scores of factors within each group is the unweighted score for that group.

Using the group weights tabulated in Table C6, the unweighted group scores are adjusted to weighted group scores. The total score of each alternative is then calculated by summing the weighted group scores of that alternative. These calculations are repeated for the three scenarios considered in this example. Table C11 summarizes the total scores of each alternative–scenario combination and provides the breakdown of weighted group scores. Table C12 through Table C14 present the completed worksheets of the screening matrix for Scenarios 1, 2 and 3, respectively.

Table C11. Summary of the alternative preference screening matrix scores.

Scenario	**Group**	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Preferred Alternative**
1	Cost considerations	50.4	45.6	36.0	1
	Construction/materials considerations	11.2	10.8	11.2	
	Other considerations	14.0	12.0	16.8	
	Total score	**75.6**	**68.4**	**64.0**	
2	Cost considerations	36.0	50.4	26.4	2
	Construction/materials considerations	25.2	27.3	25.2	
	Other considerations	3.5	3.0	4.2	
	Total score	**64.7**	**80.7**	**55.8**	
3	Cost considerations	50.4	45.6	36.0	3
	Construction/materials considerations	2.8	2.7	2.8	
	Other considerations	18.2	15.1	34.3	
	Total score	**71.4**	**63.4**	**73.1**	

Note: All values in percent.

STEP 5: INTERPRETING RESULTS

The alternative with the highest score can be selected as the most preferred alternative for each scenario. Note that the outcomes in these scenarios are different, reflecting changes in agency goals and project needs. In Scenario 1, Alternative 1 scored best, largely because of the advantages it provides in initial costs. In Scenario 2, Alternative 2 emerged as the preferred alternative with more weighing on future costs and the surface type continuity factor.

In Scenario 3, there apparently is no major difference in scores between Alternative 1 and Alternative 3. Where two alternatives are comparable, both could be selected as candidates for alternative bidding; however, since the agency priorities in Scenario 3 focus on experimenting with new technology and achieving superior noise and safety performance, Alternative 3 is selected as the most preferred alternative.

Table C12. Alternative preference screening matrix worksheet for Scenario 1.

Factors and Groups	Factor Weight	Alternative 1		Alternative 2		Alternative 3	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Group A. Cost considerations							
Initial costs	30.0	High	30.0	Low	6.0	Low	6.0
Life Cycle costs	50.0	High	50.0	High	50.0	High	50.0
User costs	5.0	Low	1.0	High	5.0	Low	1.0
Future rehabilitation costs	10.0	Low	2.0	High	10.0	Low	2.0
Future maintenance costs	5.0	Low	1.0	High	5.0	Low	1.0
Group A unweighted total	***100***		***84.0***		***76.0***		***68.0***
Group B. Construction/materials considerations							
Roadway/Lane Geometrics	0	No difference	0.0	No difference	0.0	No difference	0.0
Continuity of Adjacent Pavements	30	Medium-high	24.0	High	30.0	Medium-high	24.0
Continuity of Adjacent Lanes	0	No difference	0.0	No difference	0.0	No difference	0.0
Availability of Local Materials and Experience	30	No difference	0.0	No difference	0.0	No difference	0.0
Traffic During Construction	40	Medium-high	32.0	Medium	24.0	Medium-high	32.0
Group B unweighted total	***100***		***56.0***		***54.0***		***56.0***
Group C. Other considerations							
Noise	10	Medium	6.0	Low-medium	4.0	High	10.0
Subgrade soils	20	Medium-high	16.0	Medium	12.0	Medium-high	16.0
Local preference	10	Medium	6.0	Medium	6.0	High	10.0
Safety considerations	15	Medium	9.0	Medium	9.0	High	15.0
Conservation of materials/energy	10	Medium-high	8.0	Low-medium	4.0	Medium-high	8.0
Stimulation of competition	25	High	25.0	High	25.0	High	25.0
Maintenance capability	10	No difference	0.0	No difference	0.0	No difference	0.0
Future needs	0	No difference	0.0	No difference	0.0	No difference	0.0
Experimental features	0	Low	0.0	Low	0.0	High	0.0
Group C unweighted total	***100***		***70.0***		***60.0***		***84.0***
Subtotals	**Group Weights**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**
A. Cost considerations	60	84.0	50.4	76.0	45.6	60.0	36.0
B. Construction/materials considerations	20	56.0	11.2	54.0	10.8	56.0	11.2
C. Other considerations	20	70.0	14.0	60.0	12.0	84.0	16.8
Grand total	**100**		**75.6**		**68.4**		**64.0**

Note: All values in percent.

Table C13. Alternative preference screening matrix worksheet for Scenario 2.

Factors and Groups	Factor Weight	Alternative 1		Alternative 2		Alternative 3	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Group A. Cost considerations							
Initial costs	20	High	20.0	Low	4.0	Low	4.0
Life cycle costs	30	High	30.0	High	30.0	High	30.0
User costs	10	Low	2.0	High	10.0	Low	2.0
Future rehabilitation costs	25	Low	5.0	High	25.0	Low	5.0
Future maintenance costs	15	Low	3.0	High	15.0	Low	3.0
Group A unweighted total	***100***		***60.0***		***84.0***		***44.0***
Group B. Construction/materials considerations							
Roadway/lane geometrics	0	No difference	0.0	No difference	0.0	No difference	0.0
Continuity of adjacent pavements	60	Medium-high	48.0	High	60.0	Medium-high	48.0
Continuity of adjacent lanes	0	No difference	0.0	No difference	0.0	No difference	0.0
Availability of local materials and experience	10	No difference	0.0	No difference	0.0	No difference	0.0
Traffic during construction	30	Medium-high	24.0	Medium	18.0	Medium-high	24.0
Group B unweighted total	***100***		***72.0***		***78.0***		***72.0***
Group C. Other considerations							
Noise	10	Medium	6.0	Low-medium	4.0	High	10.0
Subgrade soils	20	Medium-high	16.0	Medium	12.0	Medium-high	16.0
Local preference	10	Medium	6.0	Medium	6.0	High	10.0
Safety considerations	15	Medium	9.0	Medium	9.0	High	15.0
Conservation of materials/energy	10	Medium-high	8.0	Low-medium	4.0	Medium-high	8.0
Stimulation of competition	25	High	25.0	High	25.0	High	25.0
Maintenance capability	10	No difference	0.0	No difference	0.0	No difference	0.0
Future needs	0	No difference	0.0	No difference	0.0	No difference	0.0
Experimental features	0	Low	0.0	Low	0.0	High	0.0
Group C unweighted total	***100***		***70.0***		***60.0***		***84.0***
Subtotals	**Group Weights**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**
A. Cost considerations	60	60.0	36.0	84.0	50.4	44.0	26.4
B. Construction/materials considerations	35	72.0	25.2	78.0	27.3	72.0	25.2
C. Other considerations	5	70.0	3.5	60.0	3.0	84.0	4.2
Grand Total	**100**		**64.7**		**80.7**		**55.8**

Note: All values in percent.

Table C14. Alternative preference screening matrix worksheet for Scenario 3.

Factors and Groups	Factor Weight	Alternative 1		Alternative 2		Alternative 3	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Group A. Cost considerations							
Initial costs	30	High	30.0	Low	6.0	Low	6.0
Life cycle costs	50	High	50.0	High	50.0	High	50.0
User costs	5	Low	1.0	High	5.0	Low	1.0
Future rehabilitation costs	10	Low	2.0	High	10.0	Low	2.0
Future maintenance costs	5	Low	1.0	High	5.0	Low	1.0
Group A unweighted total	***100***		***84.0***		***76.0***		***60.0***
Group B. Construction/materials considerations							
Roadway/lane geometrics	0	No difference	0.0	No difference	0.0	No difference	0.0
Continuity of adjacent pavements	30	Medium-high	24.0	High	30.0	Medium-high	24.0
Continuity of adjacent lanes	0	No difference	0.0	No difference	0.0	No difference	0.0
Availability of local materials and experience	30	No difference	0.0	No difference	0.0	No difference	0.0
Traffic during construction	40	Medium-high	32.0	Medium	24.0	Medium-high	32.0
Group B unweighted total	***100***		***56.0***		***54.0***		***56.0***
Group C. Other considerations							
Noise	25	Medium	15.0	Low-medium	10.0	High	25.0
Subgrade soils	0	Medium-high	0.0	Medium	0.0	Medium-high	0.0
Local preference	15	Medium	9.0	Medium	9.0	High	15.0
Safety considerations	25	Medium	15.0	Medium	15.0	High	25.0
Conservation of materials/energy	10	Medium-high	8.0	Low-medium	4.0	Medium-high	8.0
Stimulation of competition	0	High	0.0	High	0.0	High	0.0
Maintenance capability	0	No difference	0.0	No difference	0.0	No difference	0.0
Future needs	0	No difference	0.0	No difference	0.0	No difference	0.0
Experimental features	25	Low	5.0	Low	5.0	High	25.0
Group C unweighted total	***100***		***52.0***		***43.0***		***98.0***
Subtotals	**Group Weights**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**	**Group Unweighted Total**	**Group Weighted Total**
A. Cost considerations	60	84.0	50.4	76.0	45.6	60.0	36.0
B. Construction/materials considerations	20	56.0	2.8	54	2.7	56	2.8
C. Other considerations	20	52.0	18.2	43	15.1	98	34.3
Grand total	**100**		**71.4**		**63.4**		**73.1**

Note: All values in percent.

APPENDIX D – FHWA MEMORANDUM ON POLICY CLARIFICATION FOR PAVEMENT ALTERNATE BIDDING

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **INFORMATION**: Clarification of FHWA Policy for Bidding Alternate Pavement Type on the National Highway System

Date: November 13, 2008

From: Peter J. Stephanos
Director, Office of Pavement Technology

In Reply Refer To: HIPT

To: Associate Administrators
Chief Counsel
Directors of Field Services
Federal Lands Highway Division Engineers
Resource Center Director
Division Administrators

Recent changes in pavement materials costs have impacted the competitive environment relative to the determination of the most cost effective pavement structure for a specific project. In response, State highway agencies (SHA's) have a renewed interest in using alternate pavement type bidding procedures to determine the appropriate pavement type. The FHWA policies relative to pavement design, pavement type selection, economic analysis, and alternate bidding procedures are distributed among several resources. The intent of this memorandum is to consolidate and clarify FHWA policy relative to alternate pavement type bidding procedures on National Highway System (NHS) projects. In accordance with Title 23 U.S.C. 109(o), contracting agencies may use State design and construction standards, including alternate pavement type bidding, for Non-National Highway System projects.

Guidance on alternate pavement type bidding procedures is contained in 23 CFR 626 Non-Regulatory Supplement. It states that "FHWA does not encourage the use of alternate bids to determine mainline pavement types primarily due to the difficulty in developing truly equivalent pavement designs". It further states that "In the rare instances where the use of alternate bids is considered, the SHA's engineering and economic analysis process should clearly show there is no clear cut choice between two or more alternatives having equivalent designs. Equivalent design implies that each alternative will be designed to perform equally, and provide the same level of service, over the same performance period, and has similar life-cycle costs."

The FHWA Pavement Type Selection Policy published in the Federal Register on November 9, 1981, states "Where (engineering and economic) analysis shows that two or more initial designs and their forecasted performance are determined to be comparable (or equivalent), the use of alternate bids may be permitted as requested by the contracting agency."

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There are several factors that should be considered prior to determining that alternate bidding procedures should be used. Additionally, there are several factors that should be considered once the determination has been made to utilize alternate bidding procedures for pavement type selection.

The factors that should be considered prior to making the determination to utilize alternate bidding procedures include:

Designs must be equivalent – The 23 CFR 626 Non-Regulatory Supplement defines "equivalent design" as a design that performs equally, provide the same level of service, over the same performance period, and has similar life-cycle costs. It is difficult for two pavement structures utilizing different materials to be truly equivalent, so engineering judgment is required in the determination of what is and what is not "equivalent design". The performance period (analysis period) should be long enough to cover at least one major rehabilitation cycle. Life–cycle cost should be considered similar when the Net Present Value (NPV) for the higher cost alternative is within less than 10 percent higher than the lowest cost alternative. This difference is appropriate due to the uncertainty associated with estimating future costs and timing of maintenance and rehabilitation. It should be highlighted that no design methodology or analysis procedures currently available will output "equivalent designs" using design lives and analysis periods typically used for high-type facilities.

Realistic discount rate – Discount rates have a significant impact on the determination of the Net Present Value (NPV) of alternate pavement designs. The Final Policy Statement on Life - Cycle Cost Analysis (LCCA), published in the Federal Register on September 18, 1996, recommends that future agency costs should be discounted to NPV or equivalent uniform annual costs using appropriate (real) discount rates. Discount rates should be consistent with OMB Circular A-94. The trend over the past 10 years indicates a discount rate in the range on 2-4 percent is reasonable.

Consideration of uncertainty – The impact of uncertainty in factors such as performance life, material costs, construction duration, and future actions should be considered in the determination of total life-cycle cost for each alternative. The RealCost Software Program (available for free download at http://www.fhwa.dot.gov/infrastructure/asstmgmt/lccasoft.cfm) is a useful tool to perform LCCA as well as quantify the uncertainty of future factors through a sensitivity or probabilistic LCCA.

Realistic rehabilitation strategy - The rehabilitation strategy selected for each "equivalent design" should accurately reflect current or anticipated owner-agency pavement management practices. If recent experience with a pavement design is limited, available "best-practice" guidance on pavement rehabilitation strategies should be utilized.

Subjective Considerations – Despite the outcome of an objective engineering and economic analysis, an owner-agency may consider non-cost related factors such as constructability, type of adjacent pavements, recycling, and conservation of materials when making the determination to utilize alternate bidding procedures for pavement type selection.

Appropriate application – Alternate pavement type bidding procedures should only be used where the pavement items impacted by the alternate bid are likely to influence the final determination of the lowest responsive bidder for the project. Projects with substantial bridge or earthwork items are generally not suited for alternate bids. Additionally, projects with substantial quantities of different pavement materials may not be suited for alternate bids due to equipment mobilization costs.

The factors that should be considered once a decision has been made to bid alternate pavement types include:

Commodity price adjustment factors – The Pavement Type Selection Policy, published in the Federal Register on November 9, 1981, specifies that price adjustment clauses should not be used when using alternate bidding procedures. Price adjustment clauses transfer some material cost escalation risk from the contractor to the owner agency. As it is very difficult, if not impossible, to administer equal treatment with price adjustment factors to alternate materials, using these clauses will result in different levels of materials cost risk being included in the bid for alternate pavement types.

Incentive/Disincentive (I/D) Provisions for quality - If quality based I/D provisions are included with alternate bidding procedures, the I/D provisions should provide comparable opportunity for each alternate.

Specifications of material quantities – Using different methods to specify/quantify alternate pavement types may result in different levels of materials quantity risk for the alternate pavement types. Owner-agencies should consider approaches that balance materials quantity risk between the alternate pavement types.

SEP 14 approval needed if using adjustment factors – Some States have utilized price adjustments to account for differences in life-cycle costs for the alternate pavement types to determine the lowest responsive bidder. If adjustment factors are used, approval under Special Experimental Project #14 (SEP14) is required. It is recommended that prior to utilizing any adjustment factors that appropriate stakeholders be provided an opportunity to provide input. Adjustment factors should include, at a minimum, anticipated maintenance costs, anticipated rehabilitation costs, and salvage value.

Approval Requirements - The Pavement Type Selection Policy, published in the Federal Register on November 9, 1981, specifies that the division administrator shall review the analysis and concur in the finding of equivalency, when bidding alternate pavement types, and no adjustment factors are used.

Guidance related to LCCA and pavement type selection is currently under review and development. Once completed, more comprehensive guidance relative to the alternative pavement type bidding procedures will be issued. If there are questions concerning bidding of alternate pavement types, please contact Mark Swanlund of my staff at (202) 366-1323 or via email at mark.swanlund@dot.gov.