# Neutral Third Party
# Ohio Pavement Selection Process Analysis

## Final Report

Prepared for
Ohio Department of Transportation
Pavement Selection Advisory Council
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## FOREWORD

During the 2003–2004 regular session of the General Assembly, the Ohio State Legislature included in Section 12 of House Bill 87 the following provision calling for an evaluation of the Ohio Department of Transportation's (ODOT's) pavement type selection process:

> The Ohio Department of Transportation shall contract with a neutral third-party entity to conduct an analysis of the Department's pavement-selection process including but not limited to life cycle cost analysis; user delay; constructability and environment factors. The entity shall be an individual or an academic, research, or professional association with an expertise in pavement-selection decisions and shall not be a research center for concrete or asphalt pavement. The analysis shall compare and contrast the Department's pavement-selection process with those of other states and with model selection processes as described by the American Association of State Highway and Transportation Officials and the Federal Highway Administration.
>
> An advisory council shall be appointed to approve the scope of study and to select the neutral third-party entity. The advisory council shall consist of the following members:
>
> (1) The director of the Ohio Department of Transportation, who shall act as Chairman of the council;
> (2) A member of the Ohio Society of Certified Public Accountants;
> (3) A member of a statewide business organization representing major corporate entities from a list of three names submitted to and appointed by the Speaker of the House of Representatives;
> (4) A member of the Ohio Society of Professional Engineers;
> (5) A member of a business organization representing small or independent businesses from a list of three names submitted to and appointed by the President of the Senate;
> (6) A representative of the Ohio Concrete Construction Association;
> (7) A representative of Flexible Pavements Association of Ohio, Inc.
>
> Members of the advisory council representing the Ohio Society of Certified Public Accountants, the Ohio Society of Professional Engineers, the small or independent businesses and the major corporate entities shall have no conflict of interest with the position. For purposes of this section, "conflict of interest" means taking any action that violates any provision of Chapter 102. or 2921. of the Revised Code.
>
> The advisory council shall be appointed no later than July 31, 2003. Once appointed, the council shall meet, at a minimum, every thirty days. The council shall publish a schedule of meetings and provide adequate public notice of these meetings. The meetings are also subject to the applicable public meeting requirements. The council shall allow a comment period of not less than thirty

days before issuing its final report. The report shall be issued on or before December 31, 2003. Upon issuing its final report, the council shall cease to exist.

The Department shall make changes to its pavement-selection process based on the recommendations included in the third-party entity's report.

This report presents the findings and recommendations reached by the neutral third party (NTP), the ERES Consultants Division of Applied Research Associates, Inc. The NTP interviewed and took testimony from representatives of the Flexible Pavements of Ohio, Ohio Concrete Construction Association, and ODOT. In addition, the NTP team traveled to 10 States/Provinces where they interviewed respective DOT staff members regarding the processes they follow in making pavement type selections. Informal discussions were also held with representatives of the asphalt and concrete pavement associations in those 10 States/Provinces, as well representatives of the Federal Highway Administration (FHWA) in the Ohio Division and Washington Headquarters offices.

This report was prepared by key staff members of the NTP. These individuals include Mr. John P. Hallin (Project Manager), Mr. David K. Hein (Assistant Project Manager), Mr. Harold L. Von Quintus, Dr. Michael I. Darter, Mr. Kelly L. Smith, and Mr. Jag Mallela.

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## INTRODUCTION

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. The stakeholders that highway administrators answer to, the traveling public, generally do not express strong feelings on the type of pavement constructed, as long as reasonable levels of service, safety, and ride quality are provided. However, administrators must deal with the spirited competition that exists between the asphalt and concrete pavement industries.

Competition can be healthy when it leads to improvements in overall quality and cost reductions. It becomes unhealthy when it results in engineering decisions being moved to the political arena. It is an agency's responsibility to provide its constituents (the traveling public) with cost effective, good-performing roads. Conversely, it is the responsibility of the industries to illustrate that their products meet or exceed established performance criteria and are cost effective. It is prudent for both parties to use innovation and new technologies to improve the overall performance and long term cost effectiveness of Ohio's roads.

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* [1]:

> 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.

To further cloud the issue of pavement type selection, highway administrators face a high degree of uncertainty regarding the types of loadings a pavement will experience during a pavement life that can range from 20 to 50 years. During the nearly 50 years since the beginning of the

Interstate program, the United States has experienced a number of unforeseen changes in traffic and traffic loadings. These have included legislative changes that increased the size and weight of trucks, a large move from rail freight movement to truck freight, and just-in-time delivery.

Because of this uncertainty, pavement type selection processes are largely subjective and tailored to the needs of each individual State highway agency. The neutral third party (NTP) was tasked by the Ohio Pavement Selection Advisory Council (PSAC) with minimizing the subjectivity of Ohio's pavement selection process by reviewing the existing process and making recommendations for improvement. We began this assignment with a number of beliefs, and those beliefs were not altered during our review of what other States are doing:

- Pavement type selection is an engineering decision that is the sole responsibility of the highway agency.
- In most cases where pavement type selections are made on high-volume routes (Interstates, freeways, toll roads), properly designed and constructed flexible or rigid pavements will provide an excellent level of service.

The recommendations provided in this document are based largely on practices of the States/Provinces selected for review, along with guidance provided by AASHTO and the Federal Highway Administration (FHWA). When reviewing the practices of other States, we tried to identify advantages and disadvantages with specific aspects of their systems. We also consulted the trade organizations in a number of the States to get their views on pavement type selection.

This report is structured to present a summary of the issues that were raised by the pavement industries in Ohio, a review of the pavement design and selection processes of 10 highway agencies, a review of AASHTO and FHWA guidance on pavement type selection, and conclusions and recommendations to address the issues raised for the pavement type selection process in Ohio. Detailed information collected during the study is presented in the appendices.

## BACKGROUND

The Ohio Department of Transportation (ODOT), as part of its responsibility to make economically sound decisions that provide the most benefit for each dollar spent, began an effort in the fall of 2001 to develop a formalized, objective, unbiased pavement selection process. It was envisioned that the revised pavement type selection would be developed through a consensus process by a committee composed of members from the ODOT Office of Pavement Engineering, Ohio/Kentucky Chapter of the American Concrete Pavement Association (now Ohio Concrete Construction Association), Flexible Pavements of Ohio, FHWA, ODOT Office of Construction Administration, ODOT Multi-Lane Coordinator, and ODOT District Offices.

The committee held three meetings between September 2001 and May 2002. Shortly after the May 2002 meeting, ODOT management became impatient with the progress being made by the committee and charged the Office of Pavement Engineering with developing a new pavement type selection by July 31, 2002.

The first draft of the revised pavement type selection was submitted for industry and FHWA review in August 2002. The revised system was a matrix type of analysis that considered various cost, traffic, and engineering factors objectively. It was based on a concept presented in National Highway Institute (NHI) Course 13114, "Highway Pavements," and the 1993 AASHTO Design Guide (section 3, chapter 2), as well as suggestions received from Flexible Pavements of Ohio. Each industry provided extensive comments on the first draft. A second draft was issued in December. Again, numerous comments were received. On April 17, 2003, a final version of "Pavement Selection the ODOT Way" was issued. This document is included in appendix A.

The controversy over the draft pavement selection documents resulted in the Ohio Legislature including Section 12 of House Bill 87 requiring a NTP review of the pavement type selection process in Ohio.

## ISSUES

As the majority of the pavement type selection issues were raised by the industry trade organizations in Ohio, the first step in the review process was to conduct detailed interviews with each of the paving industries. The significant issues raised by each trade organization are summarized in the following sections.

### Flexible Pavement Industry Issues

Flexible Pavements of Ohio was interviewed on September 3, 2003, with a follow-up interview on October 14, 2003. Transcripts were made of these interviews, and they are available on the Internet at http://www.ohiopavementselection.org/. The following were the significant comments and issues raised by Flexible Pavements of Ohio at these interviews:

- The first scheduled rehabilitation for flexible pavements should be revised from 12 to 17 years. Furthermore, the mill and overlay should be limited to the mainline only. Currently, the first rehabilitation is mill and overlay of 1.5 inches. The second mill and overlay should be 14 years after the first rehabilitation and should consist of a 2-inch thick overlay instead of 3.75 inches. Industry feels that the initial pavement design provides adequate structural capacity for the full analysis period.
- The cost analysis should consist of a life cycle cost and a future cost, which should be considered separately.
- The cost analysis would be easier to understand if both initial and life cycle costs had the same weight but different levels of importance (e.g., I=10 initial, I=8 future).
- Spread factors for initial cost, life cycle cost, initial user delay, and future user delay should be 1.0, 0.75, 0.50, 0.25, and 0 to provide a uniform separation.
- There is a need to evaluate engineering and administration costs and relate the percentages to the type of work. Currently, a figure of 7 percent is used by ODOT, and industry believes that this is excessive. The costs for engineering and administration should be commensurate with the complexity of the project.
- There should be an attempt to quantify the actual maintenance of traffic cost (the industry believes that the 10 percent currently applied to all projects may not reflect actual costs).
- Maintenance of traffic, and engineering and administration costs should be added to both the initial costs and the future costs.
- Noise is an important consideration and should be included in the scoring evaluation. Noise should be a scoring factor with an importance of 8 in urban areas and 6 in rural areas. The spread factor should be quantified as follows:
  - 0 to 2 decibels of the quietest pavement equals 1.
  - 2 to 4 decibels of the quietest pavement equals 0.5.
  - 4 to 6 decibels of the quietest pavement equals 0.25.
  - 6 to 8 decibels of the quietest pavement equals 0.125.
  - Greater than 8 decibels of the quietest pavement equals 0.
- Warranty asphalt unit price tables should be based on a trend line of average price.
- The price for warranty asphalt for quantities greater than 100,000 cubic yards does not agree with the source data that ODOT used to develop the tables.

- User delay should have an importance factor for future maintenance of 3 instead of 6, which gives it the same importance as initial construction user delay.
- The reliability of ride should be increased from 3 to 5, since the measurement of ride quality is standard for pavement construction projects in Ohio.
- Flexible reconstruction projects should be treated the same as rigid pavement reconstruction projects in terms of construction traffic management. In other words, if traffic is diverted to one side for rigid pavements, it should be the same for flexible pavements.
- Step 4 of the pavement selection process should be modified to evaluate other factors, such as bridge construction, that could be the primary factor influencing traffic disruption.
- Revise layer coefficients.
    - Increase surface and intermediate layers from 0.35 to 0.45
    - Revise bituminous base from 0.35 to 0.37 (these revisions would reduce the required layer thicknesses and, therefore, initial cost).
- Recycled asphalt.
    - ODOT should review the current limitations on use based on an ODOT study performed by CTL Engineering.
- Break and seat.
    - ODOT should allow the use of break and seat rehabilitation, based on a study completed by the University of Cincinnati.

**Rigid Pavement Industry Issues**

The Ohio Concrete Construction Association (OCCA) was interviewed on September 4, 2003. A transcript was made of the meeting and is available on the Internet at http://www.ohiopavementselection.org/. The following were the significant comments and issues raised at this interview:

- There is an inherent bias at ODOT that favors hot mix asphalt (HMA).
    - Bias = systemic familiarity with HMA.
    - Much of Ohio's interstate system was built using long jointed reinforced concrete (JRCP). The JRCP designs still carried several times their initial design traffic.
    - Many early portland cement concrete (PCC) pavements in Ohio suffer from D-cracking, which is caused by the deterioration of certain aggregates under freeze thaw conditions. Improved aggregate selection has largely addressed this problem.
- Industry has a major concern with the methods used to estimate initial construction costs for PCC pavements.
    - There are insufficient representative projects and geographical diversity to develop an accurate unit cost for life cycle cost analysis (LCCA).
    - The unit cost data being used to establish unit costs include non-mainline paving and/or small projects that are not representative of the true costs of concrete pavement construction.

- The estimating procedure should be similar to that used by contactors and include items such as materials, labor, equipment, and placement costs at a specific project location.
- A shorter time horizon than 3 years should be used for the development of unit prices.
- Unit prices should be developed and published every 6 months.

- "Pavement Selection the ODOT Way."
  - The OCCA is not in favor of the scoring system used in this document, preferring decisions based primarily on life cycle cost analysis. There is no basis or documentation for the scoring factors (weight, importance, reliability, spread). OCCA feels that the scoring system is unnecessarily complex and that any system should be readily understandable and transparent.
  - User delay costs, not user delay days, should be factored into the LCCA calculations.
  - There is no provision for making future changes (e.g., how would you include another pavement type, such as composite pavements?).
  - No provision for specification changes.
  - No factor for pavement-related safety (e.g., rutting, lighting).
  - Should include routine maintenance in LCCA (e.g., crack sealing, pothole patching, seal coats, joint sealing).
  - Due to the limited use of the current PCC pavement design in Ohio, consideration should be given to using pavement performance data from other agencies to assist in developing the future rehabilitation schedule for concrete pavements.
  - ODOT does not plan to review post-bid information to see if their procedure for determining unit prices is valid or to assess the impact of the asphalt price adjustment on the unit price of HMA.
  - There is general agreement with the schedule for future rehabilitation for PCC; however, an asphalt overlay should not be required as a structural enhancement at year 32.
  - The maintenance repair quantities for PCC pavements at Year 22 are too high.
  - The initial cost is over-weighted in the decision matrix.
  - Ride should not be included in the scoring system because it is already accounted for in the pavement smoothness specifications.
  - Recycling should not be used as a scoring factor, and even if it is used, the spread factors for recycling should be the same for PCC and HMA.
  - Discount rate should be based on factors in Ohio, not OMB A94.
- Pavement design.
  - The relationship used to convert California Bearing Ratio (CBR) to resilient modulus may not be appropriate for use in Ohio.
  - The improvement in the CBR value due to soils stabilization is questionable.
  - The quantity of undercutting during construction should be less for PCC than HMA.
  - Since both pavement types are constructed to the same ride quality specifications, the same initial serviceability level should be used for both pavement types.
  - Pavement type selection should be revisited if the projects have been delayed for any significant time, as the traffic data may be out of date.

- Construction/specifications.
  - The asphalt price adjustment provides an unfair advantage to the HMA.
  - PCC should be considered recyclable.
  - The method of payment for HMA and PCC should be the same (i.e., by the square yard for a specified thickness). Currently, HMA is paid by the cubic yard not to exceed planned quantity and PCC is paid by the square yard with a penalty for thickness less than the plan thickness, which results in PCC contractors increasing the quantity of concrete placed to ensure that they are not penalized for low thickness.

**Issues Raised by the General Public**

There was a presentation by two private citizens on tire/pavement noise for PCC pavements at the August 7 meeting of the PSAC. In addition, numerous e-mails were received at the project Web site related to the subject of pavement noise. It is these citizens' opinion that it will be a disservice to roadway users if pavement noise is not included in the list of pavement selection process criteria.

## PRACTICES OF COMPARISON STATES/PROVINCES

### Background

A major component of this study was to visit 10 highway agencies and to document their pavement type selection procedures to permit comparison with ODOT's selection process. The selection of the States/Provinces to be interviewed was made in consultation and with the concurrence of the Pavement Selection Advisory Council. Selection of the 10 States interviewed was based on the following criteria:

- Climate similar to Ohio—This evaluation was accomplished using the climatic zones contained in Part III, Section 3.3.5 of the *AASHTO Guide for Design of Pavement Structures* [1]. As shown in figure 1, the United States is divided into nine regional zones that are formed by the intersection of three moisture regions and three temperature regions. The three moisture regions are:

  I. High potential for moisture presence in the entire pavement structure throughout the year
  II. Seasonal variability of moisture in the pavement structure
  III. Very little moisture in the pavement structure during the year

  The three temperature regions are:

  A. Severe winters with a high potential for frost penetration to appreciable depths into the subgrade
  B. Freeze-thaw cycles in the surface and base. Severe winters may produce frozen subgrade, but long-term freezing problems are minor.
  C. Low temperatures are not a problem. Stability at high temperature should be considered.

  Pavements within a given climatic zone typically exhibit similarities in performance, moisture-related distress, and drainage-related rehabilitation work required.

- Traffic volumes similar to Ohio—The selected State was to have interstate routes carrying high volumes of total traffic and truck traffic.
- Existence of sizeable metropolitan areas—The selected State was to have several medium to large urban areas.
- Balance of pavement types used—The selected States were to represent a mix of pavement types on their system. This would include a balance of States that predominately build one type of pavement.

Table 1 provides a list of the States selected for review, along with details concerning their conformance with the selection criteria.

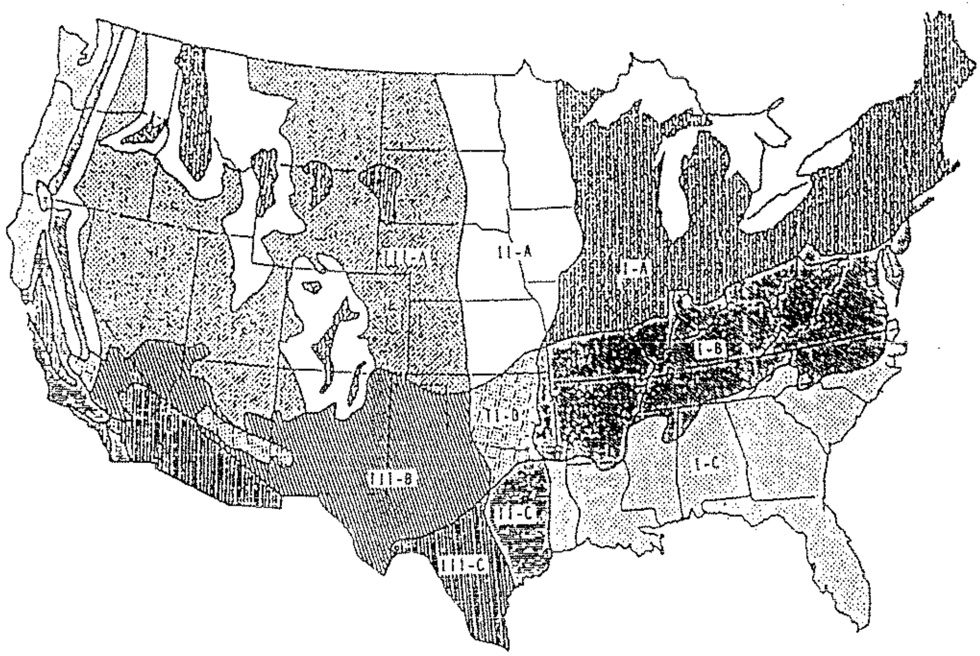


Figure 1. Climatic zones in the United States [1].

Table 1. States selected for comparison and their conformance with selection criteria.

| Rank | State | Climatic Zone | Truck Volumes | Total Traffic | Urban Areas | NHS Divided ≥ 4 lanes (Miles) | Interstate System | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | % ACP | % PCC | % Comp[1] |
| 1 | Illinois | I-A | High | High | Large | 3408 | 3.0 | 25.2 | 71.8 |
| 2 | Michigan | I-A | High | High | Large | 2243 | 12.3 | 50.7 | 37.0 |
| 3 | Pennsylvania | I-A | Med-High | High | Large | 3217 | 11.0 | 32.7 | 56.2 |
| 4 | Indiana | I-A | High | High | Large | 1984 | 7.9 | 14.4 | 77.8 |
| 5 | New York | I-A | Med-High | High | Large | 3060 | 27.7 | 17.7 | 54.6 |
| 6 | Maryland | I-B | High | High | Large | 1205 | 88.6 | 6.2 | 5.2 |
| 7 | Wisconsin | I-A | Med-High | Med High | Medium | 2012 | 0.0 | 49.5 | 50.5 |
| 8 | Ontario | I-A | High | High | Large | 1286 | 69.1 | 6.6 | 24.2 |
| 9 | Washington | II-A/III-A/I-C | Med-High | High | Large | 1306 | 60.4 | 36.0 | 2.2 |
| 10 | Minnesota | I-A/II-A | Med | Med High | Large | 1930 | 12.2 | 54.7 | 33.1 |

1. Includes pavements originally constructed as PCC and overlaid with asphalt concrete (AC) as a rehabilitation activity.

The highway agency reviews were performed in September and October 2003. Each review consisted of meeting with the person responsible for developing the pavement type selection documentation and/or overseeing its application/use within the agency. During the interview a review questionnaire was completed. The completed questionnaires for each of the agencies are included in appendix C. Copies of manuals containing the agencies' procedures for pavement type selection were also obtained during the interview. In addition, the agency's construction specifications, available at each agency's Web site, were reviewed for information on methods of payment for pavement items and specifications related to the use of recycled materials.

A flow chart was developed for each agency summarizing their pavement type selection process. These flow charts are included in appendix B. A spreadsheet was also developed as an aid in comparing each of the agencies procedures with those of ODOT. This spreadsheet is included in appendix D.

**Agency Pavement Type Selection Processes**

In our reviews, we found three processes that were being followed. For later reference, we will label them as methods A, B, and C. The processes are described in the following sections.

Pavement Type Selection Method A

This is the process generally followed by Indiana, Maryland, Washington, Illinois, Wisconsin, and Pennsylvania. This process, which is illustrated in figure 2, consists of two principal steps:

1. Alternatives are developed and LCCA is performed. If the life cycle cost is within a set range, generally 10 percent (Washington 15 percent, Wisconsin 5 percent), the life cycle costs are considered equivalent.
2. Alternatives with equivalent life cycle costs are evaluated subjectively. Factors that may be considered include adjoining pavement types, constructability, traffic control, subgrade support, and traffic volumes.

   A variation of this method is currently under consideration by Maryland. They are considering a modification to their system, as shown on page B-5, to replace the subjective evaluation of other factors with a matrix driven of evaluation of these factors.

The range of 10± percent at which deterministic life cycle cost values are considered equal is based on the fact that all of the inputs used in the LCCA are estimates with potential for significant variability. Table 2 is from the FHWA *Technical Bulletin on Life Cycle Cost* [2]. This table highlights the fact that there are no fixed values used when performing a LCCA.

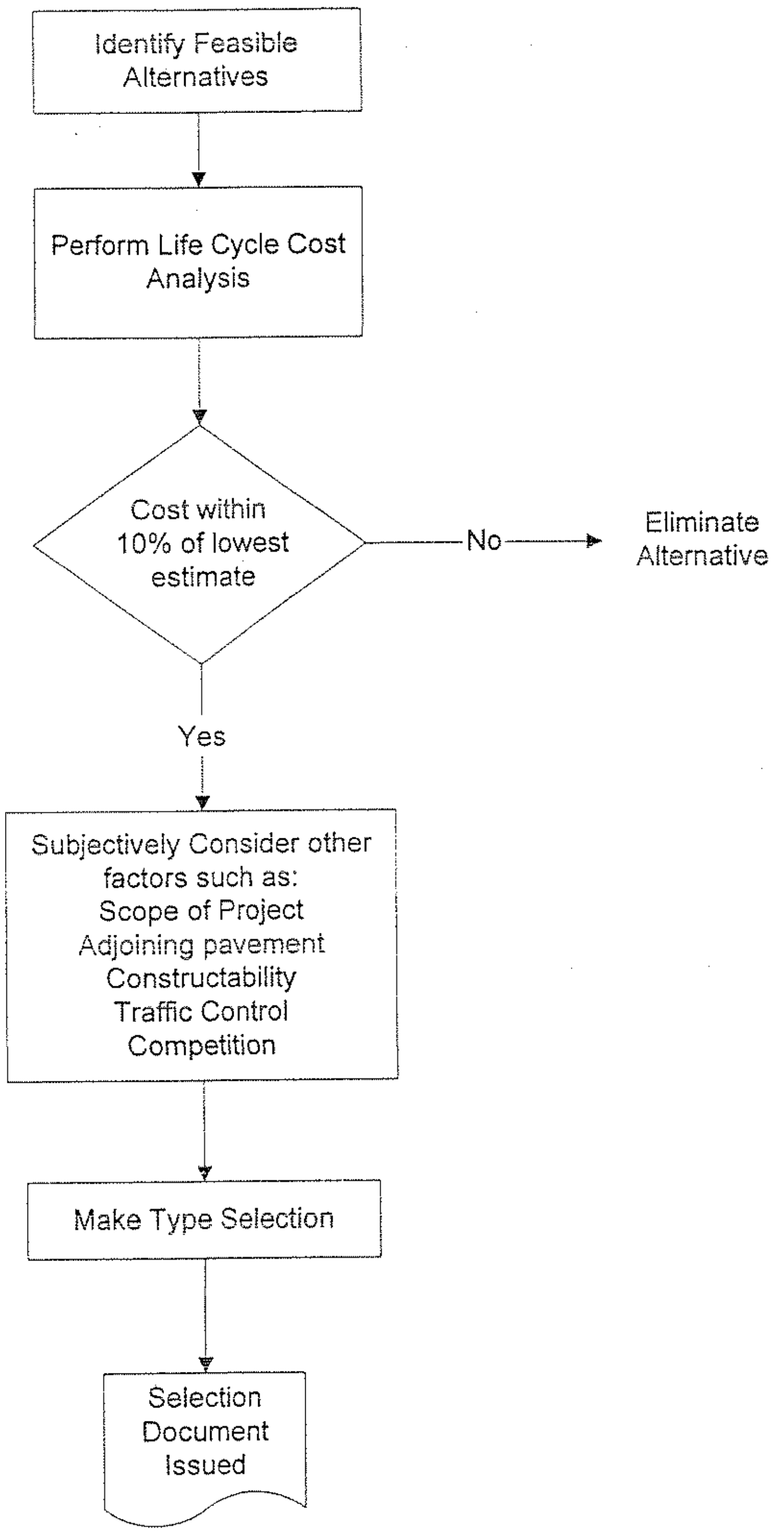


Figure 2. Pavement type selection method A.

Table 2. LCCA input variables (from FHWA).

| LCCA Component | Input Variable | Source |
|---|---|---|
| Initial and Future Agency Costs | Preliminary Engineering | Estimate |
| | Construction Management | Estimate |
| | Construction | Estimate |
| | Maintenance | Assumption |
| Timing of Costs | Pavement Performance | Projection |
| User Costs | Current Traffic | Estimate |
| | Future Traffic | Projection |
| | Hourly Demand | Estimate |
| | Vehicle Distributions | Estimate |
| | Dollar Value of Delay Time | Assumption |
| | Work Zone Configuration | Assumption |
| | Work Zone Hours of Operation | Assumption |
| | Work Zone Duration | Assumption |
| | Work Zone Activity Years | Projection |
| | Crash Rates | Estimate |
| | Crash Cost Rates | Assumption |
| Net Present Value | Discount Rate | Assumption |

Pavement Type Selection Method B

This is the process followed by New York and Ontario. The process is illustrated in figure 3 and involves two principal steps:

1. Each alternative is evaluated to determine if it meets the engineering criteria for the project site.
2. If the alternative satisfies the engineering criteria, preliminary designs are developed and a life cycle cost analysis is performed on each design. The design with the lowest life cycle cost is selected. In the case of Ontario, for projects longer than 10 lane km and annual equivalent single axle load repetitions expected to be greater than 1,000,000 within the next 4 to 5 years, detailed designs for flexible and rigid design are prepared and the pavement type is selected through an alternate bidding process.

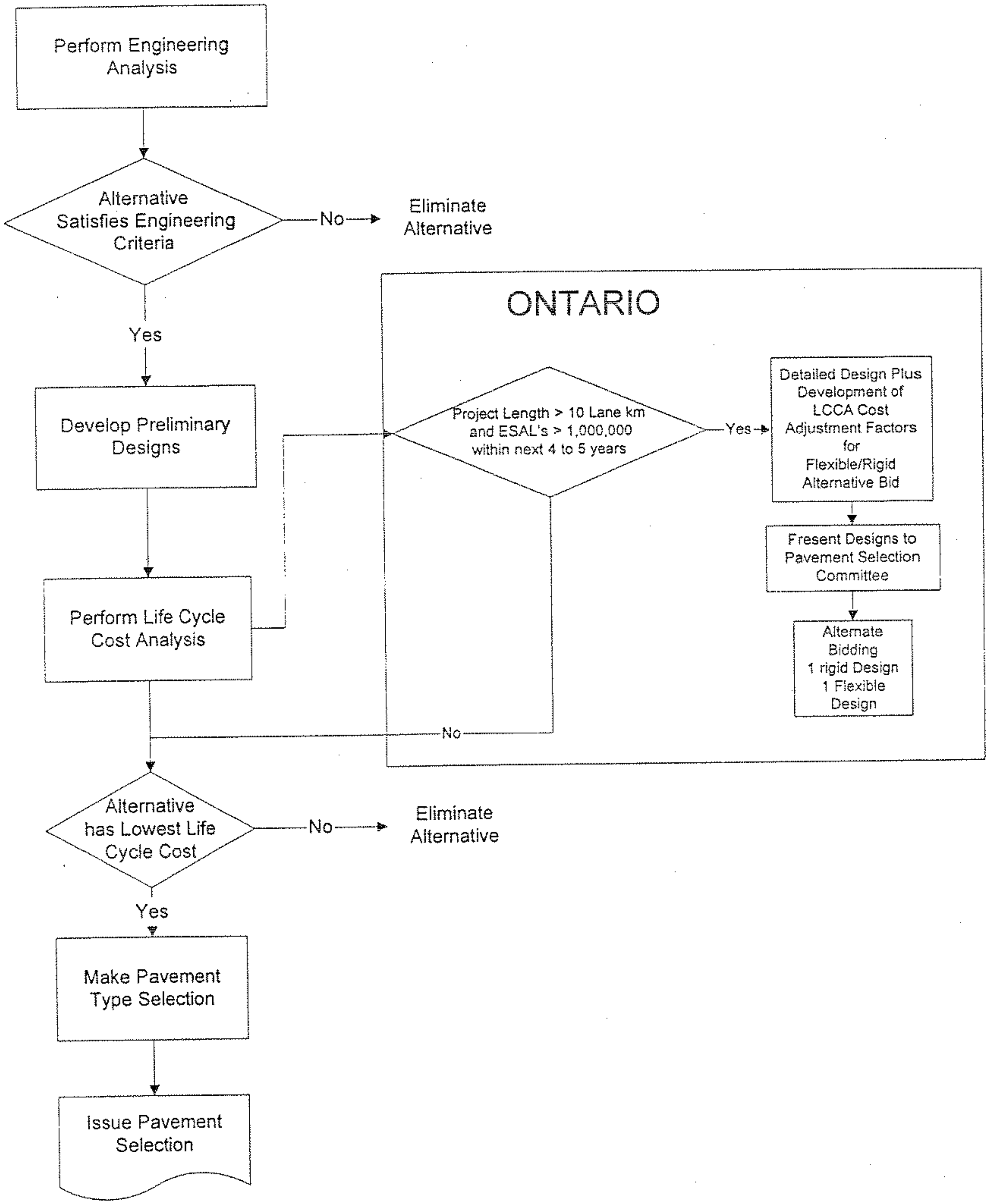


Figure 3. Pavement type selection method B.

Pavement Type Selection Method C

Pavement type selection method C (figure 4) is the process followed by Minnesota and Michigan. In this process, type selection is based solely on LCCA.

In reviewing the flow chart for Minnesota in appendix B, one might get the impression that traffic loadings rather than cost result in the type of pavements selected. Between 1990 and 1995, Minnesota completed life cycle cost comparisons on all projects involving new or reconstructed pavements. In all cases where the design traffic loadings were greater than 7 million, based on bituminous equivalent axle loadings (BESAL's), they found that the rigid design had the lowest life cycle cost. Where the design BESAL's were less than 7 million and the subgrade soil R-value was greater than 40, flexible pavement always had the lowest life cycle cost.

Therefore, in 1997 it was concluded that performing LCCA on projects falling into these categories was not a worthwhile exercise. In 2001, the process was modified to raise the threshold for determining that all pavements would be a rigid design from 7 million to 10 million BESAL's. Minnesota has indicated that when the new AASHTO mechanistic/empirical design process is adopted, they will begin performing LCCA on all designs.

In Michigan, legislation drives the format of the pavement type selection process. Senate Bill No. 303 of the 1997 Session of the Michigan Legislature contained the following section:

> Sec. 1g. The department shall develop and implement a life cycle cost analysis for each project for which total pavement costs exceed $1,000,000 funded in whole, or in part, with state funds. The department shall design and award paving projects utilizing material having the lowest life cycle cost. All pavement design life shall ensure that state funds are utilized as efficiently as possible.
>
> (2) As used in this section, "life-cycle cost" means the total cost of the initial project plus all anticipated costs for subsequent maintenance, repair, or resurfacing over the life of the pavement. Life-cycle cost shall also compare equivalent designs and shall be based upon Michigan's actual historic project maintenance, repair, and resurfacing schedules and costs as recorded by the pavement management system, and shall include estimates of user costs throughout the entire pavement life.

Because of the wording of this section, there are several questionable aspects of the Michigan process. Future costs must be based on the historic performance of pavements in Michigan. In reality, most pavements constructed in Michigan today use different designs and/or materials than were used in the past. For example, in the past Michigan used JRCP; now they are using short jointed plain pavements. Michigan has adopted Superpave mix design and stone matrix asphalt (SMA) design for their HMA pavements. However, none of the expected improvements in performance can be reflected in the LCCA.

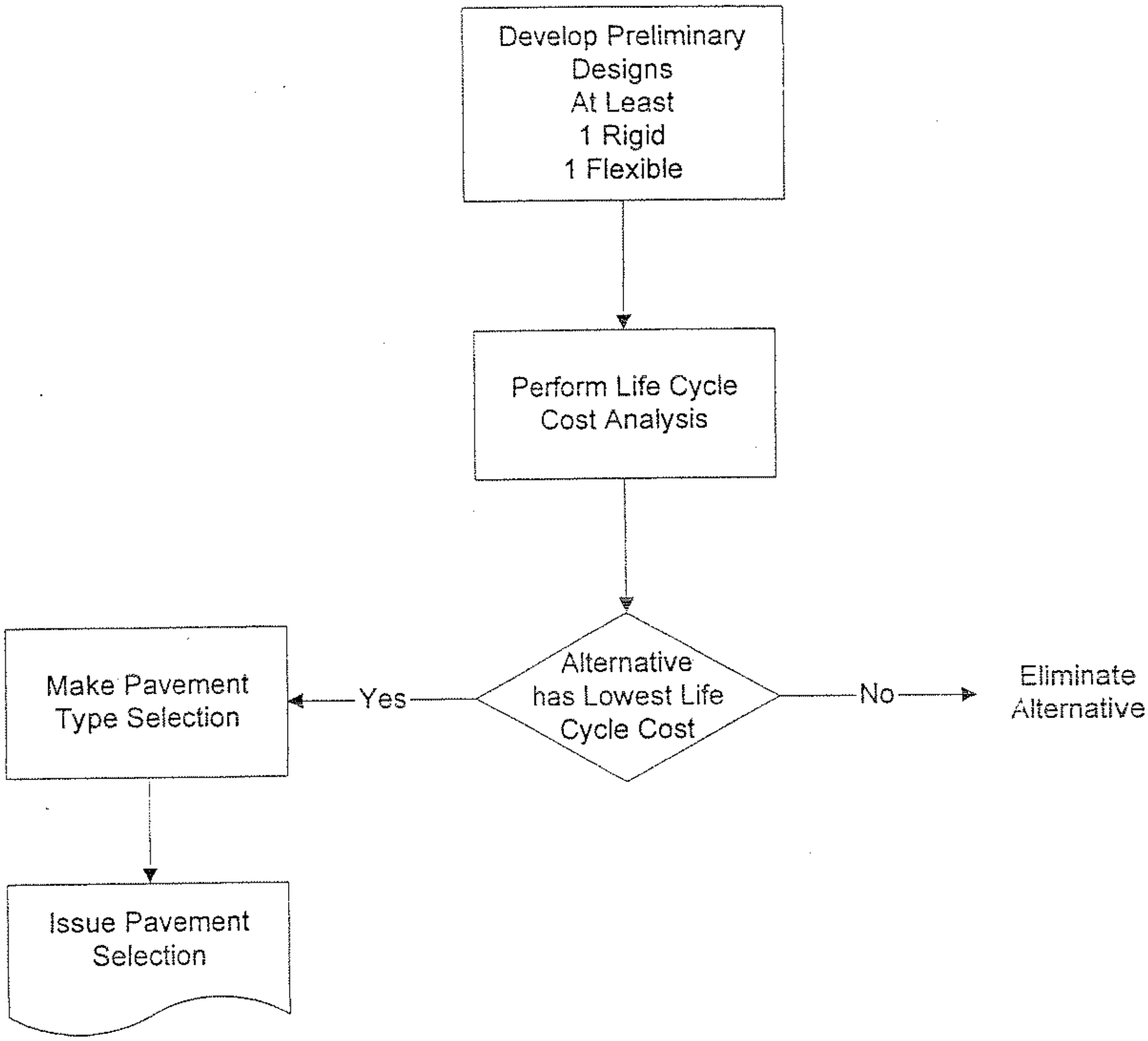


Figure 4. Pavement type selection method C.

Neither the Minnesota procedure nor the Michigan procedure considers the variability of the inputs for the LCCA when evaluating their results. In their approach, assumptions, projections, and estimates are used for input, but the results are considered final, no matter how small the difference in the results of the LCCA.

**Detailed Findings of State Practices**

<u>Life Cycle Cost Analysis</u>

All of the highway agencies interviewed utilize LCCA as part of their pavement type selection. Nine of the States use the net present value approach for calculating the life cycle cost. These States use the same analysis period for all alternatives considered in the analysis. Michigan uses the equivalent uniform annual cost (EUAC) approach and varies the analysis period for the strategy. The length of Michigan's analysis period is equal to the service life of the alternative being considered. A summary of the State highway agency practices is provided in the paragraphs below and in table 3.

| | |
|---|---|
| Life Cycle Cost Analysis: | All highway agencies interviewed use a life cycle cost analysis that consists of the sum of initial construction costs and discounted future costs. Ohio does not use the typical LCCA and is not considered consistent with other highway agency practice. |
| Analysis Period: | Ranges from 35 to 60 years, with most agencies using 40 years. Ohio and Minnesota have the lowest analysis period of 35 years. Ohio is considered consistent with other highway agency practice. |
| Discount Rate: | Discount rates ranged from a low of 3 percent in Illinois to a high of 6 percent in Pennsylvania. Ohio is using the OMB A94 specified discount rate of 3.2 percent. Ohio is considered consistent with other highway agency practice. |
| Sensitivity Analysis: | Sensitivity analysis is used by only three highway agencies. Ohio does not currently use a sensitivity analysis. Ohio is considered consistent with other highway agency practice. |
| Initial Cost: | Four agencies, including Ohio, have centrally developed cost data for LCCA. The other agencies interviewed have project-specific costs or are centrally developed with discretionary adjustments for the LCCA. While there is a similarity in the general practice, several States have addressed life cycle cost issues more rigorously. For example, Wisconsin and Michigan complete a statistical analysis of their unit cost data. If sufficient cost data are not available in a specific project area, the data included in the analysis are expanded until sufficient information is available to develop a confident estimate of the costs. In Minnesota, cost estimates are based on site-specific factors such as materials costs. |
| LCCA Quantity Adjustment: | No agencies surveyed developed or used any adjustment factors to account for the difference between estimated and as-built quantities. Ohio is considered consistent with other highway agency practice. |
| Routine Maintenance: | Only two agencies include the cost of annual routine maintenance. Ohio does not include annual routine maintenance in its LCCA, which is considered consistent with other highway agency practice. |

Table 3. State highway agency LCCA practices.

| Practices | Illinois | Indiana | Maryland | Michigan | Minnesota | New York | Ontario | Pennsylvania | Washington | Wisconsin | Ohio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Use LCCA | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Mod[1] |
| Analysis Period (years) | 40 | 40 | 40 | var.[2] | 35 | 50[3] | 50[3] | 40 | 60 | 50 | 35 |
| Discount Rate (%) | 3 | 4 | 4 | OMB[4] | 4.5[5] | OMB[4] | 5.3[6] | 6 | 4 | 5[7] | OMB[4] |
| Sensitivity analysis | No | 0%-10% | 3%-5% | No | No | No | ±2% | No | 2%-5%[8] | No | No |
| Initial Cost | | | | | | | | | | | |
| Centrally developed | Yes | No | Yes | Yes[9] | No | No | No | No | No | No | Yes |
| Project-discretionary | No | Yes | No | No | Yes[10] | Yes | Yes | Yes | Yes | Yes | No |
| Adjust LCCA for as built quantities | No | No | No | No | No | No | No | No | No | No | No |
| Routine Maintenance ($/lane mile) | Yes[11] | No | No | No | No | No | No | Yes | No | No | No |
| Scheduled Maintenance | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | No |
| How estimated | Com[12] | MM[13] | n/a | Hist[14] | Com[12] | Est[15] | Est[15] | MM[13] | n/a | MM[13] | n/a |
| Rehabilitation Cost | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| How estimated | Est[15] | PM[16] | PM[16] | PM[16] | Est[15] | Est[15] | Est[15] | PM[16] | PM[16] | PM[16] | Est[15] |
| HMA | | | | | | | | | | | |
| 1st rehab (years) | var.[17] | Proj[18] | Proj[18] | 10[19] | 15 | 15 | 19 | 10 | 15 | 18 | 12 |
| 2nd rehab (years) | var.[17] | Proj[18] | Proj[18] | 13[19] | 27 | 27 | 31 | 20 | 30 | Proj[18] | 22 |
| PCC | | | | | | | | | | | |
| 1st rehab (years) | 20 | Proj[18] | Proj[18] | 9[19] | 17 | 15 | 18 | 20 | 20 | 25 | 22 |
| 2nd rehab (years) | none | Proj[18] | Proj[18] | 15[19] | 27 | 30 | 28 | 30 | 40 | Proj[18] | 32 |
| Residual Value | No | No | No | No | No | No | No | No | No | No | No |
| Salvage Value | No | RL[20] | RL[20] | No | No | RL[20] | RL[20] | No | RL[20] | RL[20] | No |
| Const. Traffic Control | | | | | | | | | | | |
| Initial | No | No | Yes | No | Yes | No | No | No | Yes | No | No |
| Rehabilitation | No | No | No | Yes | No | No | No | Yes | Yes | No | Yes |
| Engr. and admin. cost | | | | | | | | | | | |
| Initial | No | No | No | No | No | No | No | No | Yes | No | No |
| Rehabilitation | No | No | No | Yes | No | 27% | No | Yes | Yes | No | Yes |
| User Delay | No | No | Yes | Yes | Fut[21] | Fut[21] | Fut[21] | Yes | Yes | No | Ind[22] |
| Spread of LCCA Considered Equal | 10% | 10% | 10% | 0% | 0% | 0% | 0% | 10% | 15% | 5% | Var[23] |

Notes:

1. Consider and weigh initial cost and future cost separately.
2. Analysis period varies to match pavement service life.
3. 50 years for new and reconstruction and 30 years for rehabilitation.
4. Office of Management and Budget Circular A94
5. Currently 4.5% but going to Office of Management and Budget Circular A94
6. Ministry of Finance social discount rate
7. Set by long standing policy
8. Use a probabilistic analysis
9. Regionally adjusted
10. Not unit cost based. Develop costs based on materials and construction costs at the specific site.
11. Fixed cost, includes striping, lane delineators, reflectors, etc.
12. Developed by committee
13. Maintenance management system
14. Past history
15. Best estimate
16. Pavement management system
17. Four categories based on traffic
18. Project specific
19. The strategies reflect the overall maintenance approach that has been used network wide for a specific fix based on historical maintenance and pavement management records.
20. Remaining life
21. Plan to incorporate user delay costs into the life cycle cost analysis in the near future
22. Consider user delay days in the type selection process
23. 3% initial cost and 10% future cost

Scheduled Maintenance: Eight agencies include the cost of regularly scheduled maintenance, such as crack sealing, joint resealing, and seal coats. Ohio does not include these items in its LCCA and is therefore not considered consistent with other agency practice.

Rehabilitation: All agencies, including Ohio, include the cost of rehabilitation activities, such as overlays and concrete pavement restoration. Ohio is considered consistent with other highway agency practice.

Time for First Rehabilitation: The year of the first rehabilitation for flexible pavements varies considerably, from 10 to 19 years, with a median of 15 years. Ohio, at 12 years, is lower than the median.

The year of the first rehabilitation for rigid pavements is highly variable, ranging from 9 to 25 years, with a median value of about 18 years. Ohio currently uses a time to first rehabilitation for rigid pavements of 22 years, which is higher than the 18-year median.

Second Rehabilitation: The year of the second rehabilitation for flexible pavements varies considerably, from 13 to 30 years, with a median of 27 years. Ohio, at 22 years, is below the median of the other highway agencies.

The year of the second rehabilitation for rigid pavements is highly variable, ranging from 15 to 40 years, with a median value of about 30 years. Ohio currently uses a time to second rehabilitation for rigid pavements of 32 years, which is considered consistent with other highway agency practice.

Method for Rehab Schedule: Six agencies used pavement management data as the basis for the rehabilitation schedule used in the LCCA and four agencies used engineering opinions. Ohio bases its rehabilitation schedules on engineering opinions.

Residual Value: No highway agencies use residual value in their LCCA. Ohio is considered consistent with other highway agency practice.

Salvage Value: Six highway agencies consider remaining life in the LCCA, so that each alternative is relatively equal from a condition standpoint at the end of the analysis period. Michigan is included, as their analysis period equals their service life. Ohio does not consider salvage value in the LCCA. The last overlay for flexible pavements is placed at 34 years, while the last overlay for rigid pavements is placed at 32 years. The maintenance schedules currently contained in "Pavement Selection the ODOT Way" result in equal remaining service lives for both pavement types negating the need for consideration of salvage value.

Traffic Control Costs: Only three of the highway agencies interviewed included the cost of initial construction traffic control costs in their analysis. Ohio is considered consistent with other highway agency practice.

Three of the highway agencies interviewed included the cost of future rehabilitation construction traffic control costs in their analysis. Ohio does include the cost of future rehabilitation traffic control. However, there is some controversy over the accuracy of these costs.

Engineering and Admin. One highway agency includes the cost of engineering and administration costs in its initial construction cost estimate for LCCA. Ohio is considered consistent with other highway agency practice.

Three agencies include the costs of engineering and administration in their cost estimate for future rehabilitation activities. Ohio includes the cost of future rehabilitation engineering and administration costs; however, there is some controversy over the accuracy of these costs.

User Delay: Four highway agencies consider user delay in their LCCA, and three others are considering including user delay in the future. Ohio does not currently include user delay costs for LCCA.

LCCA Spread Equivalency: Four highway agencies consider life cycle costs within ±10 percent to be equivalent. One agency uses 15 percent and another uses 5 percent. Four highway agencies use 0 percent. Ohio does not use the typical LCCA.

<u>Pavement Design Practices</u>

A summary of the State pavement design practices is provided in table 4 and in the paragraphs below.

*Flexible Design*

Design Method: Seven of the highway agencies interviewed use the AASHTO 1993 design procedure. One agency uses the AASHTO 1972 design procedure, one agency uses a modified procedure based on AASHTO data, and one agency uses a mechanistic-empirical procedure. Ohio uses the AASHTO 1993 design procedure.

Table 4. State pavement design practices.

| Practices | Illinois | Indiana | Maryland | Michigan | Minnesota | New York | Ontario | Pennsylvania | Washington | Wisconsin | Ohio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Flexible pavements | | | | | | | | | | | |
| Design method | M-E[1] | A93[2] | A93[2] | A93[2] | MN[3] | A93[4] | A93[2] | A93[2] | A93[2] | A72[5] | A93[2] |
| Design life | 20 | 20 | 15 | 20 | 20 | 50 | 20 | 20 | 40 | 20 | 20 |
| "a" surface | n/a | .34 | .44 | .42 | n/a | .42 | .42 | .44 | .44 | .44 | .35 |
| "a" intermediate | n/a | .36 | .40 | .36 | n/a | .42 | .42 | .44 | .44 | .44 | .35 |
| "a" bound base | n/a | .34 | .25 | .36 | n/a | .42 | .42 | .40 | .30 | .30 | .35 |
| Rigid pavements | | | | | | | | | | | |
| Design method | M-E[1] | A93[2] | A93[2] | A93[2] | A86[6] | A93[4] | A93[2] | A93[2] | A93[2] | A72[5] | A93[2] |
| Design life | 20 | 30 | 25 | 20 | 35 | 50 | 30 | 20 | 40 | 20 | 20 |
| PCC Mr ($S'_c$) psi | 650[7] | 652 | 700 | 670 | 675 | 650 | 725[8] | 631[8] | 650 | 650 | 700 |
| PCC Ec psi x $10^6$ | | 3.4 | 5.0 | 4.2 | | 4 | 4.35 | 4.0 | | 4.2 | 5.0 |
| Flexible/rigid foundations equal | Yes | Yes | Yes | No | No | Yes | Yes | No | Yes | Yes | Yes |
| Initial serviceability same for PCC and HMA | n/a | Yes | No[9] | Yes | n/a | n/a[10] | Yes | No[9] | Yes | No[11] | No[12] |

Notes

1. Mechanistic/empirical design procedure developed in Illinois
2. AASHTO – 1993 version
3. Procedure developed by Minnesota based on AASHO Road Test data
4. Modified procedure based on AASHTO – 1993 version
5. AASHTO – 1972 version
6. AASHTO – 1986 version
7. 14-day center point loading
8. Based on actual field data
9. $p_o$ = 4.5 for PCC pavements and 4.2 for flexible pavements
10. Not directly considered in the modified procedure
11. Not an input variable in the 1972 Guide where $p_o$ is fixed in the equation at 4.5 for PCC pavements and 4.2 for flexible pavements
12. $p_o$ = 4.2 for PCC pavements and 4.5 for flexible pavements, based on measurements of new pavements

Traffic Design Life: The range is from 15 to 50 years with a median of 20 years. Ohio uses 20 years and is consistent with the other highway agencies.

Asphalt Layer Coefficients: For surface courses, the range was from 0.34 to 0.44 with a median of 0.42. Ohio currently uses a surface course layer coefficient of 0.35.

For intermediate asphalt courses, the range was from 0.36 to 0.44 with a median of 0.42. Ohio currently uses an intermediate asphalt course layer coefficient of 0.35.

For base courses, the range was from 0.25 to 0.42 with a median of 0.36. Ohio currently uses a base course layer coefficient of 0.35.

*Rigid Design*

Design Method: Seven of the highway agencies interviewed use the AASHTO 1993 design procedure. One agency uses the AASHTO 1972 design procedure, one agency uses a modified procedure based on AASHTO data, and one agency uses a mechanistic-empirical procedure. Ohio uses the AASHTO 1993 design procedure.

Traffic Design Life: The range is from 20 to 50 years with a median of about 25 years. Ohio uses 20 years and is consistent with the other highway agencies.

PCC Modulus of Rupture: The modulus of rupture ranges from 631 to 725 psi with a median of 650 psi. Ohio uses a modulus of rupture of 700 psi. Based on a limited amount of test data provided for our review, the value of 700 psi appears reasonable.

PCC Modulus of Elasticity The modulus of elasticity (Ec) varies from 3,408,390 to 5,000,000psi. Ohio uses an Ec of 5,000,000. This value is based on testing of concrete on Ohio SHRP Project DEL-23. Further, as shown in figure 5 the impact of Ec on pavement thicknesses designed using the 1993 AASHTO Guide is minimal.

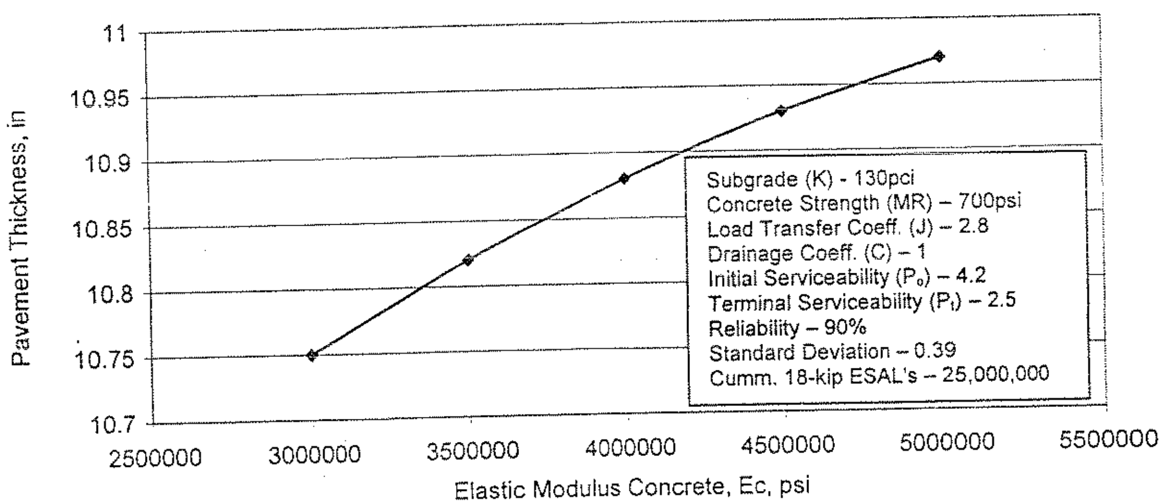


Figure 5. The impact of the elastic modulus of concrete on thickness.

*Common Design Parameters*

Foundation Requirements: Seven highway agencies treat the foundation requirements the same for flexible and rigid pavements. Ohio also treats the foundation requirements the same for both pavement types.

Initial Serviceability: Four highway agencies use the same initial serviceability for both flexible and rigid pavement types. Three agencies do not use initial serviceability for both pavement types. Two agencies use an initial serviceability value of 4.2 for flexible and 4.5 for rigid pavements. Ohio uses an initial serviceability of 4.5 for flexible and 4.2 for rigid pavements. ODOT indicated that the initial serviceability values used were based on measurements of newly constructed pavements, in conformance with the 93 AASHTO Guide; however the original study could not be located. In late 2002, the State reviewed the serviceability values on one-year old pavements constructed since 1997. The data indicated that the initial serviceability of asphalt pavements was approximately 0.5 higher for flexible pavements than rigid pavements. The study indicated that recently constructed flexible pavements were smoother than rigid pavements and provides support for the initial serviceability numbers being used. Because of the limited nature of the study, ODOT decided not to modify the values being used at this time.

Construction-Related Issues

As part of the review, methods of payment and the reuse of salvaged materials were investigated. The findings are summarized in table 5 and discussed in the paragraphs below.

Payment for HMA: Eight agencies use tonnage produced as a method of payment for HMA. Two agencies pay by square yards. Ohio pays for HMA based on a cubic yard using a unit weight conversion factor based on laboratory-measured density.

Payment for PCC: Seven agencies pay for PCC based on plan area. One agency uses a combination of square yards and cubic yards based on plan area and thickness. One agency uses cubic yards based on plan area and thickness. One agency pays based on plan area and measured thickness up to 0.5 inch over the plan thickness. Ohio pays based on plan square yards and is consistent with the majority of the other highway agencies.

Table 5. State pavement construction practices.

| Practices | Illinois | Indiana | Maryland | Michigan | Minnesota | New York | Ontario | Pennsylvania | Washington | Wisconsin | Ohio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Method of payment | | | | | | | | | | | |
| Hot mix asphalt | sq y | ton | ton | ton | ton | ton | ton | sq y | ton | ton | cu y |
| Concrete pavement | sq y | sq y | sq y | sq y | [1] | cu m | sq m | sq y | [2] | sq y | sq y |
| Recycling | | | | | | | | | | | |
| PCC | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Uses | [3] | sb[4] | b/sb[5] | b/sb[5] | b/sb[5] | b/sb[5] | b/sb[5] | Bf[6] | g m[7] | [8] | gm[7] |
| HMA | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Uses | HMA | HMA | HMA | HMA | HMA | HMA | HMA | HMA | HMA | [9] | HMA |
| Max % surface | 30[10] | 25[11] | 15 | 14[12] | 30[13] | 20 | [14] | [15] | 20[16] | 20[17] | 20[18] |
| Max % intermediate. | 30[10] | 25[11] | | 28[12] | 50[13] | 20 | [14] | [15] | 20[16] | 35[17] | 35[18] |
| Max % base | 30[10] | 25[11] | 25 | 28[12] | 50[13] | 30 | 30 | [15] | 20[16] | 35[17] | 35[18] |
| Liq. asphalt price adj. | No | No | Yes | No | No | Yes | Yes | Yes | No | Yes | Yes |

Notes:

1. Payment is a combination of sq. yd. plus cu. yd. based on plan quantity
2. Payment is cu. yd based on core thicknesses up to 0.5 over design
3. Capping, subbase, concrete, shoulders, fill
4. Subbase
5. Base and subbase
6. Backfill for structures
7. Granular materials
8. Unbound base (generally) and portland cement concrete (rarely)
9. HMA and unbound base
10. The maximum percentage of RAP is a function of mix design and ranges from 0 percent for an Ndesign of 105 to 30 percent for an Ndesign of 30 and is not allowed in polymer modified mixes.
11. Up to 15% use grade of asphalt binder specified for the project. 15% to 25% asphalt softer required
12. Percentage is by weight of total binder in the mix. Above 17% binder grade adjustments required
13. Subject to meeting mix design requirements
14. Varies between 10% and 30%
15. Permit 5% to 15%. For mixtures with more than 15 percent RAP, the department evaluates the asphalt cement content of the RAP source material and determines the grade of the asphalt cement and recycling agent the contractor will be required to use in the final mixture. When RAP is used, a plan to control RAP and procedures to handle the RAP of different compositions must be developed and provided to the department.
16. Up to 20% no new mix design, over 20% required a new mix design
17. Combined RAP and virgin aggregate shall meet percent crushed and natural sand quality requirements. The blend of new asphaltic material with extracted RAP asphaltic material shall meet the penetration or viscosity requirements for the specified asphaltic material.
18. Whenever more than 10% of reclaimed asphalt concrete pavement is used it must be included in the mix design to establish the job mix formula and conform to the requirements of the specified asphalt binder for the asphalt binder proposed for use in the mixture, by the combination of reclaimed asphalt, virgin asphalt, and rejuvenating agents. A maximum of 10% RAP is allowed in polymer modified surface mixtures.

Liquid AC Price Adjustment: Five highway agencies use a liquid AC price adjustment. Ohio uses a liquid AC price adjustment.

PCC Recycling: All highway agencies interviewed permit the use of recycling PCC on the project. Generally, the recycled materials must meet the specification requirements for which the material is being substituted. In most agencies, the PCC material removed from the project becomes the property of the contactor who uses this material for other non-highway agency projects. Ohio is consistent with the practices of the other States.

HMA Recycling: HMA recycling is permitted by all highway agencies interviewed. All agencies permit the use of recycled asphalt pavement (RAP) in HMA from 10 to 30 percent. For amounts ranging from 10 to 20 percent, mix design adjustments are not generally required. Above these values, the HMA must meet the requirements of virgin HMA. Ohio permits varying amounts of RAP in new HMA mixes.

## FHWA AND AASHTO GUIDANCE

### FHWA Policy and Guidance

The FHWA's policy on pavement design and type selection is contained in Part 626 of Tile 23 of the Code of Federal Regulations.

> **Sec. 626.1 Purpose.**
>
> To set forth pavement design policy for Federal-aid highway projects.
>
> **Sec. 626.2 Definitions.**
>
> Unless otherwise specified in this part, the definitions in 23 U.S.C. 101(a) are applicable to this part. As used in this part:
>
> Pavement design means a project level activity where detailed engineering and economic considerations are given to alternative combinations of subbase, base, and surface materials which will provide adequate load carrying capacity. Factors which are considered include: Materials, traffic, climate, maintenance, drainage, and life-cycle costs.
>
> **Sec. 626.3 Policy.**
>
> Pavement shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost effective manner.

As written, the policy provides a broad framework under which the State highway agencies are required to operate. The regulation does not specify procedures to be followed to meet this requirement. Instead, each highway agency is expected to use procedures that are appropriate for their conditions. In a non-regulatory supplement, the FHWA provides the following additional guidance on pavement type selection:

> 4) Engineering Economic Analysis. The design of both new and rehabilitated pavements should include an engineering and economic evaluation of alternative strategies and materials. The project specific analysis should be evaluated in light of the needs of the entire system. The "1993 AASHTO Guide for Design of Pavement Structures" (Appendix B) and the "FHWA Pavement Rehabilitation Manual," provide guidance on engineering considerations. The engineering evaluation should include consideration of the use of recycled materials and/or pavement recycling techniques, where feasible. Economic considerations include an economic analysis based on Life Cycle Costs (LCC). The FHWA Final Policy Statement on LCC analysis published in the September 18, 1996, Federal Register provides guidance on LCC Analysis. The FHWA Memorandum "National Highway System Designation Act - Life Cycle Cost Analysis Requirements" (April 19, 1996), provides supporting information and guidance to assist in

implementing Life-Cycle Cost Analysis (LCCA) requirements in the National Highway System (NHS) Designation Act of 1995. The FHWA Office of Pavement Technology's "Interim Technical Bulletin: Life Cycle Cost Analysis in Pavement Design FHWA-SA-98-079, September 1998" and FHWA's "Demonstration Project 115: Probabilistic Life Cycle Cost Analysis in Pavement Design" provide technical guidance and training on good practice.

(a) Pavements are long-term public investments and all the costs (both agency and user) that occur throughout their lives should be considered. LCCA identifies the long-term economic efficiency of competing pavement designs. However, the resulting numbers themselves are less important than the logical analysis framework fostered by LCCA in which the consequences of competing alternatives are evaluated. When performing LCCA for pavement design, the variability of input parameters needs to be considered. The results of LCCA should be evaluated to determine whether differences in costs between competing alternatives are statistically significant. This evaluation is particularly important when the LCC analysis reflects relatively small economic differences between alternatives.

(b) The FHWA's policy on alternate bids, which would include bids for alternate pavement types, is addressed in 23 CFR 635.411(b). This section requires the use of alternate bid items "When ... more than one... product... will fulfill the requirements... and these... products are judged...equally acceptable on the basis of engineering analysis and the anticipated prices... are estimated to be approximately the same."

> (1) The FHWA does not encourage the use of alternate bids to determine the mainline pavement type, primarily due to the difficulties in developing truly equivalent pavement designs.
>
> (2) In those rare instances where the use of alternate bids is considered, the SHA's engineering and economic analysis of the pavement type selection process should clearly demonstrate that 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 have similar life-cycle costs.

In reading the policy and supplement guidance, the conclusion can be drawn that both engineering factors and LCCA should be considered in selection pavement alternatives. They further highlight the non-deterministic nature of LCCA in their supplemental guidance when they state:

> When performing LCCA for pavement design, the variability of input parameters needs to be considered. The results of LCCA should be evaluated to determine

whether differences in costs between competing alternatives are statistically significant.

A number of highway agencies recognize the uncertainty and variability of LCCA and have adopted a spread factor to account for these differences. For example, if the life cycle costs of two alternatives are within a certain percentage of each other (e.g., 10 percent), they are considered equal in terms of life cycle cost.

The guidance is also clear that the FHWA discourages the use of alternate bidding as a routine means of pavement type selection. One of the primary problems with the bidding of pavement alternates is that the contract may not be awarded to the contactor with the lowest bid for initial construction. Because the two pavement types have different rehabilitation costs, the contractor's bid incorporates the bid for construction plus a valuation for future rehabilitation costs. The valuation for future costs is a value determined by the agency based anticipated performance.

However, over the past 7 years a number of agencies have expressed the desire to utilize alternate bidding. This interest developed as a result of both the agencies' and industries' desire to foster additional competition. The FHWA has accommodated this desire by incorporating alternative pavement design bidding under Special Experimental Project No. 14 (SEP-14), Innovative Contracting Practices. The objective of SEP-14 is to evaluate contracting processes that have the potential to reduce life cycle costs, while at the same time maintain quality. Missouri (5 projects), Kentucky, Louisiana (7 projects), Michigan (2 projects), and Maryland have used alternate pavement bidding procedures under SEP-14.

### AASHTO Guidance

AASHTO's guidance on pavement type selection is found in appendix B of the *AASHTO Guide for Design of Pavement Structures* [1]. Figure 6 outlines the pavement selection process contained in the Guide.

The Guide lists factors that may have some influence on the decision-making process. These factors are placed into two groups. Principal factors are those factors that may have a major influence and may dictate the pavement type in some instances. Secondary factors include those factors that have a lesser influence and are taken into account when there are no overriding considerations or one type is clearly not superior from an economic standpoint. The principal and secondary factors are listed below:

Principal Factors

1. Traffic.
2. Soils characteristics (problem soils).
3. Weather.
4. Construction consideration (stage construction, maintenance of traffic).
5. Recycling (opportunity to recycle from existing pavement or future opportunities).
6. Cost comparison.

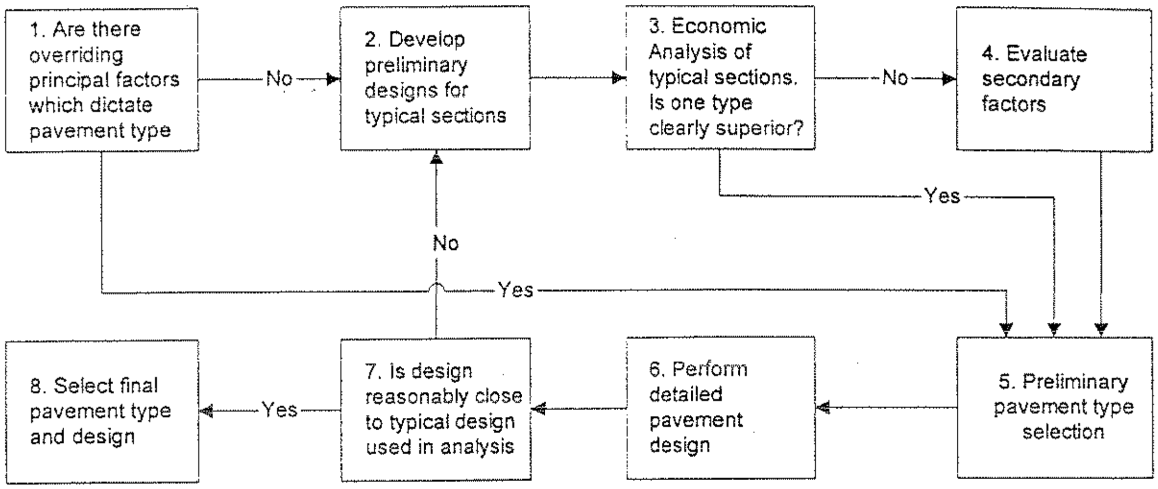


Figure 6. Pavement type selection process (figure B.1, AASHTO Guide).

<u>Secondary Factors</u>

1. Performance of similar pavements in the area
2. Adjacent existing pavements
3. Conservation of materials and energy
4. Availability of local materials or contractor capabilities
5. Traffic safety
6. Incorporation of experimental features
7. Stimulation of completion
8. Municipal preference, participating local government preference and recognition of local industry

## CONCLUSIONS AND RECOMMENDATIONS

This study called for a review and analysis of ODOT's pavement type selection process. The primary benchmark for the analysis was to be based on comparing and contrasting Ohio's process with those used by other highway agencies and recommendations of AASHTO and the FHWA.

The NTP team visited 10 highway agencies and reviewed and discussed their processes. When reviewing the practices of other highway agencies, we tried to identify advantages and disadvantages with specific aspects of their systems. We also consulted the trade organizations in a number of the States to get their views on pavement type selection.

The team has reviewed the written guidance provided by AASHTO and the FHWA. In addition, we have had informal discussions with FHWA officials in their Ohio Division Office and the Pavement Division and Contract Administration Group in the headquarters Office of Infrastructure.

### Conclusions

As the review of the highway agencies indicated, there are many and diverse approaches to the pavement selection process. The team's approach was to extract and evaluate, from the highway agencies visited, those attributes that address issues in Ohio. Further, we attempted to comply as closely as possible with the recommendations of both AASHTO and FHWA.

ODOT has attempted to develop an objective process that will eliminate second-guessing of their project-level decisions, by industry or other affected groups. As we have observed in Ohio and other highway agencies that have objective systems, the affected pavement industries realize that every detail in the process may have a significant impact on their future ability to obtain work in Ohio. This is in contrast to a more subjective system followed by a majority of the highway agencies interviewed, where, when net-present value is approximately equal, the highway agency has more flexibility in choosing secondary factors to help make the decision on pavement type. While in our opinion the Department has the sole authority to develop and implement a pavement type selection procedure, it is imperative that both the public and the pavement industries perceive the process as unbiased.

In the development of an objective type selection process it is important that the agency and the paving industries work together to try and reach some type of accord on the factors being considered. From what we have observed, coupled with the history and issues raised, this will be difficult in Ohio. The problem with this type of controversy is that it can lead to direction from outside sources. One avenue that is often pursued is a legislative remedy. This has been tried in the past, often with less than satisfactory results.

One example was Section 1038(d) of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), which mandated the use of quantities of asphalt pavement containing recycled rubber. This Section also contained specific penalties for those States unable to certify to the annual usage requirement. Section 205(b) of the NHS Designation Act of 1995 amended Section

1038 by striking subsection (d) eliminating the crumb rubber mandate and all associated penalties. One of the consequences of the Act was the inappropriate (from an engineering standpoint) application of the material resulting in excessive costs and in some cases to premature pavement failure. The problems encountered during the time of the mandate hampered implementation after the mandate ended. In addition, the mandate caused political fallout within the rubber asphalt industry and thus created a rift from its parent industry.

The issue of systemic bias raised by OCCA was not something that the NTP believes can be solved through technical modifications of the selection process. This must be addressed by the OCCA through effective marketing, education, product improvement, etc.

**Recommendations**

Based on all the above considerations, the NTP makes the following recommendations concerning the pavement type selection process in Ohio.

Recommendation #1—Improve Communication

Both the pavement industry and ODOT need to make a strong commitment to implement a plan to improve communications. The assertions of bias, legislative involvement, and the large number of detailed issues raised by both industries, indicate a need to improve the communication process.

We strongly encourage that all parties minimize the level of rhetoric and establish a more effective approach to address the many detailed issues that arise relative to pavement design, construction, and type selection. It is apparent that this will not be an easy recommendation to implement. As a first step we recommend that a facilitator be used to conduct meetings between industry and ODOT. The facilitator would work with the participants to develop a common understanding of the issues, to understand the interests of all the parties, to identify and evaluate solutions and to create an agreement that parties can implement. Meetings should be held on a regularly scheduled basis. The meetings should focus on technical issues. Industry suggestions should be supported with facts/data, and ODOT responses should also be supported by facts/data. The primary ODOT participants should be those technical managers responsible for pavement design and pavement type selection.

We would expect the use of a facilitator to be limited to approximately 6 one- to two-day meetings occurring during calendar year 2004. A scope of work for obtaining and selecting a facilitator is included in appendix F.

*Implementation*—Facilitator selected and meetings initiated during the first quarter of calendar year 2004.

*Benefit*—The benefit of implementing Recommendation #1 is that it will promote a more productive interaction between ODOT and the paving industries. It will provide a forum more conducive to addressing and resolving pavement design, pavement type selection, and specification issues. It is believed that many of the technical issues raised by the paving industries during the NTP interviews could have been resolved if there was an effective communication system in place.

Recommendation #2—Adopt a Modified Pavement Type Selection Procedure

This recommendation consists of modifying "Pavement Selection the ODOT Way" to more closely follow a management decision-making process. In the recommended process, the primary and secondary engineering factors and the economic factors would be evaluated. Rather than basing a decision on the absolute values developed by the process, the manager responsible for pavement type selection would weigh all the factors and make a decision. The current system has most of the components in place, and the intent of this recommendation is to strengthen certain aspects of the process and provide ODOT managers with needed flexibility. The NTP does not believe ODOT's current procedure is so flawed that pavement selection should be deferred pending implementation of a new process. Rather, we would expect that recommended modifications to the process will occur incrementally over the next 12 months.

Based on our review of the practices used by other highway agencies and the recommendations of AASHTO and FHWA, it is recommended that ODOT modify its pavement type selection procedure to follow the process shown in figure 7. This procedure is a modification of method A (see figure 2). The modifications are based on the AASHTO procedure outlined in figure 6. The key components of the procedure are as follows:

1. Complete an engineering review and analysis of the principal factors (as defined by AASHTO and ODOT) to determine which pavement alternatives are feasible for the project site.

2. Perform a LCCA in accordance with Recommendations 2a thru 2f below.

3. Evaluate the differences in life cycle costs between the various alternatives. This evaluation should consider the uncertainty and variability of the input factors used in the LCCA. Because of the uncertainty and variability in input factors, when the life cycle cost of an alternative is within 10 percent of the lowest life cycle cost alternative, they should be considered equivalent. The value of 10 percent is the typical value used by other highway agencies in evaluating equivalent costs. It is expected that the appropriateness of the 10 percent value will be better addressed as more highway agencies apply the probabilistic approach to LCCA outlined in FHWA's *Technical Bulletin on Life-Cycle Cost Analysis in Pavement Design* [2].

   At ODOT's discretion, an industry review of the LCCA would be appropriate at this time. This review would be primarily for the purpose of insuring that appropriate input factors used in the analysis are appropriate for the specific project.

4. For those alternatives with equivalent life cycle costs as defined above, an engineering analysis of the secondary factors as identified by AASHTO and ODOT should be completed. This process could follow a matrix type approach similar to the one currently being used in ODOT's type selection process.

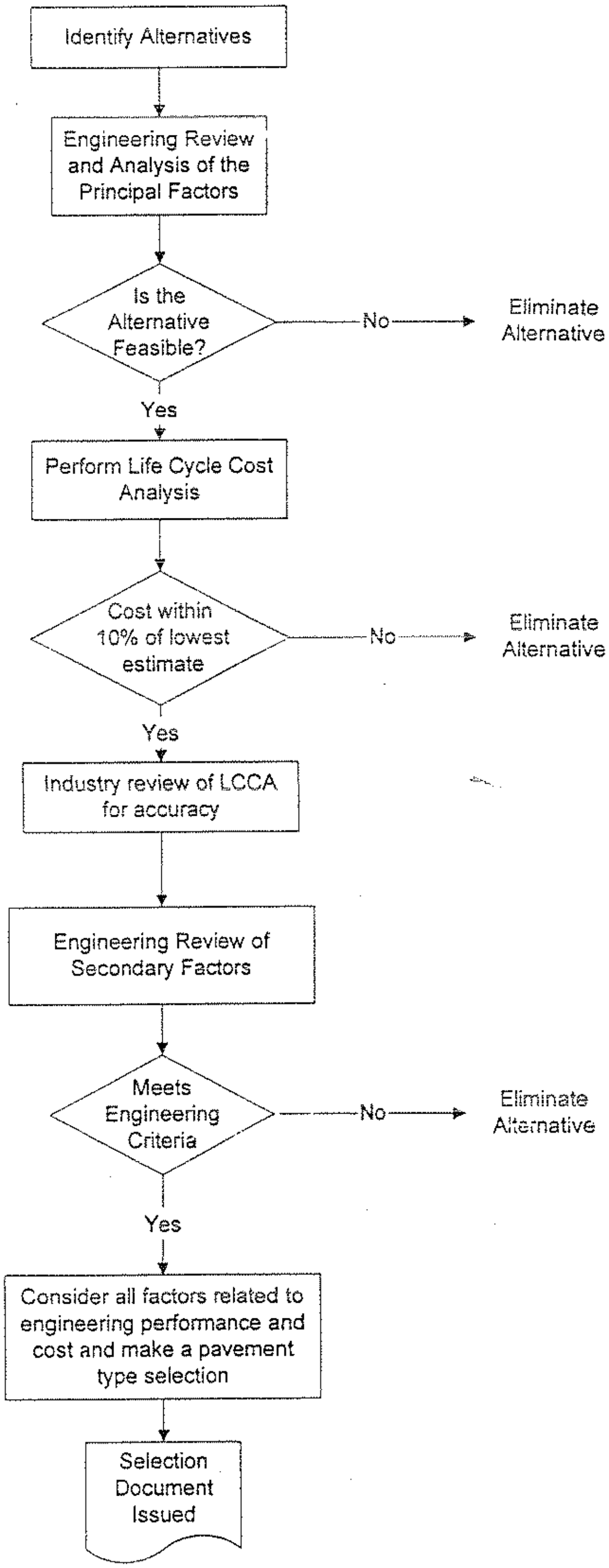


Figure 7. Recommended pavement type selection procedure for Ohio.

5. Upon completion of the secondary analysis those alternatives identified as being essentially equivalent from both engineering and LCCA standpoint would be evaluated. If the alternatives being evaluated are considered equivalent, it would be appropriate to consider factors such as first cost, minor differences in life cycle cost, or uncertainty about the expected level of performance.

Implementation—It is expected that the decision-making process outlined above can be implemented for all pavement type selections (on major rehabilitation projects longer than 4 lane miles calling for new or reconstructed pavements) made after January 1, 2004, using the data currently being developed for use in "Pavement Selection the ODOT Way." Incremental improvements in the development of the data used in the pavement selection process are expected to occur over the following 12 months. The NTP expects that over time ODOT may also find it necessary to make modifications to the process to meet their management needs.

Benefit—While the "Pavement Selection the ODOT Way" process is objective in its application, it is composed entirely of subjective factors. The NTP-recommended process recognizes the subjectivity of pavement type selection. It permits ODOT management to weigh the engineering and economic factors on a project-by-project basis, permitting site conditions to be addressed. The recommended process fully complies with the recommendations of AASHTO and FHWA.

The following are recommended modifications to strengthen the process:

*Recommendation #2a—Adopt a Traditional LCCA Approach*

The factors for initial construction and future maintenance should be eliminated and combined into one factor, life cycle cost. The LCCA should calculate a net present value that includes an initial cost comprised of all differential agency costs between the pavement alternatives and the total discounted future agency costs including all expected contract resurfacing and rehabilitation work. Where the remaining lives of the alternatives being considered are not equal, a salvage value based on remaining life should be included in the analysis. This type of LCCA is used by all of the 10 highway agencies interviewed.

Implementation—Traditional LCCA is expected to be used on all pavement type selections made after January 1, 2004. The data currently being used to estimate current and future costs can be used as input for the initial implementation of the LCCA, with recommended improvements to the data occurring incrementally.

Benefit—Adoption of a traditional LCCA approach will provide a process that is more transparent and easier to explain and understand than the weighting system currently used to evaluate current and future costs.

*Recommendation #2b—Develop Pavement Survival Curves to Better Establish Pavement and Overlay Lives for Use in LCCA*

The State should undertake a program to utilize pavement survival curves for Ohio pavements to evaluate and adjust the maintenance and rehabilitation schedules in their LCCA. ODOT should critically review the features of its pavement management database to ensure that the database will support the continued development and updating of project-related survival curves. The survival curves should reflect the current designs that are being used, age and traffic, etc. Examples of agencies that have developed survival curves include Illinois [3] and Ontario [4]. Other highway agencies that have reported using survival curves include Wisconsin and Michigan.

During the course of the review it was suggested that the NTP undertake the development of survival curves. However, it was determined that ODOT had an ongoing research project, "Evaluation of the Variation in Pavement Performance Between ODOT Districts," that includes the development of an informational database of all relevant pavement performance data and analysis procedures that will allow for the development and updating of pavement survival curves. This work is scheduled to be completed in April 2004. Appendix E contains a discussion on the application of survival curves.

At the request of the PSAC, the NTP explored the development of interim maintenance schedules for use in the LCCA pending the implementation of Recommendation 2b. The results of the NTP's analysis are contained in appendix G. Based on this analysis, the NTP believes the schedules currently included in "Pavement Selection the ODOT Way" are suitable for use on an interim basis. However, based on the practices followed by ODOT during the last 5 years, the NTP recommends that the width of planing for the 1.5-inch functional overlays of flexible pavements be reduced to mainline only.

Implementation—Within 6 months of the completion date of the research project, ODOT will adjust the pavement rehabilitation schedules in the LCCA procedure to reflect the expected performance of Ohio pavements.

Benefit—Developing and maintaining survival curves for pavements constructed in Ohio will provide the basis for developing logical and defensible pavement maintenance and rehabilitation schedules for Ohio pavements. Although this recommendation will require a commitment of resources to implement, it will eventually form the basis for most of the inputs required to evaluate future costs in the LCCA. The survival curves will also provide a benchmark for measuring the effectiveness of design changes or the implementation of new technologies.

*Recommendation #2c—Continue to Use the OMB A94 Discount Rates*

The OMB A94 30-year real discount rate should continue to be used in the LCCA. This is the rate recommended in FHWA's *Technical Bulletin on Life-Cycle Cost Analysis in Pavement Design*, dated September 1998 [2].

All of the highway agencies reviewed are using the discount rate contained in OMB A94 or one closely paralleling that rate (3 to 6 percent).

Benefit--The OMB A94 discount rate is widely accepted for LCCA and is easily defended. The development and basis of this rate is described in the circular prepared by OMB.

*Recommendation #2d—Evaluate the Application of Engineering and Administration Costs and Traffic Maintenance Costs in LCCA*

ODOT should not include the current 7% engineering and administration and 10% traffic maintenance costs in their LCCA. There are questions relative to proportion of these factors directly applicable to the pavement portion of a project and whether the percentage should vary by the type of rehabilitation work. The majority of highway agencies interviewed do not consider maintenance of traffic costs and engineering and administration costs in their LCCA. Most agencies consider these costs to be equal for each pavement type or the difference is considered to be insignificant between pavement types.

Implementation—This recommendation is expected to be incorporated into all pavement type selections performed after January 1, 2004. In the future, ODOT may wish to reconsider application of these factors as the LCCA process matures and improvements are made to the cost database.

Benefit—There has been controversy over the magnitude of the maintenance of traffic and engineering and administration costs that should be included in LCCA. Removal of these factors, pending the future availability of conclusive data to develop the factors, eliminates controversy over factors that many other States are not including in their analysis.

*Recommendation #2e—Develop Alternate Methods of Determining Unit Costs for PCC*

Until such time as ODOT has an adequate number of PCC projects to provide reliable unit costs for PCC pavements, ODOT should evaluate alternative procedures for developing initial cost estimates for PCC pavements. Because of the limited number of projects being constructed in Ohio, there is the possibility that cost estimates for some locations in the State may not be accurate. In areas where sufficient unit cost data are not available, it is recommended that estimating processes that consider the differences in materials or labor costs be used to adjust statewide unit prices for that area.

Implementation—Full implementation of this recommendation is expected within 6 months. In the interim, it is recommended that ODOT solicit industry comments on the unit costs being incorporated into the LCCA.

Benefit—Estimated initial cost is one of the most significant factors in LCCA. Improvement in procedures for estimating initial cost will make LCCA a more effective tool for managing the limited resources available for highway construction.

*Recommendation #2f—Develop User Delay Costs Procedure*

Four of the highway agencies that were interviewed are using (and three are developing) user delay models to include in their LCCA. It is recommended that ODOT undertake a research project develop a user delay cost procedure for incorporation in its LCCA. Since this research may take several years, in the interim, it is recommended that the current ODOT method of determining user delay days be used as a secondary factor in the pavement selection process.

As indicated in FHWA's Interim Technical Bulletin on LCCA [2] the decision to include or exclude user costs can significantly affect LCCA results. They describe several approaches for considering user costs, including consideration of the combined agency and user costs, as well as the separate evaluation of user costs. Development work for the user cost element of the LCCA process should include a state-of-the-art review of the various State practices for incorporation of these costs into the analysis process.

*Implementation*—This is a long-term effort expected to take 1 to 3 years for full implementation.

*Benefit*—Including user delay costs in the LCCA ensures that the impact on the highway user is considered during the pavement design process. With the advent of techniques such as just-in-time delivery, even minor impacts on traffic flow can have an adverse impact on the local economy.

Recommendation #3—Implement Alternative Bidding Trial Projects

Because of the issues raised relative to the lack of reliable unit costs for PCC pavements, we recommend that ODOT utilize FHWA Special Experimental Project 14 (SEP-14), Innovative Contracting Practices, to let (sell) a number of alternative pavement bidding projects over the next 2 years. It is recommended that 5 to 10 projects involving new or reconstructed pavements be selected for this effort. Projects selected should be those for which there are no significant engineering reasons for selecting a specific pavement type and the estimated life cycle costs show a difference of less than 10 percent. Projects selected should be on Interstate routes or non-Interstate routes with greater than 35 million rigid ESAL's for the 20-year design period or average daily traffic (ADT) greater than 30,000 vehicles/day, based on the most recent Traffic Survey Report and be approximately 5 centerline miles or greater in length.

At least five States have utilized alternative pavement type bidding under SEP-14. Its use is recommended for Ohio as a means of addressing issues raised regarding the development of initial cost estimates in the life cycle cost analysis. Michigan, Missouri, and Louisiana have used the process on a number of projects and have documentation on specifications and procedures followed. The Province of Ontario is also using the alternative bid process. ODOT should consult with these highway agencies to assist in establishing the most appropriate alternative bid process for Ohio. The typical approach followed by each of the agencies is to develop a life cycle adjustment factor for each of the pavement alternatives to be bid. The life cycle adjustment factor is a fixed-dollar amount added to each bid and is based on the agencies' estimate of the net present value of future rehabilitation work to be performed over the analysis period for each alternative. Since a certain amount of consensus with industry will be required to accomplish this, facilitated meetings are recommended.

Because of the increased engineering costs involved in developing plans for alternative bidding and the ongoing controversy that will arise in applying future costs to the contract bids, the NTP is not recommending that the use of alternative bid be adopted as a routine practice or extend beyond a maximum of 10 projects.

*Implementation*—This recommendation is expected to be accomplished during calendar years 2004 and 2005.

*Benefit*—This recommendation will go a long way toward improving the cost competitiveness of the two pavement types in Ohio. Alternative bidding provides a means of insuring that Ohio gets the most cost-effective pavement on major projects. It will also address the issue of appropriate initial costs for use in LCCA.

Recommendation #4—Address Pavement-Tire Noise Issues

ODOT should undertake a review to determine which noise mitigation techniques will ensure that future pavements provide suitable noise levels to adjacent property owners and motorists. Further, test sections should be constructed to verify the suitability of the techniques.

Pavement-tire noise is an issue that ODOT should address. Based on experience in other highway agencies, the concerns raised by a number of citizens in Ohio are real. There are four methods currently being used by agencies to address pavement-tire noise. They are as follows:

- Overlaying with open-graded HMA.
- Performing longitudinal tining of the PCC surface.
- Using the random transverse spacing developed in Australia.
- Using a random-spaced tining pattern developed in Wisconsin.

According to the FHWA, there has been good success with the first three techniques and varied success with the Wisconsin random tining concept. Good results with the longitudinal tining concept have been reported by California, Michigan, Kansas, and Colorado. The tining spacing and size is critical in reducing noise on PCC-surfaced pavements. Diamond grinding has also been shown to reduce the tire pavement noise levels on existing pavements. FHWA is currently developing a Technical Advisory on this subject and may be able to provide additional guidance.

*Implementation*—The full study is expected to take approximately 2 years. In the interim, the most promising techniques, based on FHWA recommendations should be incorporated into noise sensitive projects.

*Benefit*—There are techniques available to address the pavement-tire noise issue at little or no additional first cost. Addressing the pavement-tire noise issue after the fact can lead to large expenditures by the highway agency to mitigate the problem.

Miscellaneous Issues

Table 6 contains a listing of a number issues raised by the industries during our review. The types of issues raised are of the type that we would normally expect States and industry to resolve in a fairly routine basis through effective communication. We have provided a recommendation for each item; however, we believe further communication between ODOT and the affected industry would be appropriate.

Table 6. Issues that should be resolved by ODOT and Industry on a routine basis.

| Issue | Recommendation |
|---|---|
| 1. Warranty asphalt unit price tables should be based on a trend line of average price.<br><br>The price for warranty asphalt for quantities greater than 100,000 cubic yards does not agree with the source data that ODOT used to develop the tables. | It is recommended that the asphalt unit price tables should be based on a trend line of average prices and the apparent discrepancy for quantities greater than 100,000 cubic yards be resolved. |
| 2. Flexible reconstruction projects should be treated the same as rigid pavement reconstruction projects in terms of construction traffic management (i.e., if traffic is diverted to one side for rigid pavements, it should be the same for flexible pavements). | Limited Concurrence. The evaluation of traffic management plans was felt to be outside the scope of the NTP's review. However, this is an area of continued disagreement and therefore, the NTP recommends that ODOT establish procedures for evaluating each flexible reconstruction project and determining the most advantageous traffic management plan from the standpoint of construction operations and user safety and convenience. |
| 3. Suggest that Step 4 of the pavement selection process be modified to evaluate other factors such as bridge construction that could be the primary factor influencing traffic disruption. | We concur. |
| 4. Revise layer coefficients<br>Surface and intermediate layers -increase from 0.35 to 0.45.<br><br>Bituminous base from 0.35 to 0.37 (these revisions would reduce the required layer thicknesses and, therefore, cost). | Layer coefficients should be increased in accordance with the study recently completed for ODOT by the University of Toledo and an AASHTO Bulletin Board survey. The increase is supported with data, generally conforms to the 1993 AASHTO Guide, and follows practices of other States. |
| 5. Recycled asphalt<br>ODOT should review the current limitations on use based on a study done for the ODOT completed by CTL Engineering. | We do not concur. While many States may appear more liberal, most require recycled mixes to meet the same specification as virgin mixes for surface courses on high volume routes. This is an area where further discussion between ODOT and industry appears warranted. |

Table 6. Issues that should be resolved by ODOT and Industry on a routine basis (continued).

| Issue | Recommendation |
|---|---|
| 6. Break and seat<br>ODOT should allow the use of break and seat rehabilitation based on a study completed by the University of Cincinnati. | Recommend further study. Break and seat has very limited use. This item is not in the scope of work of the NTP study. |
| 7. The relationship used to convert CBR to resilient modulus may not be appropriate for use in Ohio. | We do not concur. The current method used to convert CBR to resilient modulus is within the range recommended in the AASHTO 93 Design Guide. |
| 8. The improvement in the CBR value due to soils stabilization is questionable. | We do not concur. No data were presented that indicated that the long-term durability of soils stabilization is a problem in Ohio. The State indicates they currently do not increase CBR when soil stabilization is performed. |
| 9. Since both pavement types are constructed to the same ride quality specifications, the same initial serviceability level should be used for both pavement types. | We do not concur. ODOT's selection of initial serviceability is based on measurement of completed pavement sections. We recommend that ODOT develop a process for continually monitoring the ride of newly constructed pavements and update the initial serviceability value annually based on this process. |
| 10. Pavement type selection should be revisited if the projects have been delayed for any significant time, as the traffic data may be out of date. | We do not concur. It would be prudent to verify the pavement designs for substantial differences in traffic expected from the original design values. Generally, time constraints and designs costs would preclude repeating the pavement type selection. |
| 11. The asphalt price adjustment provides an unfair advantage to the HMA. | NTP makes no recommendation on this issue. The current stability of asphalt prices makes this a minor issue at this time. Asphalt prices adjustments are used by half of the highway agencies interviewed. |
| 12. PCC should be considered recyclable. | ODOT specifications relative to the use of recycled concrete generally conform to the practices of the States reviewed. FHWA is currently reviewing the use of PCC materials and may provide further guidance on this issue. |
| 13. Method of payment for HMA and PCC should be the same (i.e., by the square yard for a specified thickness). Currently, HMA is paid by the cubic yard not to exceed planned quantity. PCC is currently paid by the square yard with a penalty for thickness less than the plan thickness, which results in PCC contractors increasing the quantity of concrete placed to ensure that they are not penalized for low thickness. | We do not concur. The method of payment used by ODOT is in general conformance with that used by other highway agencies. |

## REFERENCES

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

2. J. Walls, III, and Michael R. Smith, *Life-Cycle Cost Analysis in Pavement Design Interim Technical Bulletin*, FHWA-SA-98-079, Washington, D.C., 1998.

3. N.G. Gharaibeh and M.I. Darter, *Longevity of Highway Pavements In Illinois—2000 Update,* Final Report FHWA-IL-UI-283, Illinois Department of Transportation, Springfield, Illinois, 2002.

4. K.L. Smith, N.G. Gharaibeh, M.I. Darter, H.L. Von Quintus, B. Killingsworth, R. Barton, and K. Kobia, "Review of Life Cycle Costing Analysis Procedures" (in Ontario), Final Report prepared for the Ministry of Transportation of Ontario, Toronto, Ontario, Canada, 1998.

5. A. Bradbury, T. Kazmierowski, K.L. Smith, and H.L. Von Quintus, "Life Cycle Costing of Freeway Pavements in Ontario," paper presented at the 79th Annual Meeting of the Transportation Research Board, Washington, D.C., 2000.

# Appendix A

## "Pavement Selection the ODOT Way"

# The ODOT Way Pavement Selection Scoring System

Draft 4/17/03

| Scoring Category | Wt. | Imp. | Rel | Spread Factors | Available Points |
|---|---|---|---|---|---|
| **Life-Cycle Cost**<br>Initial Cost | 40 | 8 | 5 | Spread: 0-3%, 3.01-6%, 6.01-10%, 10.01-15%, >15%<br>Points: 1, 0.8, 0.5, 0.3, 0 | 1600 |
| Future Maint. Cost | 25 | 8 | 2 | Spread: 0-10%, 10.01-20%, 20.01-30%, 30.01-40%, >40%<br>Points: 1, 0.8, 0.5, 0.3, 0 | 400 |
| **User Delay**<br>Initial Construction | 30 | 3 | 3 | Spread: 0-25%, 25.01-50%, 50.01-75%, 75.01-100%, >100%<br>Points: 1, 0.8, 0.5, 0.3, 0 | 270 |
| Future Maintenance | 30 | 6 | 2 | Spread: 0-25%, 25.01-50%, 50.01-75%, 75.01-100%, >100%<br>Points: 1, 0.8, 0.5, 0.3, 0 | 360 |
| **Constructability**<br>Subgrade | 20 | 7 | 3 | Unbonded Concrete Overlay and Whitetopping = 1.0<br>New pavement and pavement replacement, all types = 0.7<br>Rubblize and Roll, and Crack and Seat = 0.6 | 420 |
| Drainage | 20 | 2 | 4 | New pavement and pavement replacement, all types = 1.0<br>Unbonded Concrete Overlay, Whitetopping, Rubblize and Roll, and Crack and Seat 0.8 | 160 |
| Uniformity of X-section | 20 | 6 | 5 | If no widening: All alternatives = 1.0<br>If widening (permanent lane addition):<br>New pavement and pavement replacement, all types = 1.0<br>Rubblize and Roll = 0.8<br>Unbonded Concrete Overlay, Whitetopping, and Crack and Seat 0.6 | 600 |
| Maintenance of Traffic | 20 | 7 | 3 | Alternatives with an advantage = 1.0<br>Alternatives with a disadvantage = 0.5<br>When no alternative has any advantage, all alternatives | 420 |
| **Environment**<br>Recycle-ability | 10 | 3 | 4 | New Flexible and Flexible Replacement = 1.0<br>Rubblize and Roll = 0.9<br>Crack and Seat = 0.8<br>New Rigid, Rigid Replacement, and Whitetopping = 0.7<br>Unbonded Concrete Overlay = 0.3 | 120 |
| Ride | 10 | 5 | 3 | All asphalt alternatives = 1.0<br>JAll concrete alternatives = 0.7 | 150 |

Wt. = Weight  Imp. = Importance  Rel. = Reliability  Total possible points = 4500

# Pavement Selection the ODOT Way

4-17-03

## The Purpose of Pavement Selection

The Pavement Selection Committee (PSC) is charged with selecting pavement type for new pavements and major rehabilitations. This authority is granted by the Pavement Design and Selection Process (Policy 515-002(P)). The selection of pavement type is not a simple one as the competing products both have advantages and disadvantages and both can provide excellent service for many years. This document describes the process the Ohio Department of Transportation (ODOT) uses to select pavement type.

There are many factors to be considered when selecting pavement type. Some factors relate to all projects, others may be project specific or may have varying importance on a project by project basis. Weighing the various factors requires a documented process for open, informed decision making. While any pavement type may be acceptable, this process provides fact-based reasoning for the pavement type selection.

## Changes in the Pavement Selection Process

Several changes in the pavement selection process have been instituted to improve the process, provide more consistency, provide better documentation, and result in more fact-based decisions. Significant changes are as follows:

- Life-cycle cost analysis (LCCA) performed by Office of Pavement Engineering (OPE);
- Unit prices determined by Office of Estimating (OoE);
- Added engineering and administrative costs on future maintenance projects;
- Added maintenance of traffic costs on future maintenance projects;
- Included industry involvement prior to the final selection;
- Eliminated Discount Rate Sensitivity Analysis in favor of a single discount rate provided annually by the federal Office of Management and Budget; and
- Developed scoring system to select one alternative.

## The New Pavement Selection Process

The new process provides a holistic approach to pavement type selection. This process depends on open and honest communication among various ODOT Divisions and Offices. To improve consistency, most of the work is performed by OPE. Increased attention to subgrade conditions is achieved by early involvement of the Office of Geotechnical Engineering (OGE) in the design process. The process includes industry involvement to allow time to identify any project specific concerns prior to the final decision.

In short, the process works as follows: the Office of Systems Analysis Planning (OSAP) identifies the projects, OGE provides subgrade recommendations, OPE designs the alternatives and prepares the LCCA and pavement selection package, OoE provides unit prices, District develops conceptual maintenance of traffic, OPE scores the alternatives and informs District and industries, and the PSC selects the approved alternative. The actual selection of the alternatives is based on a scoring system which encompasses many factors including construction and maintenance costs, user impact, constructability issues, and environmental factors.

Pavement Selection Steps

1. OSAP identifies projects as potential major rehabilitation candidates. Also, new pavement alignments identified.

2. OPE organizes a meeting with the District, Priority System Manager, and OGE to determine the critical path time line, date for delivery of soils recommendation and other issues as needed.

3. OPE schedules and performs Dynaflect testing and coring, and researches the pavement history.

4. OPE performs field review with the District and Priority System Manager to discuss potential alternatives, determine which alternatives are feasible, review the existing conditions, and determine the preliminary scope. At this time it may be determined that some projects do not require major rehabilitation and they will become minor rehabilitation.

5. Upon receipt of the soils recommendation, OPE designs the rehabilitation alternatives.

6. OPE calculates LCCA quantities and initial and future user delay. Alternatives such as rubblize or unbonded concrete overlay that require more than 40% removal and replacement due to bridge clearances, etc., will be eliminated from the analysis. The 40% figure was selected by the PSC as the amount beyond which alternatives will not be considered. Below that amount, economics and the scoring system will judge the worthiness of the alternative.

7. OoE provides unit prices. District provides documentation of any maintenance of traffic differences.

8. OPE calculates LCCA, prepares selection package and score, and distributes to District and industries.

9. OPE corrects any errors, submits LCCA package and scoring, and any District or industry comments to PSC.

10. PSC meets and selects the approved alternative. Pavement Selection the ODOT Way - 4-17-03 Page 3 of 10

11. OPE notifies District, FHWA, and industry of the approved alternative and maintains a file of the selection documents.

Roles and Responsibilities

OPE Coordinate with OSAP

Coordinate with District

Coordinate with OGE

Perform Dynaflect testing

Perform coring

Research pavement history and determine the existing buildup

Perform traffic loading predictions

Design pavement alternatives

Calculate LCCA initial construction quantities for all alternatives

Select future maintenance schedule for all alternatives

Calculate LCCA future maintenance quantities for all alternatives

Perform LCCA calculations

Calculate initial and future lane closure days

Score the alternatives

OSAP Supply list of potential major rehabilitation candidate projects

Revise list based on feedback or changes from OPE and District

OGE Coordinate with OPE

Coordinate with District

Perform subgrade investigation

Analyze subsurface investigation

Provide subgrade CBR recommendation

Provide stabilization and undercut recommendations

Determine feasibility of alternatives based on subgrade conditions

OoE Determine unit prices for all items

District Coordinate with OPE

Coordinate with OGE

Supply OPE with needed information

Develop conceptual maintenance of traffic for each alternative and define advantages or disadvantages to each

PSC Review the pavement selection scoring

Select approved alternative

**Unit Price Determination**

Unit prices will be estimated by the Office of Estimating in accordance with their business rules.

**Future Maintenance Schedules**

The new process has defined future maintenance schedules for the different pavement types. There are both advantages and disadvantages to this approach. The main advantage is that this removes another variable and a potential area for conflict. The disadvantages are that it does not account for local differences in performance and the schedules may not always be revised quickly to respond to changes in performance, materials, etc.

The schedules are divided by traffic levels. Interstate and other high traffic routes receive more maintenance than low traffic routes. On all future maintenance, once the pavement costs are calculated, they will be increased by an additional 7% to account for the Department's engineering and administrative costs. Also, the pavement costs will be increased by 10% to account for maintenance of traffic costs. The future maintenance schedules are as follows:

I. Interstates (all), Non-interstate routes with greater than 35 million rigid ESAL's in the 20- year design period **or** greater than 30,000 ADT in the most recent Traffic Survey Report from the Office of Technical Services.

A. Flexible, Rubblize, and Crack and Seat Pavements:

1. Year 12: 1.5" overlay with planing (full width of mainline and shoulders);

2. Year 22: 3.25" overlay with planing (full width of mainline and shoulders) and with 1% patching planed surface (percent of planed area); and

3. Year 34: 1.5" overlay with planing (full width of mainline and shoulders).

B. Rigid, Unbonded Concrete Overlay and Whitetopping Pavements:

1. Year 22: Diamond grinding (mainline plus one foot of shoulder), full depth repair 4% of mainline surface area; and

2. Year 32: 3.25" asphalt overlay, full depth repair 2% of mainline surface area.

II. Non-interstate routes with less than 35 million rigid ESAL's in the 20-year design period **and** less than 30,000 ADT in the most recent Traffic Survey Report from the Office of Technical Services.

A. Flexible, Rubblize, and Crack and Seat Pavements:

1. Year 14: 1.5" overlay with planing (mainline only); and

2. Year 25: 3.25" overlay with planing (full width of mainline and shoulders) and with 1% patching planed surface (percent of planed area).

B. Rigid, Unbonded Concrete Overlay and Whitetopping Pavements:

1. Year 25: Diamond grinding (mainline plus one foot of shoulder) and full depth repair 4% of mainline surface area.

**Pavement Selection Scoring System**

A scoring system was developed to weigh and combine all the factors important to pavement type selection. This approach is expected to provide for a more criteria-based pavement type selection.

The scoring system includes many factors. The four major categories are: Cost, User Delay, Constructability, and Environment. A weighting factor is applied to each of the scoring items to differentiate them from one another. This allows the importance factor, discussed later, to be judged independent of how it affects the final score. Initial Construction Cost receives a weight of 40, Future Maintenance Cost receives a weight of 25, all User Delay items receives a weight of 30, all Constructability items receives a weight of 20, and all Environment items receives a weight of 10. The four major categories are further broken down into individual sub-categories where the actual scores are applied.

There are four parts to the score for each factor. Part one is the weighting factor, 40, 25, 30, etc., discussed above. The second part is an importance factor. The importance factor is the relative importance of the item to ODOT. It is to be expected that other entities would assign different levels of importance but as the pavement selection decision belongs to ODOT, so does determining the importance factors. Importance factors vary between one and ten. The third part is a reliability factor. The reliability factor is the accuracy of or confidence in the data. For example, initial cost data is well established and has a high reliability factor but since future maintenance of traffic techniques are unknown, the reliability of future user delay is low. Reliability factors vary between one and five. The final part is a spread factor. The spread factor accounts for the differences between the alternatives. Spread factors vary between 0 and 1.0 depending on the difference between the alternatives. All of the factors, their weight, importance, and reliability are given below. Spread factors are detailed later.

1. Cost

   a. Initial Construction, Weight = 40, Importance (I) = 8, Reliability (R) = 5
   b. Future Maintenance, Weight = 25, I = 8, R = 2

2. User Delay (Weight = 30)

   a. Initial Construction, I = 3*, R = 3
   b. Future Maintenance, I = 6, R = 2

3. Constructability (Weight = 20)

   a. Subgrade, I = 7, R = 3
   b. Drainage Concerns, I = 2, R = 4
   c. Uniformity of Cross-Section, I = 6, R = 5
   d. Maintenance of Traffic, I = 7, R = 3

4. Environment (Weight = 10)

   a. Recycle-ability, I = 3, R = 4
   b. Ride, I = 5, R = 3

* User Delay - Initial Construction is given a low importance rating because it is expected that the same number of lanes as currently exist will be maintained during the initial construction in accordance with ODOT policy 516-003(P). Since the number of lanes is not reduced, the importance is judged to be low.

Definitions

1.a. Cost - Initial Construction

Cost of initial construction for each alternative. Initial construction cost is not affected by discount rate. Lower initial cost is preferable.

1.b. Cost - Future Maintenance

Total cost to maintain the pavement for the entire 35-year analysis period, using the real discount rate for 30-year or greater programs published in the current revision of Circular A-94, Appendix C from the federal Office of Management and Budget. Lower future maintenance cost is preferable.

2.a. User Delay - Initial Construction

Time in lane closure days to complete initial construction of the pavement items. Less time is preferable, however, time to construct the pavement may not be the controlling factor. This factor will not be used for pavements built in new locations or when it is determined that bridge or other work is the controlling factor.

2.b. User Delay - Future Maintenance

Time in lane closure days to complete all of the future maintenance activities. Less time is preferable.

3.a. Constructability - Subgrade

Potential risk due to unanticipated subgrade problems during initial construction. Higher risk could result in higher costs for initial construction due to change orders or could result in reduced performance if problems are not identified and corrected. Various alternatives and their level of risk are as follows:

Unbonded Concrete Overlay No risk

Whitetopping No risk

Rubblize and Roll High risk

New Flexible Pavement Medium to high risk

New Concrete Pavement Medium to high risk

New Composite Pavement Medium to high risk

Lower risk is preferable.

3.b. Constructability - Drainage Concerns

This relates to the ability to provide drainage. When the existing pavement is removed, a new drainage system can be properly located and easily installed. If the existing pavement is left in place, retrofitting new underdrains or replacing outlets of the existing drains is more difficult, may not be properly located, can undermine the existing pavement if the underdrain trench collapses, and may not provide the same level of drainage a new system would. New drainage is preferable to retrofitting.

3.c. Constructability - Uniformity of Cross-Section

Alternatives that do not include removing the existing pavement usually result in a large elevation increase and may require pavement removal and undercutting to lower the elevation at bridges. The result is non-uniform typical section along the length of the project. Also, if a new lane is being added, there will be non-uniformity across the width unless the existing pavement is removed. Non-uniform sections can result in differential performance. The entire pavement may have to be treated because a part of it is distressed. Uniformity across the length and width of the project is preferable.

3.d. Constructability - Maintenance of Traffic

This relates to the cost and ability to maintain traffic during the initial construction. District must develop a conceptual maintenance of traffic plan for each alternative and define the differences between alternatives. Alternatives with cheaper and/or easier maintenance of traffic are preferable.

4.a. Environment - Recycle-ability

This concerns the future recycle-ability of the pavement to be constructed. There are environmental and performance concerns with using recycled concrete in many applications. Disposal of old concrete may be expensive if no locations exist within the right of way to bury it. Recycled asphalt has none of these concerns when used according to the specifications. The ability to recycle is preferable.

4.b. Environment - Ride

A smooth ride is one of the most noticeable and important factors affecting the traveling public. Pavements built smoother initially tend to maintain smoothness longer. Smoother pavement is preferable.

Spread Factor

The spread factor accounts for the differences between the alternatives. Spread factors vary between 0 and 1.0 depending on the difference between the alternatives.

Initial Construction Cost

Alternatives within the specified percentage of the alternative with the lowest initial cost are assigned the given spread factor. Lowest cost alternative always receives 1.0.

| 0-3% | 3.01-6% | 6.01-10% | 10.01-15% | >15% |
|---|---|---|---|---|
| 1.0 | 0.8 | 0.5 | 0.3 | 0 |

Future Maintenance Cost

Alternatives within the specified percentage of the alternative with the lowest future maintenance cost at the real discount rate for 30-year programs published in the most recent federal Office of Management and Budget Circular A-94

Appendix C (3.2% as of Jan. 2003) are assigned the given spread factor. Lowest cost alternative always receives 1.0.

| 0-10% | 10.01-20% | 20.01-30% | 30.01-40% | >40% |
|---|---|---|---|---|
| 1.0 | 0.8 | 0.5 | 0.3 | 0 |

User Delay - Initial Construction

Alternatives within the specified percentage of the alternative with the fewest number of days of lane closure for initial construction are assigned the given spread factor. Alternative with fewest days always receives 1.0.

| 0-25% | 25.01-50% | 50.01-75% | 75.01-100% | >100% |
|---|---|---|---|---|
| 1.0 | 0.8 | 0.5 | 0.3 | 0 |

User Delay - Future Maintenance

Alternatives within the specified percentage of the alternative with the fewest number of days of lane closure for future maintenance are assigned the given spread factor. Alternative with fewest days always receives 1.0.

| 0-25% | 25.01-50% | 50.01-75% | 75.01-100% | >100% |
|---|---|---|---|---|
| 1.0 | 0.8 | 0.5 | 0.3 | 0 |

Subgrade

Unbonded Concrete Overlay and Whitetopping = 1.0

New pavement and pavement replacement, all types = 0.7

Rubblize and Roll, and Crack and Seat = 0.6

Drainage Concerns

New pavement and pavement replacement, all types = 1.0

Unbonded Concrete Overlay, Whitetopping, Rubblize and Roll, and Crack and Seat = 0.8

Uniformity of Cross Section

If no widening (permanent lane addition), all alternatives = 1.0

If widening:

New pavement and pavement replacement, all types = 1.0

Rubblize and Roll = 0.8

Unbonded Concrete Overlay, Whitetopping, and Crack and Seat = 0.6

Maintenance of Traffic

Alternatives with an advantage = 1.0

Alternatives with a disadvantage = 0.5

When no alternative has any advantage, all alternatives = 1.0

Recycle-ability

New Flexible and Flexible Replacement = 1.0

Rubblize and Roll = 0.9

Crack and Seat = 0.8

New Rigid, Rigid Replacement, and Whitetopping = 0.7

Unbonded Concrete Overlay = 0.3

Ride

All asphalt alternatives = 1.0

All concrete alternatives = 0.7

The table below shows each factor, its weight, importance, reliability, and the possible spread values.

| Factor | Weight | Importance | Reliability | Spread | | | | |
|---|---|---|---|---|---|---|---|---|
| Initial Const. Cost | 40 | 8 | 5 | 1 | 0.8 | 0.5 | 0.3 | 0 |
| Future Maint. Cost | 25 | 8 | 2 | 1 | 0.8 | 0.5 | 0.3 | 0 |
| User Delay - Initial Construction | 0 | 3 | 3 | 1 | 0.8 | 0.5 | 0.3 | 0 |
| User Delay - Future Maintenance | 30 | 6 | 2 | 1 | 0.8 | 0.5 | 0.3 | 0 |
| Subgrade | 20 | 7 | 3 | 1 | | 0.7 | | 0.6 |
| Drainage | 20 | 2 | 4 | 1 | | | | 0.8 |
| Uniformity of Cross Section | 20 | 6 | 5 | 1 | | 0.8 | | 0.6 |
| Maintenance of Traffic | 20 | 7 | 3 | 1 | | | | 0.5 |
| Recycle-ability | 10 | 3 | 4 | 1 | 0.9 | 0.8 | 0.7 | 0.3 |
| Ride | 10 | 5 | 3 | 1 | | | | 0.7 |

Other factors considered for the scoring system include: force account work, snow and ice differences, late season paving, highway lighting, and pavement markings. These factors were discarded because of low importance, low reliability or both, lack of any defensible spread difference between alternatives, or current research in the area. For example, highway lighting is designed the same for all pavement types so there is no difference between alternatives.

The score for each factor is determined by multiplying the weight by the importance by the reliability by the spread. For example, the alternative with the lowest initial construction cost would get a score for initial construction cost of $40*8*5*1.0 = 1600$. The total score for each alternative is the sum of the individual scores for each factor. The total number of points available is 4500.

### Future Updates to the Pavement Selection Process

It is expected that this process will be revised and updated in the future. A documented process will be developed to consider and implement or reject any changes which will affect pavement type selection. This will include design changes, specification changes, changes to the future maintenance schedules, changes to the scoring system, and all supporting information such as rules for estimating unit prices, production rates for lane delay, etc.

### Summary

The new process provides a more holistic approach to pavement selection. It is intended to account for all of the important differences between different pavement types and rehabilitation treatments. Each step in the process is clearly documented and the responsibilities are clearly defined. The process is not intended nor expected to make everyone happy. In a competitive environment between two industries, there will always be a winner and a loser on each project. This process will clearly show why one alternative was selected since decisions are made on technical criteria. The new process is an improvement and provides ODOT with a valuable tool to select the proper pavement type for a long-life, quality pavement.

Appendix B

# Pavement Type Selection Flow Charts

**for**

**10 Comparison States**

## ILLINOIS DEPARTMENT OF TRANSPORTATION PAVEMENT TYPE SELECTION PROCESS