PAVEMENT TYPE SELECTION: WHAT IS THE IDEAL PROCESS?

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ABSTRACT

Pavement type selection is often one of the more challenging and controversial decisions highway administrators face. The process involves weighing engineering factors such as materials, structural, and even long term performance against initial and life-cycle costs to help agencies decide between various pavement alternatives. Given the expenditure of significant public monies invested in pavement construction and rehabilitation, concerns have arisen recently about the equity and effectiveness of the pavement type selection process, particularly in light of ever-increasing needs, construction inflation, and dwindling resources to address the needs of the nation’s highways. In the United States, pavement type selection has been the subject of numerous publications over the last 50 years. This paper explores the history of pavement type selection in the U.S.; the guidance behind these practices; and a proposed pavement type selection process that attempts to include all possible and proper measures to ensure the taxpaying public receives full value of every highway dollar spent. This process considers pavement design equivalence, life cycle cost analysis, transparency, and most notably, the benefits that healthy competition between paving industries can provide.

KEY WORDS

CONCRETE PAVEMENTS / CONCRETE ROADS / COMPETITION / PAVEMENT TYPE SELECTION / LIFE CYCLE COST ANALYSIS.

1. BACKGROUND AND HISTORY

One of the earliest discussions about pavement type selection in the United States was published by the American Association of State Highway Officials or AASHO (now the American Association of State Highway and Transportation Officials or AASHTO) in 1960. This document, titled, “An Informational Guide on Project Procedures,” was developed in part to help state transportation engineers and other transportation officials make informed and transparent decisions about pavement types selected. This was deemed important because of the significant public monies invested in the construction of the nation’s system of Interstate highways. As noted in the guide, “The objective of every recommendation in every area ... is to assure the public of full value for their highway dollar.”

The guide acknowledges that highway engineers and other transportation officials do not have available generally accepted theoretical or rational tools to give an absolute and indisputable comparison of competitive pavement types for set conditions (AASHO, 1960). It goes on to highlight a series of prerequisites for the development of such an evaluation procedure moving forward, including:

- Improved scientific structural design methods for both rigid and flexible pavement structures to render comparable service under similar traffic and weather conditions.
- Availability of reliable cost accounting data, including maintenance costs for each pavement type.
- Improved understanding of pavement performance and applied loads (related to the AASHO road tests conducted in the late 1950s).

The guide then suggests that while improved data, tools, and methods are being developed, highway officials must rely on assumptions and empirical approaches, based on professional highway engineering judgement and experience.
Such an approach can result in a firm base for a pavement type decision if it includes the judicious and prudent evaluation and consideration of a number of governing factors. According to the AASHO document, there are a host of such factors, including ones pavement designers will easily recognize. These include traffic, soils characteristics, weather, past pavement performance, and economic/cost comparison. There are also several other governing factors that may no longer be that familiar to personnel involved in pavement type selection, however. These include conservation of aggregates, construction consideration, availability of local materials, and stimulation of competition.

The complete list of factors developed by the AASHO Special Committee on Project Procedures in 1960 is as follows:

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

It is significant to note that these factors, which were obviously relevant in 1960, are still key considerations today. However, understanding and characterizing many of these factors have evolved significantly during the past 54 years. In particular, structural design methods, pavement performance modeling and cost analysis have evolved dramatically as a result of decades of research, experimentation, observation, and modeling. Examples of advances in design and performance modeling include AASHTOWare’s Pavement ME Design software and ACPA’s StreetPave software. Economic or cost comparisons are made significantly easier with tools such as the Federal Highway Administration’s (FHWA’s) RealCost software, as well as good pavement management systems.

Notwithstanding these significant modeling and analytical advancements, challenges still remain before we are able to provide reliable and meaningful comparisons of competitive pavement solution for the purposes of pavement type selection. This fact was recognized and articulated in the 1960 AASHO document, “An Informational Guide on Project Procedures.”

In the section on “Traffic” and “Cost Comparison,” the authors discuss the virtues of considering cost on the basis of service life or service rendered by a pavement structure. The authors note: “Since the matter is one of basic economics, the cost comparison must also include not only the cost of original construction, but that of needed periodic repairs and routine maintenance over the service life of the pavement, and an estimate as to what its probable useable salvage value will be at the end of that time.” However, the authors go on to caution that “doubt as to the validity [of such analysis] arises in the case where one[ ]type of pavement has been given monopoly status by the long-term exclusion of a competitive type.” This makes the point that a cost analysis (i.e., an LCCA) may not be meaningful where you have only one pavement type available; the cost-data is not meaningful. This challenge is often not recognized or considered appropriately by decision makers today, despite the fact that it can render their cost analyses meaningless, even with the availability of powerful probabilistic life cycle analysis tools.
In the section discussing "Stimulation of Competition," the authors emphasize the value that competition between paving industries provides to highway agencies: "It is desirable that monopoly situations be avoided, and that improvement in products and methods be encouraged through continued and healthy competition among industries involved in the production of paving materials." Clearly, the authors of the day recognized the importance of healthy and spirited competition in providing value to the public. It is worth noting that the emphasis is on competition among industries involved in the production of paving materials – not just competition among companies within one industry.

To fully appreciate the significance of this recommendation, it is useful to understand the context in which highway officials of the day authored this guidance. In the early years of the U.S. Federal-aid highway program, there were a few, but very public instances of fraud and abuse related to the vast amounts of public funds expended (Weingroff 2006). Most of the fraud pertained to right-of-way acquisition, but there were also instances of collusion by industry, and questions concerning monopolies and pavement type selection. In the early days of the U.S. Interstate era, concrete was the predominant highway paving material. In much of the country, concrete pavement was the only realistic option. The lack of competition among industries involved in the production of paving materials not only stifled innovation and maintained higher costs for the public agencies, but also increased the potential for improper business dealings by the paving industry.

As a result of significant negative press surrounding these instances of neglect and abuse related to what FORTUNE magazine’s Justin Fox called "the greatest public works project in U.S. history," the public and the U.S. Congress started losing confidence in the entire administration of the highway program. At one point, the negative press was so prevalent that the future of the entire U.S. Federal-aid highway program seemed in question. The Federal Bureau of Investigation, the General Accounting Office, and even the U.S. House Special Subcommittee on the Federal-Aid Highway Program (also known as the Blatnik Committee), were engaged in probing the allegations of irregularities in the highway program. It was in this rather hostile environment that U.S. highway officials were charged with developing sound guidance regarding contract construction, pavement type selection, and right-of-way acquisition. As the resulting AASHO document notes, "It is imperative that all possible and proper measures be taken to ensure the tax payers of this country that they are receiving full value of every highway dollar spent… The recommendations included in this Guide are designed to keep the public confidence in the highway program at a maximum."

The authors of the day recognized that although improvements in understanding and characterizing factors such as traffic, materials, weather, pavement performance, cost estimation, etc. can enhance the basis for firm pavement type selections, the process is only meaningful if there exists healthy and spirited competition among the industries involved in the production of paving materials.

2. US FEDERAL GUIDANCE

In 1981, the U.S. Federal Highway Administration issued a Pavement Type Selection Policy Statement (Federal Register, 1981). This policy invoked and affirmed the guidance set forth in AASHO’s 1960 Guide.

The policy was designed to provide the public with acceptable highway service at a minimal annual or life-cycle cost, while also permitting maximum flexibility. It addresses four key issues:
1. Pavement type selection should be based upon an engineering evaluation considering the factors contained in the 1960 AASHO publication titled, “An Informational Guide on Project Procedures.”

2. Pavement type determinations should include an economic analysis based on life cycle costs of the pavement type. Estimates of life cycle costs should become more accurate as pavement management procedures begin providing historical cost, serviceability, and performance data. States without this data are encouraged to obtain it.

3. An independent engineering and economic analysis and final pavement type determination should be performed or updated a short time prior to advertising on each pavement type being considered.

4. Where the analysis reflects that two or more initial designs and their forecasted performance are determined to be comparable (or equivalent), then alternate bids may be permitted if requested by the contracting agency. The Division Administrator shall review the analysis and concur in the finding of equivalency prior to PS&B approval. Price adjustment clauses where utilized would also have to be treated on an equal basis.

This FHWA policy statement established guidance set forth in 1960 as the de facto pavement type selection policy for U.S. federal aid projects. It also emphasised the importance of using life cycle cost analysis as part of the decision making, and pointed out that the decision should be revisited immediately prior to advertising to ensure conditions have not changed. Finally, the policy encourages alternate bidding as a means to stimulate competition. The stated objective of this policy was to take advantage of fluctuating materials prices while not compromising good design and pavement management practices.

This federal pavement type selection policy remains in effect today, and is the basis for guidance provided in the 1986 and 1993 versions of the AASHTO Guide for Design of Pavement Structures.

4. CURRENT PRACTICE AND GUIDANCE

Despite the excellent guidance available in AASHO’s 1960 Guide and the existence of FHWA’s 1981 pavement type selection policy, there are vast differences in how state departments of transportation (DOTs) address pavement type selection in the U.S.

According to a recent survey of U.S. DOTs, twenty-two (22) of the responding thirty-five (35) state DOTs have a formal type-selection process that requires the consideration of alternative pavement types on major new and reconstruction projects (TRB, 2011). Of these twenty-two (22) state DOTs, twenty-one (21) require a life-cycle cost analysis (LCCA). Twenty-nine (29) of the thirty-five (35) responding state DOTs perform LCCA for new construction/reconstruction projects, out of which twenty-two (22) report having formal procedures, six (6) indicate use of a probabilistic process, and fourteen (14) indicate consideration of user costs in the analysis. Some states make decisions project-by-project; others make decisions programmatically; and others still make decisions at the district level. Several states use formal selection panels, while others do not. There are even some DOTs that have begun to experiment with alternate pavement-type bidding, where bidders are permitted to select a pavement type among two or more equivalent alternatives provided by the agency.

In 2011, the Transportation Research Board published a Guide for Pavement-Type Selection as part of National Cooperative Highway Research Program (NCHRP) Project 10-75 (TRB, 2011). This document provides a comprehensive set of procedures that highway agencies can use to
develop pavement-type selection policies and processes. An overarching goal of the effort is to provide the maximum utility value for both road users and taxpayers over the long term. The document calls for careful and rational consideration of economic, engineering, and environmental factors. It is broadly based on the list of governing factors presented in the 1960 AASHTO document as the basis of the pavement type selection.

Based on the findings of the NCHRP 10-75 work, a pavement type selection process should include a number of key components, including the following elements:

- A formal process for the identification of pavement type alternatives to be considered. This should be both comprehensive and transparent, involving both agency and industry personnel.
- A framework for LCCA, including establishing factors such as the analysis period, appropriate discount rates, and the handling of user costs.
- Use of an alternative screening matrix to weigh both economic and non-economic factors.
- Use of alternate bidding for projects having alternatives with equivalent performance where the analysis of economic and noneconomic factors does not indicate a clear preference.
- Where a significant period of time elapses between the original PTS and call for bids, the selection should be reviewed to ensure that conditions and costs have not changed appreciably.

The recommendations also note, “To maximize the economic value, the agency should consider alternatives that stimulate competition and incorporate innovative approaches.” (TRB, 2011)

A simplified flow chart illustrating the pavement type selection process is provided in Figure 1.

Figure 1 – Overview of the pavement type selection process
This process conforms substantially with the chart developed through the NCHRP 10-75 effort, although a few important adjustments have been made for emphasis and clarification. To facilitate a better understanding of the process, some additional explanation and detail is useful in several places (A detailed discussion on each of these steps is provided in the NCHRP report.) These include the following considerations, keyed to the appropriate section:

4.1. Selection Committee
The process starts with a pavement type selection committee to identify a broad range of alternatives for consideration in a systematic and unbiased manner. The committee should include representation from pavement design, materials, construction, and maintenance, and there should be a mechanism for industry to provide input. Transparency should govern the activities of this committee, as all reasons entering into the selection of pavement alternatives should be fully outlined and explained.

4.2. Life Cycle Strategies for Equivalence
Each alternative identified by the selection committee should be designed for the same traffic conditions, service life, and reliability – they should deliver equivalent performance to the road-user. AASHTOWare’s Pavement ME Design and ACPA’s StreetPave software are useful tools to establish this equivalence. The life cycle strategies for each alternative include the required maintenance and rehabilitation activities and their timing.

4.3. LCCA
After life cycle strategies for equivalence are developed, the life cycle cost for each alternative must be established, and then in turn, compared. Of paramount importance is the use of realistic data for pavement performance and maintenance intervals. Long term, real discount rates should be used, as published annually by the Office of Management and Budget Circular A-04 Appendix C. It is also important to consider real or relative prices changes in the analysis, as inflation rates for different materials can have a significant impact on the outcome of analysis (Lindsey et al). Both FHWA and the GAO have excellent guidance on how to conduct an LCCA, including what the important considerations are. (FHWA, 2003 and GAO, 2009)

4.4 Other Controlling Factors
After the life cycle costs are established, they should be weighed with other factors as well. This can be accomplished using an alternative-preference screening matrix. A detailed discussion of the economic and noneconomic factors in such a matrix are presented in the 2011 NCHRP report. However, it is critical that industry competition is adequately considered and accounted for at this stage. In some cases (e.g. where there is an absence of competition between paving industries) an agency could elect to select an alternative that does not have the lowest life-cycle cost, if the broader goal of stimulating competition between the industries is deemed to be of greater economic benefit to the agency. In such a case, the bigger financial goals of the agency govern. The question considered is whether the agency is benefitting appropriately from competition between industries? Where competition is deemed adequate, the lowest life-cycle cost alternatives would be considered as qualifying alternatives. Although there may be other non-economic and programmatic considerations that need to be weighed as well, none are as important and impactful as competition among industries.

4.5 Life Cycle Cost Comparison
If the life cycle cost of any one of the qualifying alternatives considered is more than 15% lower than all the others, that alternative should be selected. If not, all alternatives that have life cycle costs within 15% should be bid as alternates (as all these alternatives are considered cost equivalent).

4.6. Alternate Bid Alternate Design (ADAB)
For an ADAB process to work, it is critical that the process does not inadvertently compromise the integrity of the low bid process. FHWA provides excellent guidance on the ADAB process.
Among important considerations are: 1) the incorporation of a life cycle cost bid adjustment factor, 2) no use of commodity price adjustments, and 3) equivalent pay items.

Once a decision has been made, it is critical that the basis for the final decision is thoroughly documented in the project file by the persons in the highway agency having the responsibility of making that decision. This is important from a transparency perspective, so that highway officials can at a future date audit the process, and determine the propriety of actions taken.

Much of the guidance established by U.S. highway officials more than 50 years ago has been affirmed and validated as part of this NCHRP effort. What is also evident is that life cycle cost analysis, competition between pavement industries, and transparency are common threads in all the recommended processes and policies.

5. THE ROLE OF COMPETITION

Now more than ever, given the significant economic restraints and growing infrastructure needs, roadway agencies cannot afford to forgo any opportunity to make infrastructure dollars go farther. As recognized and documented in pavement type selection guidance over the last 50 years, ensuring competition between pavement industries can be a significant contributor in this regard.

Competition between industries in the transportation-construction marketplace is important because it assures the highest return on investment of taxpayer dollars by driving down costs. It also fosters innovation, which further increases value to agency/owners and the traveling public. Moreover, competition among contractors that construct different pavement types adds a dimension to the competitive environment that is not achieved where only one pavement material is used regularly or exclusively. This is commons sense and intuitive to most consumers in a free-market economy. Consumers in every sector of the economy (automobiles, consumer electronics, software, etc.) desire and value competition among industries and products, in order to benefit from both product improvements and cost savings.

To illustrate how this also applies in the pavement sector, the chart in Figure 2 was developed, using publicly available highway agency bid information published by Oman Systems, whose data represents 45 states. Average five-year state cost data confirms that states that use a stronger balance of pavement types (asphalt and concrete) get a bigger “bang for the buck” than those that use only one pavement type (asphalt). This occurs regardless of whether the state uses life cycle cost analysis or has embraced the latest mechanistic pavement design tools. In states where both pavement types are specified on a regular basis, healthy industries with skilled personnel develop; construction quality improves; and risks decline, bringing about more cost efficient pavement construction and significant savings.
Figure 2 - 2013 weighted unit costs vs. five-year average balance of DOT pavement type usage (based on publicly available data in Oman Systems bid tabulation database).

Figure 2 illustrates that when competition between the pavement industries grows (as indicated by an increasing share of pavement spending on concrete, moving right on the x-axis), the average unit costs for both concrete and asphalt pavements are lower. The additional competition allows the agency to extend its current budget, build more pavements, and add long-life solutions to their system. The fact that long-life (concrete) pavements benefit the system’s remaining service life is an added bonus.

Another way to use this information is to perform a break-even analysis to find out what happens with varying levels of competition between industries (balance in use of concrete and asphalt pavements). Table 1 illustrates the benefit.

Table 1 - Break-even analysis for $200 million per year budget for pavements

<table>
<thead>
<tr>
<th>Budget</th>
<th>Concrete Portion of Budget</th>
<th>Expenditure on Asphalt ($)</th>
<th>Asphalt Unit Price ($)</th>
<th>Tons of Asphalt</th>
<th>Expenditure on Concrete ($)</th>
<th>Concrete Unit Price ($)</th>
<th>Square Yards of Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>$200 M</td>
<td>0%</td>
<td>$200 M</td>
<td>$83.88</td>
<td>2,384,232</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$200 M</td>
<td>5%</td>
<td>$190 M</td>
<td>$81.24</td>
<td>2,338,829</td>
<td>$10 M</td>
<td>$66.94</td>
<td>149,380</td>
</tr>
<tr>
<td>$200 M</td>
<td>10%</td>
<td>$180 M</td>
<td>$78.59</td>
<td>2,290,382</td>
<td>$20 M</td>
<td>$56.13</td>
<td>356,314</td>
</tr>
<tr>
<td>$200 M</td>
<td>15%</td>
<td>$170 M</td>
<td>$75.94</td>
<td>2,238,558</td>
<td>$30 M</td>
<td>$49.81</td>
<td>602,348</td>
</tr>
<tr>
<td>$200 M</td>
<td>20%</td>
<td>$160 M</td>
<td>$73.29</td>
<td>2,182,989</td>
<td>$40 M</td>
<td>$45.32</td>
<td>882,666</td>
</tr>
<tr>
<td>$200 M</td>
<td>25%</td>
<td>$150 M</td>
<td>$70.65</td>
<td>2,123,255</td>
<td>$50 M</td>
<td>$41.84</td>
<td>1,195,137</td>
</tr>
<tr>
<td>$200 M</td>
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<td>$140 M</td>
<td>$68.00</td>
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<td>$60 M</td>
<td>$38.99</td>
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<td>$130 M</td>
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<td>1,989,266</td>
<td>$70 M</td>
<td>$36.59</td>
<td>1,913,236</td>
</tr>
</tbody>
</table>

For example, assume a state spends $200 million per year on pavement items, and 100 percent of its pavement dollars are spent on asphalt. At this level, with no competition between the industries, the asphalt would cost approximately $83.88 per ton. Thus, the state can purchase a little under 2.4 million tons of asphalt for their $200 million budget. Now suppose the state instills more competition by using concrete pavement (via alternate bidding, programmatic selection or some other means). Assume the state plans to spend the same $200 million, but this time, 15% of its budget is spent on long-life concrete pavement. The additional competition drops the asphalt unit cost to $75.94 per ton and one might expect to pay $49.81 per square yard for the concrete pavement. For the same $200 million budget, the state still gets about the same tonnage of asphalt as before, but it also receives more than 600,000 square yards of concrete pavement. If 30% of the budget is spent on long-life concrete pavement, then the asphalt unit cost falls to $68.00 per ton, and one can expect to pay $38.99 per square yard for the concrete pavement. The state agency can get almost two million square yards of concrete pavement.

The examples presented in Figure 2 and Table 1 are based on a very rudimentary analysis of actual bid data, which are publicly available. It is important to acknowledge that there is significant scatter in this data, particularly when concrete share is less than 20%. This is likely due to other actors influencing the relationship between competition, as well as asphalt and concrete unit prices. Such actors could include the total number of bidders and overall paving volume (size of market). A more in-depth analysis would need to be undertaken to better isolate and quantify the impact of concrete share on unit prices, particularly when share is less than 20%. Regardless, the following observations may be made about the data:

There is clear trend toward lower unit prices for both asphalt and concrete when the share of pavement spending for concrete versus asphalt increases within the range from zero to 40%.
Variability in the unit prices for both materials decreases with increasing levels of competition. States with higher levels of competition tend to be states with a stable and predictable paving program. This implies that sustained programs (for both concrete and asphalt) are important in maintaining predictable and low unit process.

Instilling competition is simply better business practice for a state highway agency. There are no downsides to fostering two healthy industries to compete for state highway projects. The state benefits in terms of cost efficiency, innovation from contractors, and network health; the paving industries benefit in terms of programs that support a quality work force to build quality pavements; and the public benefits from it all.

6. CONCLUSION

Much has been written about pavement type selection in the last half-century. To that end, guides have been developed, studies have been conducted, and policies have been written. Most U.S. pavement type selection procedures acknowledge and account for improvements in understanding and characterization factors such as traffic, materials, weather, pavement performance, cost estimation, etc. However, what appears to have been either forgotten or overlooked, is that the pavement type selection process is only meaningful if there exists healthy and spirited competition among the industries involved in the production of paving materials.

A proposed pavement type selection procedure was presented, based largely on a process developed by NCHRP in 2011, with some important adjustments and enhancements to increase the likelihood of an equitable and rational pavement type decision. Design equivalence is paramount, and the latest pavement design tools can help agencies ensure they are comparing equivalent pavement sections. The process must consider competition overtly in the process for the cost analysis to be meaningful. Finally, the pavement type selection must be fully detailed and documented in the project files for the purposes of transparency and future review.

An analysis was performed of actual bid cost information for concrete and asphalt pavements in 45 U.S. states to illustrate the important role that competition between industries plays in the process of assuring the highest return on investment of taxpayer highway dollars.

In conclusion, for pavement type selections to be equitable and meaningful, they must be made in the context of a competitive market place. None of the other governing factors has such a pronounced effect on the ability of highway agencies to address the mounting infrastructure challenges using severely constrained resources. Competition represents the most significant opportunity for highway agencies in today’s economic environment.

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