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Life-Cycle Cost Adjustment Factors in Alternate Design/Alternative Bid Pavement Bids: Added Value or Added Controversy?

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Abstract

Alternative design/alternative bids (ADAB) provides a mechanism for the asphalt and concrete paving industries to compete for the same paving project. It operates on the principle of the market pricing of each material determining which is most economical when the bids are opened, rather than selecting the pavement type during design based on a life-cycle cost analysis (LCCA). This paper reviews including LCC-based bid adjustment factors in the ADAB award decision. Data are from a survey that received responses from 40 U.S. Departments of Transportation (DOT) and the Canadian province of Ontario, and a content analysis of 55 ADAB project outcomes in 13 U.S. states and three Canadian provinces. Seven algorithms in use to calculate an ADAB bid adjustment factor were found, and six U.S. DOTs that award ADAB projects without an adjustment factor. The paper finds that the adjustment factor formula rarely influences the award decision and, generally, the pavement type with the lowest bid cost wins with or without the adjustment factor. The paper models the ADAB process in financial terms as an exercisable commodity option that accrues value from the differential rates of volatility between asphalt and concrete. It concludes that an LCC-based bid adjustment factor complicates the award process, creating potential for controversy over what the factor inputs are, and does not add value over bidding the pavement types head to head and awarding to the low bidder. The ADAB process increases the number of bidders and reduces unit bid prices for both pavement types.

Selecting the pavement type for a highway construction project is a decision that transcends the technical design process. It has become increasingly controversial over the past several decades as the asphalt and concrete paving industries fight for market share by trying to influence the decisions made by public officials on fundamental highway design. The issue is made more contentious by the persistent perception by both engineers and non-engineers that is expressed succinctly by a quote from Suvo and Stonecypher: "Concrete roads are highly durable and more environmentally friendly as compared to asphalt roads. However, asphalt paving costs far less than concrete paving" (*1*). The fight spilled out of the technical realm and into the financial realm when the FHWA promoted the use of life-cycle cost analysis (LCCA) as the means to determine the most economical pavement type during the design process (*2*). The quest for the most economical solution eventually led to the development of alternative design/alternative bids (ADAB) as a means of providing a mechanism to allow both industries to compete for the same project (*3*). However, even when both materials are available as acceptable options, the controversy over the means for selecting the winning bidder remains because the generally accepted approach is to develop an LCC adjustment factor that is applied to the bid price for the asphalt, and sometimes also the concrete bid, to account for the difference in service lives and maintenance costs.

The objective of this paper is to detail the state of the practice regarding ADAB and LCC adjustment factors, and then discuss the technical and financial advantages and disadvantages of the LCC adjustment factor in ADAB bidding. The information provided comes from a 2016 NCHRP study on the topic which drew survey responses and case studies from 40 U.S. state Departments of Transportation (DOTs) and the Ministry of Transportation of the Canadian province of Ontario (MTO). The study identified seven different formulae

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for calculating the LCC adjustment factor and identified six DOTs that bid hot-mix asphalt (HMA) and Portland cement concrete (PCC) pavement types head to head without an LCC adjustment factor. Lastly, the paper posits that although the philosophy of LCCA-based pavement design decisions is certainly intuitive, the practice is far from standardized, as seen from the seven different LCC adjustment algorithms, and that the volume of LCCA research indicates that LCC is highly sensitive to the input assumptions made for variables, like the discount rate, the period of analysis, and the residual (salvage) value for the pavement type with the longer life (*2, 4, 5*). These facts make one question the utility of the LCC adjustment factor itself in the ADAB bidding process, considering the well-documented continuing controversy over appropriate input values (*4–6*).

Background

NCHRP Synthesis 499: *Alternate Design/Alternate Bid Process for Pavement-Type Selection* concluded the following about ADAB practices:

> Alternate Design/Alternate Bid (ADAB) allows the pavement-type selection decision to be made as part of the procurement process by permitting contractors to bid their preferred alternative using real-time market pricing for the paving materials. This synthesis found that many ADAB projects documented an increased number of bidders on a given paving project by allowing both the asphalt and concrete paving industries to compete. ADAB projects also document a general trend of overall bid unit price reduction for both pavement types. (*3*)

FHWA *Technical Advisory T 5040.39: Use of Alternate Bidding for Pavement-Type Selection* (*7*) defines ADAB as a procurement in which two or more equivalent pavement designs are furnished, allowing the marketplace to determine the most economic pavement type based on real-time pricing for both alternatives at the time of letting. The Technical Advisory advises that ADAB is "a suitable approach for determining pavement type when engineering and economic analysis does not indicate a clear choice between different pavement designs" (*7*) Synthesis 499 also found that many agencies that use ADAB have established a criterion for the relative values of asphalt and concrete pavement LCCs, such as being within a given percentage of each other, as the trigger for implementing ADAB on a given project (*3*). The synthesis found that the cost of preparing two sets of equivalent designs was trivial. In fact, the Indiana DOT calculated a saving of $3.8 million on nine ADAB projects, which yields a benefit cost ratio of 11.4 for the additional fee paid to its design consultants for the extra pavement design (*8*).

Lastly, Synthesis 499 found that "implementing ADAB contracts can lead to increased competition and reduced pavement material costs" (*3*). The Missouri DOT reported an average increase of two more bidders per letting, and a 5% to 8% decrease in price in asphalt and concrete paving prices in over 187 lettings. The Indiana, Louisiana, and Michigan DOTs all reported a decrease in pricing on their ADAB projects when compared with conventional paving projects. The Portland Cement Association maintains ADAB "gives the contractor a choice to bid on either a concrete or an asphalt option, thereby increasing the number of bidders on each job and enhancing competition" (*9*).

Impact of Construction Material Price Volatility

The difference between classical LCCA and the development of ADAB LCC adjustment factors has to do with the timing of the pricing data. FHWA provides guidance for LCCA that is intended to compare the total whole life costs of design alternatives to make the pavement-type selection decision (*2*). The FHWA LCCA primer maintains that construction costs are only a part of the analysis and it provides a method for comparing the life-cycle costs and benefits of possible pavement design alternatives (*10*). Typical pavement includes costs for design, construction, maintenance, rehabilitation, and user costs over a period of analysis spanning at least one major rehabilitation (*11*). However, this analysis is conducted using estimate prices for costs that will all occur several years in the future after the project is awarded. Therefore, estimates for material price escalation must also be made, and this is when volatility in the construction materials market can affect actual costs.

The term "price escalation" denotes an inherent bias to inflate all future costs as a conservative measure to keep the project's budget sufficient to allow an award as scheduled. This philosophy unintentionally eliminates the ability to accrue savings as a result of deflation in one commodity versus its competing alternate. Figure 1 shows the differential changes in liquid asphalt and Portland cement commodity prices over the period of January 2004 to June 2017 (*12*). The figure shows that during the period from June 1, 2008 to December 1, 2008 that asphalt's commodity price experienced a swing of 16% (+11% in June to −5% in December). In the same period, cement's volatility was only about 2%. In the first 5 months of 2017, the asphalt volatility ran from +8% to −5% with cement running from +3% to −1%.

Figure 2 shows the Federal Reserve Bank of Saint Louis' asphalt and Portland cement indexes over the same period (*12*). Although the two metrics are not calibrated to one another, they have been graphed in juxtaposition to provide a visual representation of how they have moved with respect to each other over the same period as the commodity prices shown in Figure 1. Figure 2 appears to indicate a slight trend to the two indexes changing in opposition to each other. In other words, when asphalt goes up, cement goes down, and vice versa. The information provided in the figures leads to two conclusions. First, making pavement-type selection decisions with LCCA based on pricing assumptions established years before letting, and escalated at some fixed discount rate to the future, is an exercise in futility. The

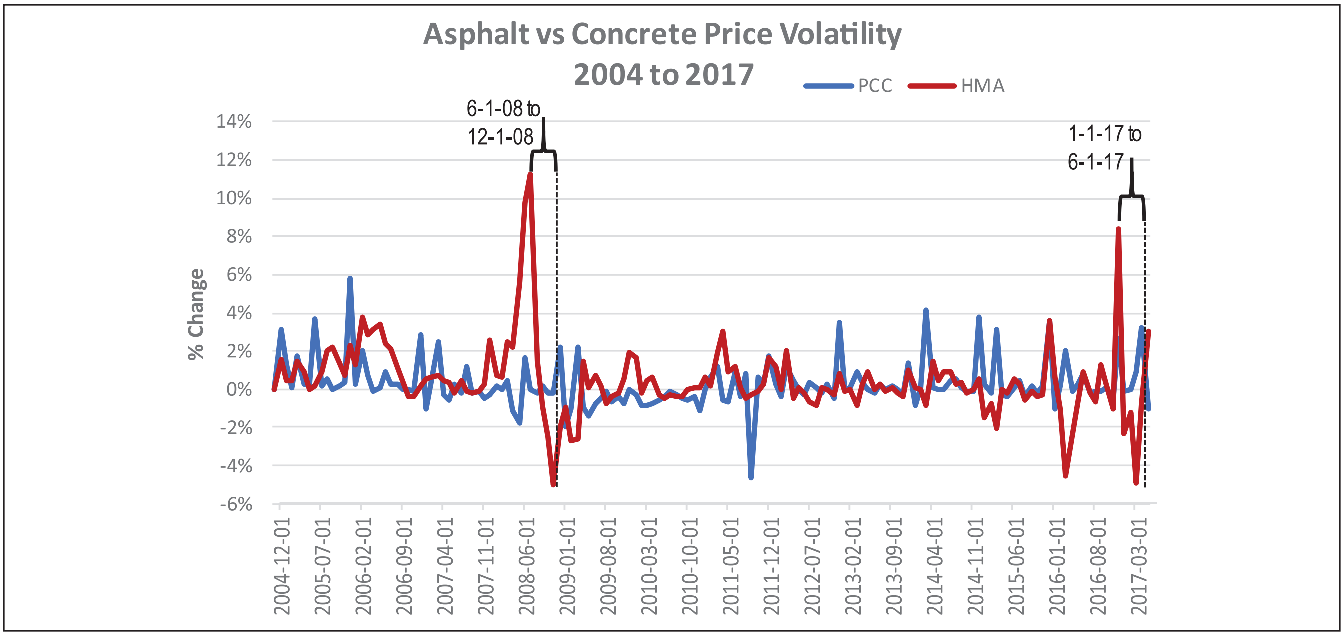

Figure 1. Pavement type volatility (*12*).

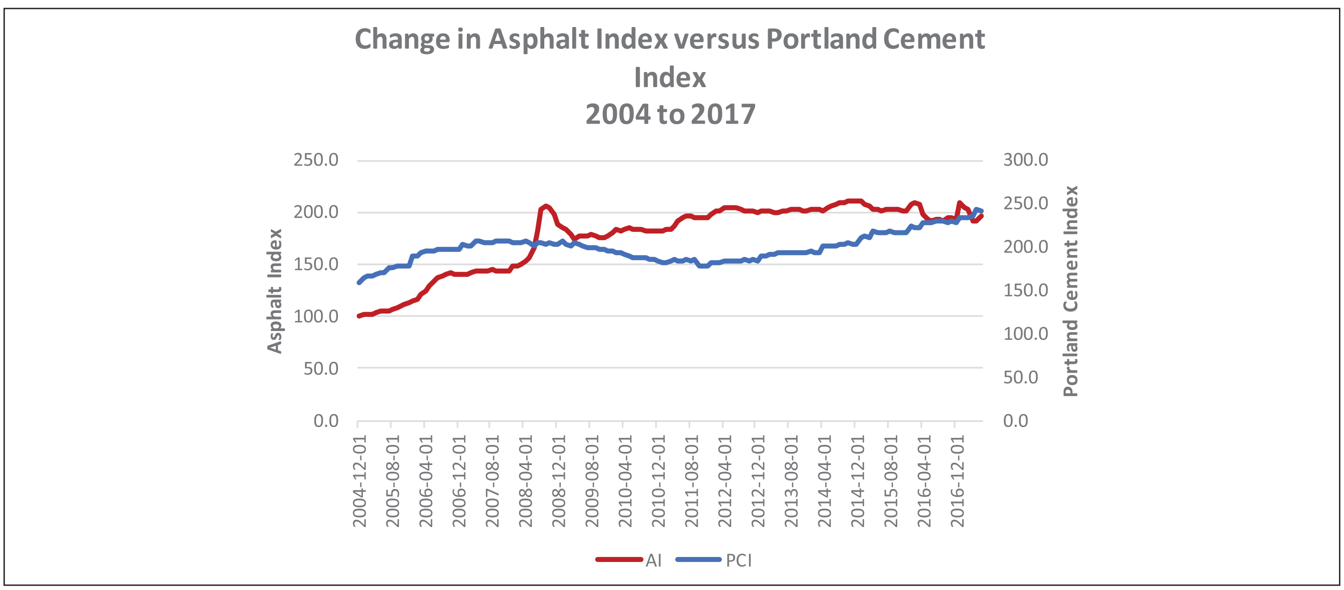

Figure 2. Relative change in asphalt and Portland cement indexes (*12*).

conventional perception that "asphalt paving costs far less than concrete" (*1*) is faulty. Second, by selecting a pavement type before the day of letting, the agency is giving up the opportunity for cost savings accrued from a favorable swing in the relative prices of the two pavement types in the commodities market.

Whereas vast volumes of forward and futures contracts are traded daily on commodity exchanges to profit from the types of volatilities described above, similar hedging strategies are not common in construction projects. For instance, the daily trading volume for West Texas Intermediate futures, which could be used to hedge exposures to asphalt prices in a pavement project, is over $50 billion (*13*).

The price volatility of different construction inputs under varying pavement-type designs creates the so-called option value, as it is referred to in the finance literature (*14*). In fact, deferring the timing of the pavement-type selection decision to test the market prices of competing design alternatives would be described as "deferment (learning) real options" (*15*). Thus, once the value embedded in the ADAB practices is recognized as option values (i.e., potential cost savings from allowing alternative design proposals to compete based on

Table 1. LCC-Based Bid Adjustment Factor Summary (*3*)

Name	Formula	Highway agencies
A + C bidding; C applied to HMA only	HMA bid = HMA contract bid amount + NPW of future HMA rehab PCC bid = PCC contract bid amount	Kansas, Montana, Oklahoma
A + C bidding; C applied to both	HMA bid = HMA contract bid amount + NPW of future HMA rehab PCC bid = PCC contract bid amount + NPW of future PCC rehab	Indiana, Kentucky
A + B + C bidding	HMA bid = HMA contract bid amount + value of time + NPW of future HMA rehab PCC bid = PCC contract bid amount + value of time + NPW of future PCC rehab	Kentucky, Louisiana
A + C + lane rental	HMA EUAC = HMA contract bid amount + lane rental + future HMA maintenance costs (capital recovery factor at OMB discount rate for 26 years) PCC EUAC = PCC contract bid amount + lane rental + future PCC maintenance costs (capital recovery factor at OMB discount rate for 26 years)	Michigan
Adjustment factor	Adjustment factor = NPW future asphalt rehab – PW future concrete rehab Low bidder = lower of (PCC bid price) versus (HMA bid price + adjustment factor) (Assuming asphalt has higher NPW M&R costs)	Missouri
LCC advantage	Low bidder = lower of (PCC bid price + NPW future concrete M&R) versus (HMA bid price + NPW future HMA M&R)	Ontario
A – D (alternative differential) bidding	Adjustment factor = fixed value set by DOT for each project Low bidder = lower of (PCC bid price- adjustment factor) versus HMA bid price (Assuming asphalt has higher NPW M&R costs)	Iowa
No adjustment	Low bidder = lower of PCC bid price versus HMA bid price	Alabama, Arkansas, Florida, North Carolina, Ohio, West Virginia

Note: NPW = Net Present Worth; EUAC = Equivalent Uniform Annual Cost; OMB = US Office of Management and Budget; M&R = Maintenance and Repair.

market conditions), the decision of whether to employ ADAB is merely a decision on the timing of when the agency's option is exercised. That is, selecting the final pavement type during design exercises the agency's option and forgoes the possibility of accruing benefits by exercising its option at letting by using ADAB. According to one author: "Bidding pavements 'head-to-head' allows the open market to determine what is constructed … not outdated assumptions made during the [pavement-type] evaluation/selection process years before letting" (*16*). The Missouri DOT made the decision to employ ADAB on all projects that exceeded 7,500 yd^2 of paved surface in 1996 (*17*). By doing so the Missouri DOT made the business decision to exercise its pavement material option as late as practical and, as will be discussed later in the paper, accrued substantial benefits as a result.

Methodology

The information contained in this paper was extracted from NCHRP Synthesis 499 (*3*). That broader effort collected survey data from 40 U.S. state DOTs (an 80% response rate), case studies from five U.S. state DOTs and the MTO in Canada, as well as a content analysis of the research literature on the topic. This paper goes on to prepare a detailed analysis of the LCC adjustment factor's impact on the pavement-type selection for a typical ADAB project to establish a conclusion on the utility of those factors in the overall process. The paper answers the following research question:

> *Does the inclusion of a LCC adjustment factor in the algorithm for determining the most economical bid price add value to the procedure?*

Table 1 shows the options found in NCHRP Synthesis 499 (*3*) that are used by DOTs to calculate a rational LCC adjustment factor. It is important to note that there seems to be no single uniform method for accounting for the difference in pavement-type service lives, post-construction operations and maintenance costs, or the amount of disruption the public will experience during construction. In addition to the various adjustment factor options, the survey found that six states apply ADAB without adjusting the bid pricing and rely on direct competition between the pavement types.

One of the major differences that can be observed in Table 1 is a difference in philosophy as to just how the LCC

Table 2. LCC Adjustment Factor Outcome Analysis

Bid	Alt	Initial bid	NPW future costs	A + C bidding; C applied to HMA only	A + C bidding; C applied to both	Adjustment factor	LCC advantage	A – D (alternative differential) bidding	No adjustment
A	HMA	29,072,406	827,376	29,072,406	29,899,782	29,899,782	29,899,782	28,245,030	29,072,406
B	PCC	25,747,900	356,240	25,747,900	26,104,140	26,104,140	26,104,140	25,391,660	25,747,900
C	PCC	27,978,568	356,240	27,978,568	28,334,808	28,334,808	28,334,808	27,622,328	27,978,568
D	PCC	29,999,350	356,240	29,999,350	30,355,590	30,355,590	30,355,590	29,643,110	29,999,350
E	PCC	43,419,000	356,240	43,419,000	43,775,240	43,775,240	43,775,240	43,062,760	43,419,000

Table 3. Summary of ADAB Project Outcomes Found in the Literature

Outcome		Outcome		Metric
Total ADAB projects	55	Total bids submitted	313	5.7 bids/project
Total HMA bids submitted	137	No. projects when HMA won	18	33%
Total PCC bids submitted	176	No. projects when PCC won	37	67%
No. projects with no HMA bids submitted	2	Total bids received when HMA won	80	26%
No. projects with no PCC bids submitted	4	Total bids received when PCC won	233	74%

adjustment should be applied. Five DOTs (Iowa, Kansas, Missouri, Montana, and Oklahoma) only apply the factor to the HMA option, whereas the rest apply it to both options. Failing to apply the factor to both options may induce an unintentional bias, as one option is being compared on the cost of its entire life against the other in which only the construction cost is considered. However, it is not the intention of this paper to critique the academic validity of each method. It will merely conduct an analysis of outcomes observed when each method is applied to the same project.

Analysis and Discussion

The analysis is straightforward. The details of an ADAB project that was found in the Special Experimental Project No. 14 (SEP-14) report series was extracted, and the LCC-adjusted bid price was calculated for the same set of bids (*18*). The project was the Shelbyville By-Pass Project in 2006 for construction of an overlay and widening of a four-lane concrete pavement in Shelby County, Kentucky (*18*). As this particular project did not contain actual data for value of time or lane rental, the A + B + C bidding and A + C + lane rental options were not included in the analysis. Table 2 contains the results of the analysis, which are quite consistent. Regardless of the presence or composition of an LCC adjustment factor, the low bidder was the same as shown by the tinted line in Table 2 for Bidder B.

The reader must keep in mind that Table 2 applies only to the specific project and the market conditions at the time of the bid. The relative unit pricing of HMA and PCC pavements move independently of each other and each material has its own level of price volatility. Thus, the results cannot be generalized. However, a report issued by the Missouri DOT found that out of 187 ADAB projects completed through 2010, the LCC adjustment factor only reversed the decision four times: about 2% of the projects (*19*). If the experience in Missouri is representative of that found in the nation, then a result like that shown in Table 2 would be more often the rule and, regardless of the composition of the LCC adjustment factor, it would not make a difference 98% of the time. Thus, it was concluded that, at least in Missouri, competing HMA and PCC head to head can be successfully implemented purely on the basis of lowest bid if the Missouri DOT chose to do so.

Table 3 attempts to put a broader representation on the Table 2 outcome by furnishing the details for 55 ADAB projects in 13 U.S. states and three Canadian provinces found in the literature. For each project, the number of bids submitted for each pavement type, the low HMA bid, the low PCC bid, the percentage difference between the two bids, and the winning pavement type were tabulated. Not all the bids were adjusted by an LCC-based factor because, as stated above, several DOTs do not use an adjustment factor and, furthermore, it is known that some agencies, like the Missouri DOT, that use a factor do not adjust all the pavement project bids (*17, 19*).

It can be seen in Table 3 that a total of 313 individual bids were attracted by ADAB projects, which translates to an average of 5.7 bidders per project. According to the literature, the average number of conventional project bids ranges from 3.8 to 5.1 bidders per project (*20, 21*). Therefore, it appears that the sample confirms the individual state results in the literature by exceeding the upper bound of the range. Next, the sample shows that 44% of the bids were for HMA and 56% were for PCC. Although not equal, the difference between the two pavement types is not large, supporting the idea that implementing ADAB does indeed give both industries an opportunity to compete. This trend is reinforced by the fact that only six of 55 projects (11%) received bids for only one pavement type.

The outcomes found in Table 3 show that PCC pavement bids won 67% of the time. The unscientific sampling procedure makes it difficult to draw authoritative conclusions based on the observed differences, but when combined with the results found in Missouri and the Table 2 demonstration of the efficacy of the various LCC factors in use, it does suggest that the inclusion of an adjustment factor to ensure a "level playing field" for PCC may not be needed. As the LCC adjustment factor is calculated before advertising an ADAB project, the volatility issues discussed in the previous section come into play as the agency "exercises its option" by calculating the factor based on unit prices current at the time the bid package is assembled. If the relative price swings shown in Figure 1 are possible, then it is not illogical to posit that the factor could be calculated when a given commodity price is high, and 2 to 3 months later when the bids are opened that the trend has reversed itself, making the LCC adjustment factor an inaccurate representation of the relative LCC.

Furthermore, research has repeatedly demonstrated that classic LCCA is highly sensitive to the input values that are based on professional judgment or assumptions, specifically the discount rate, the analysis period, and salvage value (*4*). Stone concludes that "the two sides had completely opposite views on the inclusion of price adjustment clauses when calculating initial construction costs and material specific escalation rates" (*22*). Thus, the composition of the adjustment factor itself creates controversy, further muddying the outcomes to the point that seven different "approved" versions of the factor are now in use to account for the same issue. When the above discussion is combined with the fact that six states do not use bid adjustment factors in their ADAB programs, it appears that the utility of the LCC-based bid adjustment factor is questionable.

Conclusion

The answer to the research question posed in the section on methodology is developed in the following manner:

- Portland cement and liquid asphalt have different rates of volatility and may even change in opposition to each other. Those rates have been extreme, a 16% swing in 5 months. When the pavement-type selection decision is viewed as a business decision in purely financial terms, it can be modeled as exercising an option in the commodities market, which according to standard financial theories becomes more valuable as volatility increases. Therefore, ADAB as means to "exercise the option" at the last possible moment creates value for money in and of itself.
- The controversy between the asphalt and concrete paving industries with regard to the proper calculation of pavement LCCs is both intense and long standing. The result is that at least seven different algorithms are in use to adjust bid prices in ADAB procurements. Some of the methods do not include all the elements of the pavement LCCA prescribed by the FHWA. Thus, it can be concluded that the current suite of different adjustment factors is the product of negotiation (*16, 17, 21, 23*), not hard, scientific engineering economics that should have only a single, theoretically correct, method for solving the problem used by all (*2*).
- The example shown in this paper and the experience of the Missouri DOT indicate that even when an adjustment factor is applied, it rarely changes the award from the lowest priced pavement type. In addition, the content analysis of ADAB project award outcomes disproves the perception that asphalt is always the lowest price option in that PCC won 67% of the 55 ADAB projects reported in the literature.
- Six U.S. states currently let ADAB projects with no bid adjustment factors. Of those, the West Virginia DOT reported a saving of $16.4 million on six ADAB projects (*9*). The Ohio DOT, based on implementing alternate bidding on 10 projects, reported savings of $58 million, with the average winning bid price for ADAB projects 15% below the engineer's estimate in 2009 (*23*).

Therefore, the research question's answer is plain. LCC-based bid adjustment factors do not add value to the ADAB process. They add controversy and may unnecessarily complicate a relatively simple process: opening the bids on bid day and awarding to the lowest bidder regardless of pavement type (*24*). The potential for industry opposition may have a chilling effect that has stopped some agencies from accruing the value inherent to the differential levels of volatility of the two commodities available by treating ADAB as an exercisable option in a business rather than as an engineering decision.

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