Quality-Related Pay Adjustment Factors for Pavements

DETAILS

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QUALITY-RELATED PAY ADJUSTMENT FACTORS FOR PAVEMENTS

This digest summarizes the findings from NCHRP Project 10-79, "Guidelines for Quality-Related Pay Adjustment Factors for Pavements." It was prepared by Amir N. Hanna, NCHRP Senior Program Officer, from the contractor's final report authored by Charles S. Hughes, James S. Moulthrop, and Shiraz Tayabji of Fugro Consultants, Inc., Austin, Texas; Richard M. Weed, Trenton, New Jersey; and James L. Burati, Clemson University, South Carolina. Charles S. Hughes served as principal investigator.

INTRODUCTION

This digest summarizes the findings of the research conducted under NCHRP Project 10-79 to develop guidance pertaining to the quality-related pay adjustment factors used for flexible and rigid pavement construction.

Highway agencies generally specify certain quality measures for the acceptance of pavement construction. However, because many factors influence construction operations, characteristics of the constructed pavement (e.g., material properties and smoothness) will generally vary somewhat from those specified. Such variance will affect pavement quality and performance and, therefore, will affect the highway agency and road users. To account for the value lost or gained by the variance from the specified values, many highway agencies incorporate quality-related pay adjustments in the form of incentives and disincentives in the construction contracts of flexible and rigid pavements.

Many of the approaches used by highway agencies for dealing with construction variance and assigning pay adjustment factors have been developed empirically and with limited consideration of the actual effect on performance. In addition, these approaches use procedures for determining the amount and method of pay adjustment that do not consider some relevant issues, such as highway functional classification, constructability, impacts on the highway users, and contractor/agency risk sharing. There has been a need to enhance these approaches and develop rational guidance on the issues associated with determining quality-related pay adjustment factors for flexible and rigid pavements. This guidance will help highway agencies incorporate pay adjustment factors that realistically reflect the expected gain or loss in pavement performance into construction contracts.

RESEARCH APPROACH

NCHRP Project 10-79 was conducted to evaluate the approaches used for assigning pay adjustment factors for flexible and rigid pavement construction and to propose enhancements to the most promising approaches. To accomplish this objective, the research included a review of information relevant to quality-related pay adjustment factors and a survey of state highway agencies to identify the different processes used for determining quality-related pay adjustment factors. The research then evaluated these processes and identified those processes that merit further consideration

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and use as a basis for developing rational guidance relevant to quality-related pay adjustment factors. Finally, the research proposed specific approaches for assigning quality-related pay adjustment factors as well as specific items for consideration in pavement construction contracts.

Literature Review

The literature review revealed investigations conducted in the 1970s to develop rational pay adjustment factors (Willenbrock and Kopac 1977) with enhancements some 15 years later (Afferton et al. 1992). Research performed in subsequent years identified the following items as necessary for developing highway construction payment relationships (Burati et al. 2003):

- Identifying the specific acceptance quality characteristics (AQCs) that are most closely associated with the performance of the finished product.
- Establishing acceptable quality levels (AQLs) for each of the characteristics that are closely related to performance (i.e., the required level to produce the desired performance).
- Ensuring the ability of the construction industry to meet the desired acceptance requirements without a need for extraordinary quality control procedures.
- Ensuring availability of valid and reliable sampling and testing methods and procedures to accurately determine the quality of the finished product.
- Developing a pay schedule for assessing incentives and disincentives that is reasonably commensurate with the expected gain or loss in performance.

Survey of Highway Agencies

A survey questionnaire concerning pay adjustment schedule practices was forwarded to all state highway agencies. The responses received from 37 agencies revealed the following observations:

- Pay adjustment factors are further developed and more often used for flexible pavements than for rigid pavements.
- The AQCs for flexible pavements vary appreciably among highway agencies but to a lesser extent for rigid pavements.
- Many agencies use weighted composite pay factor equations, although the weights and AQCs vary considerably.

The responses to the questionnaire revealed the following practices for flexible pavements:

- The stepped (tabular) and continuous (equation) forms of pay adjustment factors are being used equally but with appreciable variations among agencies.
- Smoothness (as a measure of ride quality) is considered separately from materials/construction AQCs by most agencies.
- Percent Within Limits (PWL) is the single most often used quality measure except for smoothness where quality is measured by the average value.
- Most agencies use maximum incentives, ranging from 1% to 15%; the most commonly used maximum incentive is 5% (15% is used only for smoothness).
- Most agencies have maximum disincentives; many agencies use a remove-and-replace provision, but only a few agencies use a shutdown provision. Different triggers are used for applying a combination of a maximum disincentive, a shutdown provision, and/or a remove-and-replace clause.
- A majority of agencies pay incentives for superior quality levels of the various AQCs, but some agencies allow use of incentives only to offset disincentives.
- Two agencies use different weights and AQCs for different highway classification.

The responses to the questionnaire revealed the following practices for rigid pavements:

- Strength, thickness, and smoothness are the three most often used AQCs, but little consensus exists among agencies about how these AQCs and others are used.
- The stepped form of pay adjustments is used more often than the continuous form.
- Little consensus exists among agencies regarding how to combine individual pay adjustment factors.
- Only one agency reported use of a composite weighted pay adjustment equation.
- PWL and the average are the most often used quality measures.

- A majority of agencies pay incentives for superior quality pavement; very few agencies use incentives only to offset disincentives.
- Most agencies use maximum incentives, ranging from 3% to 15%; the most commonly used maximum incentive is 5% (15% is used only for smoothness).
- Many agencies have maximum disincentives or use a remove-and-replace provision, but very few agencies use a shutdown provision.

Quality-Related Pay Adjustment Factor Methods

The literature review and survey identified the available methods for determining quality-related pay adjustment factors. These methods can be categorized based on the quality-adjustment factor relationship as (a) engineering-based, (b) empirical, or (c) experience-based methods.

Engineering-Based (Complex) Methods

These methods are complex, incorporate proprietary analytical models, and use software to perform the necessary analysis. They use the fundamental engineering properties as a means for predicting pavement performance, and the software incorporates means for identifying the appropriate AQCs and their relationship to these properties.

These methods have been developed using engineering and mathematical principles. Typically, they include performance relationships based on mechanistic or pavement design theory and use established cost-evaluation procedures such as life cycle cost (LCC) analysis. These methods conform to the definitions of performance-related specifications (PRS) provided in AASHTO R 10: Standard Practice for Definition of Terms Related to Quality and Statistics as Used in Highway Construction (AASHTO R10). These methods have the potential for providing accurate relationships but they tend to be complex and not easy to implement. Examples of these methods are the following:

- The PaveSpec software developed for rigid pavements under research for FHWA (Hoerner et al. 2000). This procedure requires over 100 user inputs to obtain the results.
- The HMA Spec software developed for flexible pavements under NCHRP Project 9-20 (Epps et al. 2002, Hand et al. 2004). About 100 user inputs are required to obtain results from this procedure.
- The Quality-Related Specification Software (QRSS) resulted from the evaluation of HMA Spec software conducted under NCHRP Project 9-22 (Fugro Consultants, Inc. and Arizona State University 2011). This software incorporates the performance prediction models of the *Mechanistic-Empirical Pavement Design Guide* (MEPDG).

Empirical Methods

Empirical methods generally use the same engineering and mathematical principles as the engineering-based methods. They use empirical relationships derived from highway agency experience and not from engineering principles. Some of these methods conform to the definitions of PRS provided in AASHTO R 10. Such methods were developed for flexible pavements (Weed 2006) and for rigid pavements (Weed 1999). These methods are simpler and easier to implement than the engineering-based methods, but they are likely to be less precise.

Experience-Based Methods

Experience-based methods usually are not derived from either engineering or mathematical principles and do not consider predicting pavement performance. These methods compute pay factors based on an approach that reflects the perceived manner and extent to which the AQCs influence pavement performance. These methods are generally compatible with AASHTO R 9: Standard Practice for Acceptance Sampling Plans for Highway Construction (AASHTO R 9) and AASHTO R 42: Standard Practice for Developing a Quality Assurance Plan for Hot-Mix Asphalt (AASHTO R 42).

Evaluation of Quality-Related Pay Adjustment Factor Methods

The PaveSpec, HMA Spec, and QRSS software products incorporate complex analytical approaches that require a large number of input variables. Because errors are likely to be associated with these inputs, the resulting output will also exhibit some error—the extent of which will depend on the extent of error in each input variable and the likelihood of a compounding effect. For these reasons, none of these methods was considered a potential

candidate for enhancement and adoption as a recommended practice.

The empirical method for rigid pavements has not been sufficiently developed to warrant further consideration as a potential candidate for enhancement and adoption as a recommended practice.

Available procedures were evaluated with consideration to accuracy, complexity, ease of implementation, and relevance to AASHTO R 9, AASHTO R 10, and AASHTO R 42. This evaluation revealed that the procedure contained in AASHTO R 9 is appropriate for enhancement and development of two practices, potentially titled (1) Recommended Practice for Flexible Pavements and (2) Recommended Practice for Rigid Pavements. The framework for performance-related specifications (Weed 1999) also can be enhanced to provide a more effective process for flexible pavements (potentially titled Empirical PRS Method for Flexible Pavements). A brief description of each of these three procedures is provided.

Recommended Practice for Flexible Pavements

This procedure uses statistically valid methods but does not stipulate the specific AQCs that should be used or the weights that should to be assigned to them. The procedure is based on experience and does not include a model or pay schedules supported by economic analysis; it uses engineering judgment combined with experience to develop quality-related pay factor adjustments.

Recommended Practice for Rigid Pavements

This procedure is similar to that for flexible pavements but contains different details. Although AQCs and quality measures are different, the procedure (similar to the flexible pavement procedure) uses statistically valid methods and does not stipulate the specific AQCs that should be used or the weights that should be assigned to them. It is also based on experience and does not include a model or pay schedules supported by economic analysis, and uses engineering judgment combined with experience to develop quality-related pay factor adjustments.

Empirical PRS Method for Flexible Pavements

This method—called the "expected-life" method in the user's manual for FHWA's SpecRisk specification analysis software—bases payment on the expected performance (service life) of the as-constructed pavement (*SpecRisk User's Manual* 2008). Because load-bearing capacity is strongly related to expected service life and resultant economic value, this method would provide rational basis for effective adjusted-payment schedules.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Findings

Since the 1980s, considerable progress has been made toward developing quality-related pay adjustment factors, with even greater progress made in recent years. Several important decisions need to be made concerning these factors. It is essential that payment relationships be reasonable, achievable, and viewed as being fair to both the contractor and the highway agency. The following findings and conclusions are derived from this study:

- Quality-related pay adjustment factors for pavements are used extensively in the United States and Canada but are not used in Europe, South America, New Zealand, or Australia. These procedures continue to evolve and have gained widespread acceptance in highway construction.
- The quality-related pay adjustment factors in use vary in the AQCs that are used and the manner and magnitude in which they are applied. Many agency specifications do not define either AQL or rejectable quality level (RQL). However, AQL is used more often than RQL.
- When considering AQL, the level of quality required to achieve the desired performance needs to be defined and described in the specifications, and the pay schedule needs to reflect an average of 100 percent when that level of quality is delivered.
- RQL provisions can enhance the highway agency's protection against acceptance of deficient quality. However, the provision of requiring removal and replacement at the contractor's expense needs to ensure that the level selected as the RQL warrants such consequences. For example, a retest provision to confirm deficient quality before enforcing a remove-and-replace provision may be included.
- PWL is the most used quality measure.
- Composite pay factors are used by many highway agencies.

- Specifications typically include ride quality (smoothness) as a separate AQC from other material and construction AQCs, but it can be included with other AQCs if desired.
- Incentive and disincentive pay adjustment factors are commonly included in state highway agency acceptance plans.
- Procedures with different levels of complexity are used for quality-related pay adjustment factors. These procedures include (1) complex engineering-based methods that often incorporate proprietary analysis techniques; (2) less complex empirical methods that use engineering and mathematical principles but are more tailored to local data and experience; and (3) intuitive methods that rely on perceived AQC-performance relationships not derived from either engineering or mathematical principles but have been used successfully for many years. The latter procedures appear to be the most adaptable for developing the least complex and easy-to-implement quality-related procedures.
- Continuous (equation-type) pay schedules are preferred because they have more desirable features than stepped pay schedules.
- Limited information is available on the consideration of functional classification in quality-related pay adjustment factors.

Recommendations

Several findings derived from this research can help highway agencies enhance their processes for quality-related pay adjustment factors. Based on these findings, the following actions are suggested:

- Use the PWL approach.
- Use only those AQCs that are considered to be best related to performance and only those necessary for defining the desired product. AQCs that are often used for flexible pavement materials are asphalt content, lab-compacted air voids, voids in the mineral aggregate, and two sieve sizes. AQCs for the constructed flexible pavement are density, thickness, and smoothness. AQCs for rigid pavements are compressive strength, thickness, and ride quality.
- Use both AQL and RQL values. The AQL may be set at PWL = 90 for flexible and rigid pavements (AASHTO R 9, 2008) but RQL value should be established by the agency based on a risk analysis.
- Conduct a risk analysis of the acceptance plan before implementing it. The software, titled "Analysis of Risks in Percent Within Limits and Percent Defective Acceptance Plans and Specifications, SpecRisk Version 2.4" (Office of Infrastructure Research and Development 2008), is an appropriate tool for this analysis.
- Consider including an incentive provision in the specification to compensate the contractor when producing product at the AQL.
- If functional class is to be considered, use quality-related pay adjustment factors for Interstates, principal urban and rural arterials, and major collectors but use method specifications for rural secondary roads, ramps, and facilities with geometric issues and uncommon features.

FINAL REPORT

The contract agency's final report, "Guidelines for Quality-Related Pay Adjustment factors for Highway Pavements," gives a detailed account of the project, findings, and conclusions and includes further information on current practices regarding quality-related adjustment factors. The report is available online at www.trb.org by searching "NCHRP10-79_FR.pdf".

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