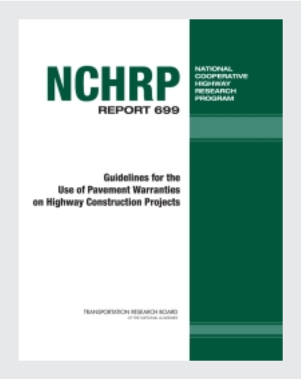

Guidelines for the Use of Pavement Warranties on Highway Construction Projects

DETAILS

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AUTHORS

Sidney Scott; Stuart Anderson; Ted Ferragut; Megan Syrnick; Transportation Research Board

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 699

Guidelines for the Use of Pavement Warranties on Highway Construction Projects

Sidney Scott III
TRAUNER CONSULTING SERVICES, INC.
Philadelphia, PA

Ted Ferragut
TDC PARTNERS, LTD.
Lewes, DE

Megan Syrnick
HILL INTERNATIONAL
Marlton, NJ

Stuart Anderson
TEXAS TRANSPORTATION INSTITUTE
College Station, TX

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The authors wish to express their appreciation for all those who participated in interviews and provided feedback and case study information. We understand that their time was valuable, and we could not have accomplished this work without their input. We would like to especially thank the representatives of DOTs in Mississippi, Florida, Wisconsin, Michigan, Colorado, and California for providing access to their comparative performance data and aiding the vetting process of the warranty decision tool.

FOREWORD

By David A. Reynaud
Staff Officer
Transportation Research Board

This report provides guidelines for establishing pavement warranty programs and identifies programmatic and project-level decision criteria that state departments of transportation (DOTs) should address to successfully implement and sustain a program. It includes a decision tool to help identify program-level issues and predict project-specific risks. The report includes strategies to mitigate these risks and also includes model warranty specification provisions. This report will be of interest to state and local highway agency officials who are concerned with the quality, durability, and cost of new pavement.

State DOTs have used both asphalt and portland cement concrete pavement warranties for many years but with mixed results because the factors that contribute to the success or failure of the program were not always well understood. The potential benefits that a successful warranty contracting program can provide for state DOTs are ensuring quality of materials and workmanship, reducing agency staffing requirements for inspection and testing of construction, promoting contractor innovation, changing the business model by shifting performance risk to the contractor, improving performance, and reducing life-cycle costs.

The objective of this research was to develop guidelines for the programmatic and project-level application of pavement warranties. These guidelines will assist state DOTs in determining when and how to use warranties for construction of both asphalt and portland cement concrete pavements.

To achieve the project objectives, the researchers first collected and reviewed information relative to the application of pavement warranties at both the programmatic and project levels. The researchers then developed a project-level method that a state DOT can use to determine whether the use of a pavement warranty is the best option for a particular project. This method was then applied to highway pavement projects for state DOTs, and the results were used to develop guidelines for how to best use pavement warranties in the construction of highway pavement projects.

CONTENTS

SUMMARY

Guidelines for the Use of Pavement Warranties on Highway Construction Projects

State departments of transportation (DOTs) develop and implement warranty provisions because of the potential benefits that warranty contracting provides for the DOT. The advantages of warranty contracting are identified in almost all of the literature related to warranties. These advantages include

- Ensuring quality of materials and workmanship,
- Reducing agency staffing requirements for inspection and testing of construction,
- Promoting contractor innovation,
- Changing the business model by shifting performance risk to the contractor, and
- Improving performance and reducing life-cycle costs.

State DOTs have gained considerable warranty experience, with varying results, since the Federal Highway Administration lifted its prohibition against the use of construction warranties in 1995. This research report summarizes current pavement warranty practices based on a review of the literature, DOT interviews, a joint industry/DOT workshop, and a review of internal DOT procedures and specifications collected as part of the research. It focuses more specifically on the question of warranty project selection. It also addresses various DOT evaluations of warranty projects that have been performed to date, identifying factors that contribute to the failure or success of a warranty program.

This report summarizes the results of research on established pavement warranty programs of various DOTs and identifies programmatic and project-level decision criteria that DOTs may consider when applying pavement warranties on highway construction projects.

The findings of this research are briefly summarized as follows:

- Three types of warranties identified in this research are currently being implemented by practitioners. These are classified as Type 1—materials and workmanship, Type 2—short-term performance, and Type 3—long-term performance.
- The number of pavement warranties implemented by DOTs in the United States varies widely. The number of pavement warranty projects within these DOTs ranges from a very small number to virtually all pavement projects, with certain limitations.
- Few DOT practitioners have developed a systematic approach to project selection. Where warranty decision criteria are used, warranties are often limited to safe projects or stable base conditions. In a very few cases, warranties are used for all pavements unless the existing conditions preclude their use on the entire project or portions of the project.
- Risk allocation on a warranty project can vary greatly depending on the type of warranty implemented and the anticipated project outcomes.

- To implement successful pavement warranty projects, owners must apply the right type of warranties to the right type of project scope of work, and the provisions must effectively manage risk based on the stated objectives and goals for the warranty project.
- A warranty decision tool was developed as part of the research. The tool is available in both manual and automated formats in Microsoft Excel (see Appendix A2). The tool first guides users through a set of programmatic criteria designed to assess whether program-level issues must be addressed before a DOT can successfully implement and sustain a warranty program. These issues may include DOT or industry resistance to changing the traditional contracting or business model, bonding limitations, resistance to transferring quality or performance risk to the contractor, or a reluctance to move from the lowest initial cost and minimum quality model to aiming for improved quality and reduced life-cycle costs.
- The warranty decision tool also includes an assessment of the risks of implementing a Type 1, 2, or 3 pavement warranty based on project-specific characteristics and suggests strategies to mitigate these risks. Project-specific characteristics may include project location, size and complexity, existing foundation and base conditions, accuracy of traffic projections, average annual daily traffic (AADT) and traffic phasing requirements, and level of control ceded to the contractor for design, construction, and quality management. If the risks are high for a given warranty type, the tool suggests strategies to mitigate risk by modifying the scope of the project or the warranty or choosing the warranty type that fits with the level of control or responsibility allocated to the contractor under the contract, the accuracy of the traffic projections, or historic pavement performance data for the pavement type.
- Comprehensive warranty guidelines are necessary to assist DOTs in implementing the appropriate warranty type for the specific project or program objectives, allocating risk, and addressing what elements are important to consider when drafting a warranty specification for hot mix asphalt (HMA) or portland cement concrete (PCC). Lastly, the guidelines include model pavement warranty provisions for HMA and PCC pavements that DOTs can use when developing their own project-specific warranty provisions.

The appendices and the warranty decision tool are provided on the CD-ROM accompanying this report.

CHAPTER 1

Background

Problem Statement

State departments of transportation (DOTs) have used warranties for both flexible pavements [primarily hot mix asphalt (HMA)] and rigid portland cement concrete (PCC) pavements for many years. Under a pavement-warranty specification, the performance of the pavement is measured over time as opposed to measuring the quality of pavement materials and workmanship during and immediately after construction. Pavement warranties require the construction contractor to guarantee the post-construction performance of the pavement at varying levels. Shifting post-construction performance risk from the DOT to the contractor is perceived as reducing premature pavement failures, reducing costs, and increasing pavement quality.

While some DOTs have reported that the use of pavement warranties has resulted in dramatic improvements in quality, reduction in premature failures, and cost advantages, the overall reported results have been mixed, in part based on the type of warranty implemented.

Objectives and Research Approach

The objective of this research was to investigate the use of pavement warranties by DOTs, develop a decision tool for applying warranties, and develop guidelines to assist DOTs in determining when to use warranties and how best to apply them. The study took into consideration various categories of pavement projects and types of warranties. Distinctions within the major categories of asphalt and concrete pavement projects were made due to the differences in risk allocation. Therefore, asphalt and concrete pavement projects were generally classified as preservation, rehabilitation, or new construction projects. Preservation includes surface treatments such as thin overlays, microsurfacing, chip sealing, and crack sealing. Rehabilitation includes overlays and partial depth replacement projects. New construction includes new alignments and full-depth replacement projects.

Phase I

The research approach for Phase I of the study included a Task 1 literature review of information relevant to the application of pavement warranties, including DOT pavement warranty evaluation reports and warranty specifications. The research team held a joint industry/DOT workshop to discuss the state of practice of warranties in the United States and overseas and conducted targeted interviews using a sample of 14 DOTs with varying levels of experience, ranging from none to using warranties as a standard practice. Information gathered through the literature review, joint DOT/industry workshop, and DOT interviews is summarized in Chapter 2. A bibliography of warranty literature and warranty-related reports is included in this report. Common definitions and terms associated with warranties are listed in the Glossary.

A list of the DOTs and interview participants is included in Appendix C2, as is the form used to guide the interview process. The research team included eight general topic areas on the interview form. This information was used to identify key issues for the application of pavement warranties before, during, and after construction and key factors to be considered in determining when and how to apply pavement warranties.

Using the information gathered from the literature, DOT interviews, and the workshop, Task 2 involved the development of a systematic decision tool to guide DOTs in deciding when to apply warranties to a project. The last step in the approach, Task 3, was applying or vetting the electronic decision tool developed in Task 2 on highway pavement projects for no fewer than five highway agencies. Based on the results of the vetting, the decision tool was refined to reflect the input received from DOTs applying it to their actual projects. Finally, the Task 4 interim report presented the results of the literature review, joint industry/DOT workshop, warranty decision tool, and vetting process. The report also provided a draft outline of the proposed guidelines as part of the Phase II effort.

Phase II

Based on feedback from the research panel, the Phase II Task 5 scope was to finalize the Phase I selection tool, including a comparison of key factors to consider in the selection of a pavement warranty type and the development of a decision process and written guidelines and forms for the pavement warranty selection tool. This final pavement warranty decision tool is included in Appendix A2.

The objective of Phase II Task 6 was to develop practical guidelines for project-level application of pavement warranties in order to assist DOTs in determining when and how to use warranties for both HMA and PCC pavements. Because many DOTs have developed warranty provisions and general guidance for project selection and implementation or have performed evaluations of their warranty programs, the focus of this research was to build on this body of knowledge and provide the most practical guidance based on the lessons learned from these programs. The warranty guidelines were designed to include key implementation topics, including project selection, the selection of performance criteria and thresholds, contracting strategy and risk allocation, monitoring and evaluation, remedial work, exclusions, bonding considerations, dispute resolution, and acceptance. The pavement warranty guidelines (as Appendix A1) and warranty decision tool are provided on the CD-ROM accompanying this report, as are the other appendices.

Finally, Task 7 addressed the development of draft technical warranty provisions for HMA and PCC pavements suitable for inclusion in the AASHTO *Primer on Contracting for the Twenty-First Century* that DOTs can use to develop their own project-specific warranty provisions. The model specification for HMA refines and updates the existing technical provision for HMA pavements. A new supplemental provision was developed for PCC pavements. These model provisions incorporate language and lessons learned from the implementation of existing warranty provisions. They also include commentary and suggested values and options depending upon the type of warranty or type of contracting method implemented.

CHAPTER 2

Research Findings

The first phase of this project involved the collection and examination of the existing literature, critical discussions with practitioners in a workshop forum, and conducting selected DOT interviews to capture the current status of warranty use. The collected literature included national research studies, state-level evaluations, and warranty specifications. These state-level evaluations and selected pavement warranty specifications can be found on the FHWA's National Highway Specifications website at www.specs.fhwa.dot.gov. The findings from these sources formed the basis for the final guidelines and model specifications developed under this research effort and are documented in the following sections of this chapter.

General Literature (Comparison of National and International Experience)

The FHWA-sponsored International Technology Scans generally concluded that the use of pavement warranties is entrenched in the international contracting model. European agencies began implementing warranties for a variety of reasons, including roadway maintenance needs, resource shortages, and the desire to improve quality and efficiency. This model uses a much higher degree of control by industry, and the warranty clause acts as a risk mitigation tool or an assurance to the agency that the pavement will perform. Furthermore, many European contracts are awarded on a best-value basis, using qualifications and price, in contrast to the U.S. practice of low-bid award. While the scans found that quality improvements can be linked to the application of a warranty, in reality, it is also probable that the sum of all European business practices produces a higher-quality product (AASHTO et al., 1991; Hancher, 1994; Bower et al., 2003; FHWA, 2005).

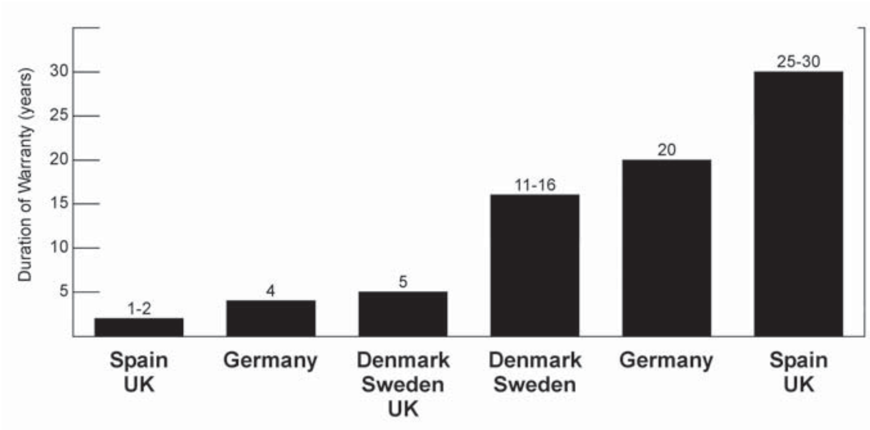
Warranty practice continues to evolve in Europe. The 2002 scan reported that many of the host countries were experimenting with alternative delivery methods that included operation and maintenance of facilities as an extension of the construction contract, in essence requiring longer-term guarantees. For example, the United Kingdom stated that its use of performance warranties had grown because design–build had become a contracting method of choice in the last decade and the addition of operation and maintenance was a natural extension. Both the United Kingdom and Spain have turned to the private sector to perform pavement maintenance or design–build–operate–maintain contracts with finance options. Warranty periods on European transportation projects range from 1 year for materials and workmanship warranties to 30 years for performance warranties under design–build–operate–warrant contracts, as shown in Figure 1.

The 2002 scan report recommended the continued implementation of warranties in the United States. The recommendations included promulgating legislation for best-value and prequalification procurement methods that incorporate quality and other technical factors in contract award and foster collaboration among federal agencies, DOTs, and industry.

Warranty use in U.S. highway construction has grown, albeit at a slower rate more recently. The progression in the use of warranty contracting over the past 12 years is drawn from synthesis and research reports published in 1994, 1998, and 2002. Research published in 1998 indicated that several DOTs implemented warranty projects in 1996 and 1997, following FHWA's publication of the final rule on warranty contracting. Figure 2 illustrates the spike in the number of warranty projects after publication of the final rule.

These reports and the national survey performed under NCHRP Project 20-07/Task 201, "Use of Warranties in Highway Construction," connected with this research project showed that the total number of pavement warranty projects completed by 2006 was more than 2,150. Table 1 shows that the majority of pavement projects are concentrated in certain states.

Of the 24 DOTs that have implemented pavement warranties, several of those noted in Table 1 gained significant warranty experience where pilot programs evolved into



Source: Bower et al., 2003

Figure 1. Warranty periods reported in the 2002 European asphalt pavement warranties scan.

standard practice, while many others have not carried their warranty programs beyond pilot implementation. Although significant warranty experience is concentrated in a relatively small number of DOTs, several others now using warranties on a limited basis reportedly plan to expand their programs.

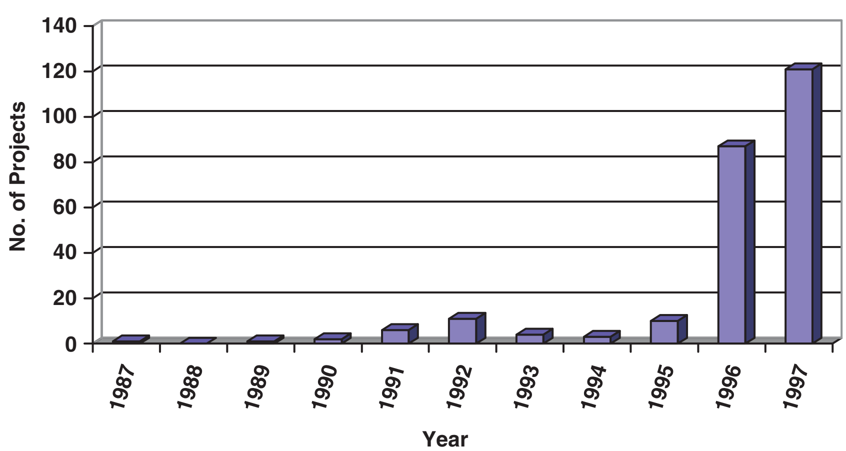
Joint DOT/Industry Pavement Warranty Workshop

The research team conducted a two-day workshop on March 2–3, 2006, to collect information and insights related to current warranty practices within and outside of the United States. The participants included industry representatives from paving associations, domestic and international contractors, materials suppliers, the Associated General Contractors of America (AGC), owner representatives from six DOTs with warranty experience, and FHWA pavement warranty specialists. The discussion addressed several topic areas, including the definitions of basic warranty types, the transition from materials and workmanship to performance warranties, what performance parameters and distresses are or should be under the contractor's control, the benefits of warranty use, factors to consider in project selection and guidelines, and implementation strategies. The list of workshop attendees and its meeting minutes can be found in Appendix C1.

Warranty Types

The workshop participants first considered and discussed warranty types/classifications and definitions. In general, warranty provisions have been implemented in conjunction with both method specifications under traditional design–bid–build delivery and performance specifications under design–build project delivery.

Practitioners classified warranty provisions under one of three general categories: materials and workmanship, short-



Source: Anderson and Russell, 1998

Figure 2. Number of warranty projects constructed per year.

Table 1. DOTs with the most significant pavement warranty experience.

DOT	Warranted Pavement Components	Years of Experience	Total Number of Projects
Michigan	Pavement Pavement preservation Pavement markings	10+ 10+ 10+	1,000+ (Standard practice; breakdown by type not available)
Florida	Pavement Pavement marking	3 2	700+ (Standard practice) 10
Ohio	Pavement Pavement preservation Pavement marking	6 6 3	156+ 33+ 44+
Wisconsin	Pavement	15+	80+
Illinois	Pavement	5	27
California	Pavement Pavement preservation	5 4	10+ 12+
Minnesota	Pavement Pavement preservation Pavement markings	4 2 3 3 3 3	20 1 4 4 4 2
Colorado	Pavement Pavement preservation	7 9	15 1
Mississippi	Pavement Bridge deck overlays	4 3	11+ 3
Indiana	Pavement Pavement preservation	10+ 3	10 2

Source: Anderson et al., 2006

term performance, and long-term performance. The FHWA used these general categories as part of the development of their selection procedures for pavement warranties. However, since these terms are not specifically codified in federal regulatory language, the researchers found significant latitude in how DOTs interpret these warranty types. A provision characterized as a materials and workmanship warranty by one DOT may be defined as a performance warranty in another, making clear distinctions between these three types of warranties difficult. There was considerable discussion among the participants concerning whether to exclude materials and workmanship warranties from the classifications because they were part of standard practices for many DOTs. The consensus among the group was that materials and workmanship should be included in the warranty classifications and guidelines because they differ from standard boilerplate code and commercial code requirements and provide additional protection under the bond or guarantee clauses. When the DOT survey evaluations were conducted as part of this research effort, classifications of warranty projects characterized by DOTs in terms of materials and workmanship and short-term or long-term performance were retained; however, the following classifications for these three types of warranties are offered based on the preponderance of the warranty specifications reviewed and the general consensus of the workshop participants.

Type 1 Warranties

Type 1 (materials and workmanship) warranties are implemented in conjunction with standard method specifications.

Type 1 warranties require the contractor to correct early defects in the pavement caused by elements within the contractor's control, namely the materials and workmanship of construction. The DOT uses a traditional, low-bid contract where the contractor assumes minimal performance risk. As shown in Figure 3, the contractor's involvement is typically limited to construction and a small portion of the maintenance

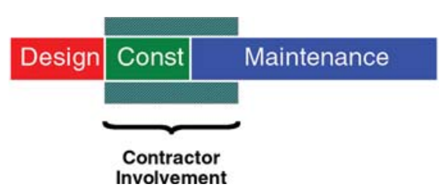


Figure 3. Type 1 (materials and workmanship) warranty.

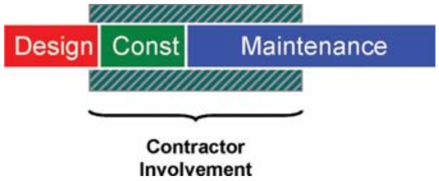


Figure 4. Type 2 (short-term performance) warranty.

period, and the warranty durations are relatively short-term, typically three years or less.

Type 2 Warranties

Type 2 (short-term performance) warranties shift more responsibility to the contractor for certain aspects of pavement performance during the warranty period.

They have been implemented under traditional low-bid or alternative design–build contracts. Type 2 warranties are the broadest category of warranties since the amount of responsibility shifted to the contractor can range from design of the mix to design of structural aspects of the pavement, particularly when combined with a nontraditional design–build contract. As shown in Figure 4, the contractor may have some degree of responsibility for design and construction and a greater involvement in the maintenance period. The provisions of the warranty include elements of both method and performance specifications but can vary between being predominately method-based or performance-based. Type 2 warranty durations generally fall within the range of 5 to 10 years.

Type 3 Warranties

Type 3 (long-term performance) warranties shift the responsibility for the long-term performance of the pavement to the contractor.

Type 3 warranties typically use higher-level performance criteria, establishing pavement performance standards or thresholds that the contractor must maintain for the service life of the pavement or beyond, and include planned and unplanned maintenance. As shown in Figure 5, the contractor involvement extends from design through construction and includes planned maintenance. They are implemented under alternative design–build–warrant, performance-based maintenance, or public–private partnership (PPP) or concessionaire agreements and typically are 20 years or longer in duration.

Transitioning from Materials and Workmanship to Performance Warranties

The workshop roundtable considered the range of options for a DOT to consider when transitioning from materials and

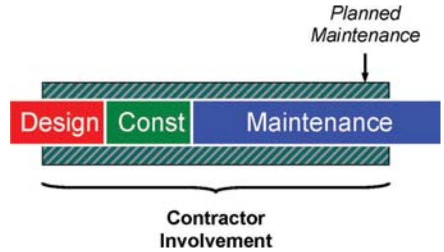


Figure 5. Type 3 (long-term performance) warranty.

workmanship to performance warranty types in the guidelines. The options considered were for mix quality management, mix constituents and design, structural design, drainage, equipment usage, manufacturers' suggested practices, and traffic considerations.

For example, when transitioning to a performance warranty, the possible options for quality management range from a conventional contractor quality control (QC) and owner quality assurance (QA) plan, to a reduction of owner QA where the owner would rely substantially on warranty provisions and records/data provided by the contractor, to the elimination of owner QA requirements for construction where the contractor would be responsible for quality management and the DOT would rely on long-term warranty provisions to ensure quality.

In terms of mix constituents and mix design options, generally the mix design and methodology can be listed as starting points with progressively more allowance to deviate from them, depending on the length of the performance warranty. Substitutions for approved material or additives or admixtures are allowed with the understanding that the contractor can deviate from the list with positive performance proof offered. However, aggregate properties that may affect long-term performance and will not be detected during the warranty period (for example alkali silica reactivity or moisture sensitivity) may still need to be prescribed by the owner.

In terms of selection of mixes and structural design/lift thickness, the workshop participants concurred that an owner needs to provide or allow progressively more access for the contractor to determine the pre-existing condition of the foundation when transitioning to a performance warranty. Obviously, there are other factors for thickness that the owner must have control of—shoulders, clearances, and guide rails are other design features.

In terms of equipment requirements, the owner will often prescribe detailed equipment specifications under a short-term materials and workmanship warranty. As one moves to a performance warranty, the owner may relax equipment requirements and still rely on QA testing to ensure that the contractor is meeting minimum quality standards, or give the contractor the flexibility to select and operate equipment and reduce QC/QA testing, relying instead on a longer-term warranty to ensure performance.

Lastly, in terms of traffic control, the contractor must have progressively more freedom in determining the traffic phasing when transitioning from a materials and workmanship to a performance warranty in conjunction with alternative delivery or lane rental and cost-plus-time bidding criteria.

Table 2 summarizes the perceived levels of flexibility when transitioning from a materials and workmanship warranty to a performance warranty in terms of quality management, responsibility for mix and structural design, equipment, and traffic control.

The transition from materials and workmanship to performance specifications gives greater flexibility to the contractor to manage quality and be responsible for pavement design and construction in return for a more comprehensive longer-term warranty obligation. These transitions in flexibility are considered in the guidelines and specifications for this research based on the type of warranty selected for a pavement construction project.

Contractor Control: What Performance and Related Distresses Can Generally Be Regarded as in the Contractor's Control?

The following tables summarize a roundtable discussion during the workshop on performance parameters that could be included in a performance warranty. Again, control depends on the flexibility and extent of design responsibility given to the contractor as noted previously. In assessing the likelihood of including a particular distress or performance parameter in a performance warranty, the workshop participants considered whether the distress was attributable to actions within the contractor's control and measurable and quantifiable through tests or analysis.

Tables 3 and 4 summarize the consensus of the participants regarding the likelihood that distresses will be measurable and quantifiable and under the contractor's control for asphalt and concrete pavements, respectively.

These discussions and remarks served as one of the sources of information for the development of guidelines for implementing asphalt and concrete pavement warranties presented in Appendix A1.

Benefits of Warranties— What Is the Motivation?

During the meeting, various potential benefits or drivers for the use of warranties were offered by the attendees. For example, DOT representatives expressed that Type I warranties may prevent "lemons," or early, premature failure based on poor contractor performance or quality control. They also may force the contractor to pay more attention to details, thereby improving quality. In the same vein, warranties may actually result in getting the product that is specified and show that it is performing the way the owner wanted it to perform.

Other commonly cited benefits were that warranties may reduce DOT inspection levels, allow for innovation in materials and processes, or reduce contractor claims. One DOT participant expressed that using warranties in conjunction with time-based incentives (A+B bidding) may be the quality (or Q factor) that balances time incentives (A+B+Q bidding).

DOT workshop participants stated that warranties may provide clarity in roles and responsibilities between owner and contractor, improve public relations with the traveling public and legislators, or allow states to earmark or secure funding for maintenance over the long-term. A caution was that tying up money for this long period could also be perceived as a negative

The research team tested these assertions through interviewing key DOTs with pavement warranty experience. One of the interview topics was feedback from practitioners on what the perceived benefits were and whether they actually accrued and could be confirmed. Once these potential benefits were vetted through the interview process, the research team planned to use them as an initial step in the warranty decision tool.

Process Offered for Owners to Define and Manage Performance

The workshop participants offered thoughts on what important steps to consider in developing a process for owners to define and manage performance under warranty provisions. These steps include

1. Determine when distress and/or performance levels should be identified. The consensus was that depending on the warranty type, distresses and performance levels or thresholds should be identified at three points in the life of the pavement: the end of construction, the end of the warranty period, and the end of the design life. In some cases, it is useful to develop performance curves based on historic data that represent expected performance during the service life of the pavement.
2. Identify which distress and/or performance levels are substantially under contractor control. These would be the basis for the distresses used in the warranty provisions.
3. Quantify the end-of-construction and beginning of warranty period distress and/or performance level. This includes the distress measurement technique, the frequency and repeatability of measurement, the tolerances, the tester qualifications, and the test equipment calibration. The

Table 2. Flexibility to allow contractor variation from traditional DOT requirements.

	Quality Management	Mix Design	Mix Selection/Structural Design	Equipment	Traffic
Minimum Flexibility	-Conventional contractor quality control with conventional owner quality assurance. These would be standards normally used in non-warranty owner work.	-Meets broad parameters established by owner with mix design work done in accordance with established owner-specified mix design protocols—Marshall, Superpave® or ACI, for example.	-Owner-prescribed mixes and thicknesses of each layer.	-Owner describes minimum plant and equipment specifications.	-Owner specifies traffic control plan.
	-Conventional contractor quality control with no owner quality assurance. The owner would rely substantially on the warranty provisions.	-Meets broad parameters established by owner with mix design work done using protocols from other sources.	-Contractor may have option to adjust mix selection and thickness for equivalent performance, assumed to be based on established owner design procedures.	-Owner allows variation to these specifications, with some evidence that the variation has been validated.	-Contractor proposes an alternative traffic control plan subject to owner approval under a design–build, lane rental, or A+B bidding system.
	-Nonconventional contractor quality plan with no owner quality assurance. Records are available to the owner.			-Contractor provides independent certification that the equipment and plan meet various standards—that weights and measures are legal.	
Maximum Flexibility	-No owner requirements. Warranty provisions are sole measure of quality.	-Meets broad parameters established by owner with mix work done with proprietary procedures. Based on the European model, this would require some evidence of performance, with in-service data that validates the mix performance.	-Contractor responsible for full structural design using mechanistic design criteria to meet performance requirements. Long-term issues such as fatigue may require some input from the owner.	-Contractor has full freedom to select and operate all equipment.	-Contractor has complete responsibility for developing a performance-based traffic management plan.

Table 3. Assessment of HMA pavement performance parameters.

Performance Parameter/Distress	Within Contractor's Control	Measurable & Quantifiable	Remarks
Rutting	Y*	Y	It is generally easy to identify the severity and the extent of rutting of the surface course, but the cause may extend to lower layers of pavement not under the contractor's control.
Smoothness	Y	Y	Owner can establish standards based on whether it is rehabilitation or new pavement versus the thickness of lifts.
Transverse and longitudinal cracking	Y*	Y	Cracking in the wheel path is usually related to loading but can extend to the base or foundations. Non–wheel-path cracking can be related to paving operations or other causes.
Shoving	Y	Y	Measurable and quantifiable, and generally under contractor control.
Friction	Y	Y	Relates to surface texture or quality of aggregate. Can be used as a performance measure if contractor can select aggregates according to state standards and the DOT gives the contractor the skid numbers and some historical data. Liability or indemnification may be an issue and may restrict use.
Raveling	Y	N	A common distress not easy to measure.
Potholes	Y*	Y	Other factors outside the contractor's control may cause potholes.
Delamination (slipping)	Y*	N	Difficult to pinpoint but measurable with photos.
Bleeding (spot sections)	Y	N	Bleeding will show up in conjunction with poor friction or rutting values. Could have some visual clues that are hard to measure.
Segregation	Y*	N	New tools are coming online to identify and minimize segregation using heat sensors and thermo imaging. The effects of segregation would show up as another distress.
Reflective cracking	N	N	Difficult to determine whether reflective cracking is attributable to the contractor.
Fatigue and moisture sensitivity	N	N	Almost never used in a performance warranty since the distress would appear well beyond a 5 to 7 year performance standard.

*Forensic study may be necessary to determine whether distress is under contractor control.

owner should be assured that all performance distresses are dealt with prior to the start of the warranty period.

4. Identify the in-service, in-warranty measurement of distress and/or performance level. This includes the distress measurement technique, the frequency and repeatability of measurement, the tolerances, the tester qualifications, and the test equipment calibration. Determine a rational way to measure traffic if it is included as a limiting factor in performance.
5. Determine the in-service, in-warranty reporting periods and the approach to remedial action, including the approval of specific fixes. While remedial action was not discussed in depth, it is important to recognize that any remedial fix should return the pavement to the performance curve. Clearly fixes that return the pavement to new or like-new condition may actually extend the service life beyond the original design life.
6. Determine the requirements for the completion of the pavement warranty and final warranty acceptance. These may include a hand-back plan with requirements for inspections and testing to meet defined performance requirements for hand-back.

Table 4. Assessment of PCC pavement performance parameters.

Performance Parameter/Distress	Within Contractor's Control	Measurable & Quantifiable	Remarks
Smoothness	Y	Y	Can establish standards based on rehabilitation versus new pavements versus thickness of lifts.
Transverse and longitudinal cracking	Y*	Y	Are measurable and quantifiable. Transverse cracks may be temperature induced.
Joints, corner distress	Y*	Y	Can be measured and may have multiple causes.
Friction	Y	Y	Under contractor's control if contractor can select aggregates according to state standards and the DOT gives the contractor the skid numbers and some historical data. Liability or indemnification may be an issue.
Joint sealant	Y*	Y	Can be used if there is sufficient data on product history to set tolerances. Complications may arise related to manufacturer installation requirements.
Durability (D) cracking	N	N	Doesn't show up early. A long-term durability issue.
Alkali silica reactivity	N	N	Almost never used in a performance warranty since the distress would appear well beyond a 5 to 10 year performance period.

*Forensic study may be necessary to determine whether distress is under contractor control.

Considerations in the Development of the Selection Guidelines

The workshop participants identified several key characteristics that should be considered when selecting candidate projects for a warranty provision. The first consideration is using projects with sections/designs that have a performance history that can be used as a basis for selecting reasonable distress thresholds. Both the industry and the DOT need to buy into or believe in the reliability of this performance history.

The second consideration is project size or complexity. Based on the current Colorado DOT procedures, the length of the project should be at least 3 miles. This would require a dedicated plant. Another consideration is the scope of work. If the primary scope of the project is paving, the prime contractor is directly responsible for the warranty. If the scope of paving is subcontracted, a pass-through warranty can occur. The prime contractor's responsibility for a pass-through warranty and how the bond is structured must be carefully considered by the DOT.

In terms of a procurement method, the design–bid–build approach will work but limits the ability of the contractor to control the design or performance outcome. It may be better to use prequalification and best-value under a design–bid–build system or move to design–build to give the contractor greater control for longer-term performance warranties.

In terms of risks, they should be considered in the selection. If they are estimated as high and will impact the bid appreciably, then the DOT should think twice about using a warranty. For example, foundation condition is one of the most significant risk issues and needs to be addressed. If possible, the DOT should consider using the design–build concept to address contractor control of the foundation design. If failures caused by the foundation are not the contractor's responsibility, the warranty would not be invoked. When considering warranties for concrete pavements, to reduce risk the design life should be 20 years or more and the minimum PCC pavement thickness should be over 9 in.

Implementation Strategies

Finally, the workshop practitioners commented on strategies that proved to be successful when implementing warranties. The first recommendation was to progress from simpler to more complex warranty projects. This may entail a transition plan from simpler to more complex longer-term warranties as DOTs gain more experience. Partnership with industry in the development and implementation of warranties is a key to success. As part of this partnership, pre-bid and constructability meetings should be held with industry to get input on the project. Based on this input, some projects could be weeded out. Also, to avoid issues related to excessive equivalent single axle loads (ESALs), a weigh-in-motion station should be included in or near the project unless a current station exists in the vicinity, and the cost benefit of weigh-in-motion should be carefully evaluated.

DOT Pavement Warranty Experience

As noted in the objectives and research approach section, the next major activity involved surveying a representative cross-section of DOTs with varying levels of pavement warranty experience to identify the key factors in the warranty decision process, warranty outcomes, issues, and keys to successful implementation. The selected DOTs included a geographical cross-section of DOTs with significant pavement warranty experience at the time of the survey, as well as two control DOTs with no warranty experience and with no plans to implement them. A survey form was used to guide the telephone interviews with selected DOT officials. A list of the DOTs, interview participants, and the form used during these interviews is included in Appendix C2. The research team included eight topic areas on the interview form, as summarized in Table 5.

The results of interviews are captured in Appendix C3. In addition to the interviews, additional information on DOT practices was drawn from warranty evaluation reports or national research reports from these DOTs, as well as selected warranty specifications and guidelines.

California DOT (Caltrans)

Between 1993 and 1999, Caltrans implemented approximately six rubberized asphalt concrete and chip seal warranty projects of varying length (1 to 5 years), most of which were emergency projects as a result of severe storm seasons that the state experienced between 1994 and 1998. In 2000, a formal pilot warranty program was initiated by Caltrans' divisions of construction and maintenance to evaluate 1-year materials and workmanship warranties on a variety of pavement seal and ultrathin overlay projects, including asphalt rubber chip seals, polymer modified emulsion chip seals, microsurface seals, conventional asphalt concrete overlays, rubberized asphalt concrete overlays, and bonded wearing courses.

Caltrans' warranty specifications are structured to allow for excluded areas, meaning certain sections of the pavement project may be exempt from the warranty based on the results of a condition survey of the existing pavement. Existing conditions that may qualify a pavement section for exclusion include rutting greater than 9 mm, patches of cold mix asphalt concrete placed within the last 12 months, existing cracks greater than 6 mm, and existing cracks filled with emulsified filler within the last 12 months or hot applied filler within the last 4 months. If the total excluded areas amount to 15% or more of the total project, then Caltrans typically does not consider the project a good candidate for a warranty.

Caltrans does not require a separate bond for the warranty period. The bonding industry agreed to extend performance warranties for one year beyond the project completion date in exchange for a warranty bond. Therefore, bonding issues do not negatively influence Caltrans' warranty program.

Based on an evaluation of the nearly 30 warranty projects constructed between 2000 and 2006, Caltrans concluded that (Cotey and Jones, 2005 and 2006):

- Cost comparisons of five warranted asphalt pavement projects with the same non-warranted asphalt pavement types/applications resulted in lower costs per mile (6% to 16% lower) for four out of the five pavement types evaluated. The lower costs applied to rubberized asphalt concrete open graded high binder, polymer modified chip seals, dense graded asphalt concrete, and bonded wearing course.

Table 5. Summary of DOT pavement warranty interview forms.

Discussion Point	Objective
General information	Understand the background of pavement warranties in the DOT
Type of warranty	Understand how the DOT distinguishes between materials and workmanship and performance
Guidelines and implementation	Understand how guideline and implementation procedures are determined and conveyed to others
Project selection	Understand the methodology for determining candidate warranty projects
Effects on contracting process	Understand the effect of warranty on procurement, competition, and construction
Warranty management	Understand the responsibility of each party during the warranty period
Benefits and future considerations	Determine the perceived and/or documented benefits of implementing warranty projects
Distress indicators and thresholds	Identify typical and potential performance values that could be established for warranties and identify primary and secondary causes of distress

- Contractors appear to apply extra effort during construction and pay more attention to binder temperature, binder spread rate, rock spread rate, and rock temperature.
- One contractor took extra effort with materials by trucking in rock from a distance to ensure that the project would perform for the warranty period.
- Bids were competitive.
- Materials supplied by contractors meet specifications.
- The warranty period provides added time for field maintenance personnel to observe performance of the pavement application.

Caltrans reported that overall the highway surface treatments on the pilot projects were performing well. It plans for continued use with certain recommendations, several of which were aimed at specification revisions (Cotey and Jones, 2005 and 2006). One key recommendation was to revise the warranty specifications to allow contractors to determine the spread rate for the chip seal and slurry seal warranties. Another key recommendation was to allow contractors to propose alternative repair methods that would result in equal or better performance. These recommendations suggest that the DOT is moving toward more performance-based requirements as it expands the warranty program.

Colorado DOT (CDOT)

CDOT has experience with materials and workmanship and performance warranties, having implemented 3-, 5-, and 10-year HMA pavement warranty projects and 5- and 10-year PCC pavement projects. CDOT commenced its warranty program in 1997 as a result of Senate Bill 97-128, a legislative mandate requiring the implementation of three warranty pilot projects by the end of 1998. The first three warranties implemented were 3-year HMA pavement projects. After completing the pilot projects, CDOT revised the warranty specification and constructed three more HMA warranty projects before publishing its first evaluation report in December 2001. This report evaluated 3-year warranty projects and concluded that the cost–benefit evidence did not support continuing or stopping the 3-year warranty pilot program. Rather, the report proposed some changes to the warranty specification based on lessons learned and suggested further research on the cost–benefit of 3-year warranties and new research on the benefits of the 5-year and 10-year warranties.

CDOT's initial 3- and 5-year materials and workmanship asphalt warranty specification was less prescriptive than the standard specification, with the DOT specifying the pavement thickness and structural design and shifting the responsibility for mix design and placement to the contractor. Subsequent versions added prescriptive requirements for longitudinal joints, smoothness, and paving limitations for weather, as well as additional instructions for quality control. Under the 10-year pavement warranties, contractors are responsible for more aspects of the pavement design, including the mix, structural thickness, and vertical alignment.

All of CDOT's warranty provisions included a weigh-in-motion (WIM) station to track ESALs during the warranty period. Additionally, CDOT's initial provisions required that warranty monitoring be performed by a pavement evaluation team (PET) consisting of three individuals not directly involved in the project, including one CDOT representative, one private consultant, and one industry representative. Almost all of the initial cost increases in the first warranty projects could be attributed to either the WIM or the PET. Subsequent versions of the specification allocated responsibility for monitoring to the CDOT representative on the PET rather than the three-member PET.

All of CDOT's warranty provisions included lane rental provisions for work performed during the warranty period; however, the 10-year provisions allow the contractors a specified number of days per year to perform work without lane rental fees. This provides an incentive for contractors to perform preventative maintenance without penalty.

Interviews with representatives of CDOT revealed the following considerations regarding the warranty program:

- The decision to apply a warranty to a particular project was made at the district level by district engineers;
- Industry was very involved with the development and application of the warranty (e.g., pre-advertisement meetings, pre-bid meetings);
- In addition to historical pavement management data, CDOT used model projects to help establish thresholds used in provisions and invited industry representatives to visit the model projects to give them a feel for the level of service required under the warranty provisions; and
- CDOT established separate guidelines for applying a 3-year hot bituminous pavement (HBP) warranty, 5-year HBP warranty, 5-year portland cement concrete pavement (PCCP) warranty, and 10-year HBP or PCCP warranty.

A cost–benefit analysis of short-term (3- and 5-year) warranties published in 2007 concluded that the use of 3- and 5-year HMA warranties was not a cost-effective tool for CDOT (Goldbaum and Aschenbrener, 2007). This conclusion was based on the evaluation of 10 warranty and control project pairs constructed between 1998 and 2003. CDOT determined that only one project resulted in improved performance at an overall cost savings. Table 6 summarizes the results of the CDOT cost–benefit evaluation.

CDOT concluded that the average initial construction cost of the warranty project was $5,318 per lane mile more than the control projects. CDOT indicated that this amount could be

Table 6. CDOT warranty cost–benefit evaluation summary.

Warranty Project	Years of Performance Data	Overall Cost Savings	Overall Improved Performance
I-25 at Fountain	8	No	No
C-470 at Santa Fe*	8	No	Yes
US-36 at Superior	8	No	No
I-25 North of Pueblo	6	No	No
I-70 at Eagle	6	Yes	Yes
US-50 and Kannah Creek	4	No	No
SH-63 at I-76	4	No	No
I-25 at Ray Nixon	4	Yes	No
US-36 at Byers	3	Not determined	No
US-287 at Ted's Place	3	Not determined	Yes

*In the sixth year after the warranty project was constructed, it needed minor rehabilitation and as a result, its performance was better than the control project after 8 years.
Source: Goldbaum and Aschenbrener, 2007

reduced by approximately $2,573 if CDOT eliminated the PET and the WIM station. It should be noted, however, that CDOT did revise the warranty provisions over the course of implementing these 10 projects, and a learning curve should be anticipated with each revision. Additionally, while every effort was made to match similar control projects to warranty projects for comparative purposes, in most cases the rehabilitation strategies did not match exactly, which may have contributed to the differences in the performance data. Table 7 shows the rehabilitation strategies on the warranty and the control projects.

Florida DOT (FDOT)

FDOT began applying a 3-year materials and workmanship warranty as standard on all pavement projects in 2004. FDOT refers to these pavements as value-added pavements. The state's pavement projects are largely HMA pavements (94% asphalt). FDOT noted that HMA pavement is preferred over PCC pavement because there have been some significant failures in concrete pavements.

In the specification development stage, FDOT organized a team consisting of FDOT and industry representatives in order to build consensus during the specification development stage. FDOT's Type 1 warranty specifications are very prescriptive. In some cases, contractors may be given some flexibility in the mix ratios; however, FDOT noted that there is little difference in the way the warranty project is constructed compared to projects under the Contractor Quality Control/Quality Assurance Program, which was implemented as a precursor to warranties.

FDOT reported that there was no apparent difference in the price of the warranty project due to the prescriptive nature of the warranty provision and the elimination of the warranty bond. In lieu of a bond, FDOT uses prequalification to guarantee the warranty. If a contractor fails to perform a warranty repair, the contractor is precluded from bidding on other work for a period of 6 months, or until the repair issue is resolved, whichever is longer.

FDOT established a statewide Disputes Review Board (DRB) dedicated to resolving pavement warranty disputes that cannot be resolved at the district level. This DRB consists of representatives of academia, industry, and the FDOT. As of this reporting, there have been four failures, two of which were repaired by the contractors before taking it to the DRB. One dispute is currently being evaluated by the DRB.

Table 7. CDOT rehabilitation strategies.

Warranty Project	Warranty Rehab Strategy	Control Rehab Strategy
I-25 at Fountain	1"(NB) & 2.5"(SB) milling	2" milling
C-470 at Santa Fe	0.5" milling	2" milling
US-36 at Superior	1" milling	0.75" leveling course
I-25 North of Pueblo	0.75" milling	2" milling
I-70 at Eagle	1" leveling course	Milling/recondition base/overlay
US-50 and Kannah Creek	Reconstruction/widening	New construction/widening
SH-63 at I-76	Full depth reclamation	Full depth reclamation
I-25 at Ray Nixon	2" milling	4" milling
US-36 at Byers	4" cold recycle	4" cold recycle
US-287 at Ted's Place	0.75" leveling course	2" to 4" milling

Source: Goldbaum and Aschenbrener, 2007

FDOT concluded that while it was still too early to conduct formal evaluations, the small number of disputes and callbacks indicated that the value-added warranty pavements are meeting expectations and protecting against early failures. FDOT noted that they are considering extending the term of the warranty by allowing contractors to bid the warranty in a best-value procurement, awarding higher scores for longer warranties; however, FDOT noted that they must develop performance-based requirements before significantly extending the warranty.

Illinois DOT (IDOT)

IDOT began implementing warranties as a result of a 1999 legislative mandate requiring a 5-year warranty on at least 20 highway construction projects let between 2000 and 2004. The mandate required that at least 10 of the projects be designed for a 30-year design life. IDOT implemented 27 projects in total under this pilot program, including 3 bituminous concrete overlay projects, 8 bituminous concrete projects, and 16 concrete pavement projects. All projects were Type 1 warranties, with IDOT retaining design, material selection, and construction methods. IDOT noted that candidate project selection was largely influenced by the design life of the pavement, but other desirable candidates included projects that were simple in scope, had no unique designs, and did not incorporate any controversial design methods or materials.

The warranty specifications were designed to work as an add-on without much change to the standard specifications since the goal of the program was to protect the department against premature failures due to inferior materials or workmanship. A committee consisting of representatives from several branches of IDOT and a representative of FHWA developed the specification. This committee examined programs at Indiana, Wisconsin, and Michigan and also held a joint work group to allow representatives of the contracting and surety industry to review and comment on the draft specifications. Historical data from the Illinois Pavement Feedback System (IPFS) and Illinois Roadway Information System (IRIS) were primarily used to select performance parameters, but the decision not to warrant reflective cracking on the overlay projects was made as a result of resistance from the industry work groups and acknowledgement that this type of distress may not be within the control of the contractor in an overlay situation. Thresholds and corrective action were determined based on statistical analysis and on the extent and severity definitions of distresses found in the *Distress Identification Manual for the Long-Term Pavement Performance Program* (Miller and Bellinger, 2003).

IDOT structured the warranty as a separate line item in the bid documents. A preliminary bid comparison revealed that the cost of the warranty ranged from 0% to 2.38% of the total contract price. IDOT noted that even with a separate line item for the warranty, it was difficult to quantify the cost of the warranty because the large cost variation in the warranty line item for the 27 projects implemented in Illinois suggests that contractors may have distributed the true cost of the warranty to other line items in their bids (Wienrank, 2004). Based on a survey of resident engineers involved in overseeing warranty projects, only one responded that the contractor paid closer attention to construction details as a result of the warranty. Resident engineers noted that on most projects, construction was completed no differently than on standard projects. Preliminary remarks based on a bid review and anecdotal observations indicated that the warranty projects cost slightly more for about the same level of performance, and that longer periods and performance requirements were needed to realize the full benefit of the warranties.

Warranties are monitored at the district level based primarily on surveys conducted as part of the pavement management data collection process. District personnel review digital images and data collected by the data collection vehicles and determine whether additional surveys and inspections are necessary. IDOT reported that this is an acceptable workload for district engineers since each district has only a few warranty projects, but as that number grows, dedicated personnel would be necessary to manage all the warranties.

IDOT published an evaluation report in 2004; however, since none of the projects had reached the end of their warranty period and several were still under construction at that time, it was recommended that a decision on whether to continue the use of warranties be deferred until more performance data became available (Wienrank, 2004).

Indiana DOT (INDOT)

INDOT's experience includes 5-year HMA and PPC pavement warranties. The first warranty project was let in 1996, and approximately 15 have been constructed to date. INDOT's warranty projects incorporate the concepts of contractor QC/QA, cost-plus-time bidding, and lane rental. INDOT applied this combination of time- and quality-based contracting methods to major projects in high-traffic areas where the goal of the project is to produce high quality in the shortest construction time frame possible. INDOT classifies these warranties as performance warranties since the contractor is responsible for the job mix design while INDOT specifies the structural design and minimum aggregate and binder mixture requirements.

INDOT published a report in 2003 evaluating the performance of approximately 7 HMA projects (involving HMA overlays on rubblized PCC or crack and seat PCC) constructed between 1996 and 2001 (Flora, Gallivan, and Huber, 2003). A subset of non-warranty HMA pavement projects completed in the last 4 to 6 years was selected to be used in a comparative analysis of average values for rutting and International Roughness Index (IRI) on warranty and non-warranty projects. The results of the analysis were that the warranty projects had less rutting and a lower IRI than the non-warranty projects. The analysis concluded that the warranty would extend the performance of the pavement 9 years at an average initial cost increase of 10%, resulting in a 25-year life-cycle cost savings of 27%.

Interviews with INDOT revealed that it worked closely with industry representatives during the development of the warranty specifications. Representatives of INDOT and the local industry collaborated to develop a white paper on warranty use. A list of recommended materials with a history of performing well was provided to aid contractors in developing job mix formulas. Once warranty thresholds for IRI were established, INDOT met with industry representatives for a demonstration on these thresholds. The demonstration included a tour of pavements of various IRI values to aid the representatives in connecting the IRI threshold to a visible example of level of service. In some cases, INDOT modified the warranty provision based on the scope of the project. For example, on crack and seat projects, transverse cracking was removed as a performance indicator since transverse cracking would be expected based on the existing conditions.

INDOT's warranty monitoring system is tied to its existing pavement management system, which is performed by an outside consultant, to mitigate the administrative burden of warranty monitoring on the agency. An INDOT representative reviews pictures taken by the consultant, and if visual defects are present, additional inspections may be scheduled. A separate verification inspection is performed by INDOT near the end of the warranty period for close-out purposes.

INDOT indicated that internally there are mixed opinions about extending the warranty beyond 5 years, and further evaluation is needed to compare the initial costs and assess the potential for lowering life-cycle costs through an extended warranty.

Iowa DOT

Iowa DOT has no experience using warranties, and in fact, has expressed opposition to the use of warranties as a solution for improving quality on highway projects. It should be noted that PCC is the predominant pavement type in Iowa. The concerns raised by representative of Iowa DOT regarding warranties are summarized as follows (Grove, 2005):

- Iowa DOT is better suited than individual contractors to assume the risk associated with long-term performance of pavements.
- Warranties have the potential to reduce competition by precluding contractors that do not have extra bonding capacity available to maintain a warranty bond for the length of the warranty period.
- Warranties only ensure quality through the warranty period, not the length of the design period.
- Shifting responsibility for quality of the pavement to contractors will not automatically make pavement quality the number one priority of contractors.
- Warranties do not promote innovation because they require contractors to minimize risk, which is accomplished by relying on what has been proven to work. Iowa DOT is better suited to shoulder the risk associated with innovation.
- The myriad of factors beyond the paving contractor's control, such as grade conditions, traffic volumes, changes in legal truck load limits after the project is completed, and agency-controlled maintenance (or lack thereof) during the warranty period makes warranties highly susceptible to disputes.
- Assessments of agency personnel savings on warranty projects must account for the significant startup cost to develop an effective warranty specification as well as the effort required to monitor warranties.
- A better understanding of the tools necessary to monitor concrete pavement construction and predict performance is necessary before that risk can be transferred to contactors without exposing Iowa DOT to liability for that risk.

Kentucky Transportation Cabinet (KYTC)

KYTC applied warranties under a multi-parameter bid process that factored price, construction time, and warranty length into the contract award. The specification was developed for use with either HMA or PCC pavement. This warranty provision gave contractors the option to bid a warranty length ranging from 5 to 10 years, and bid values were adjusted for evaluation based on a pre-specified credit for the length of warranty proposed. KYTC specified minimum required structural thicknesses for both designs (HMA and PCC) and shifted responsibility for job mix formulas to the contractor under this warranty provision. The provision also specified separate threshold requirements for HMA and PCC.

Louisiana Department of Transportation and Development (LaDOTD)

LaDOTD's warranty experience includes two 3-year HMA projects and one 3-year PCC project, implemented as a result of a legislative mandate. All three projects involved new construction and included a Type 1 warranty.

LaDOTD did not publish a formal evaluation report on these projects; however, an interview with LaDOTD resulted in the following conclusions concerning its warranty program:

- The warranty period was largely determined by the industry's willingness to accept a 3-year instead of a 5- or 7-year duration;
- Standard inspection and testing responsibilities were carried out by the DOT on all warranty projects;
- Performance indicators were chosen based on using engineering judgment to determine what defects would show within the first 3 years;
- Thresholds for performance indicators were based on a statistical analysis of the pavement management system data; and
- Initial impressions based on anecdotal observations are that the warranty projects cost more and are of equal quality to the non-warranted projects and were therefore not cost-effective.

Michigan DOT (MDOT)

MDOT is the most experienced agency implementing warranty contracting, having constructed over 1,000 warranty projects since 1997. MDOT implemented its warranty program as a result of a legislative mandate. MDOT has not yet conducted a formal evaluation of the warranty program, noting that quality data is not easy to correlate to the warranty given all the variables that can exist within a contract, and MDOT does not yet have enough data points for a fair, accurate performance review of the program. However, the consensus is that contractors pay more attention to quality issues as a result of the implementation of warranties (MDOT, 2005).

Regarding project selection, the first criteria for candidate projects were high-volume roads. Warranties in Michigan are now applied as the standard practice for all paving projects. Exceptions are made in certain circumstances where the existing conditions justify that the warranty requirement should be waived. MDOT recognizes that it may not be able to apply the ideal repair in every rehabilitation situation due to limitations in funding. Therefore, the warranty requirement may be waived in situations where the project is scoped as a quick fix to buy more time until funding is available for the necessary larger rehabilitation. MDOT has developed a project selection tool that addresses when not to use a warranty based on where existing conditions cannot be addressed or the administrative costs would be high relative to the size and scope of the project (MDOT, 2002).

Projects are classified into two categories: capital preventative maintenance (CPM) and rehabilitation and reconstruction (R&R). The majority of projects let each year are CPM projects, and MDOT has more HMA than PCC pavements. Projects included under the CPM program are

- Cold milling and one-course hot-mix asphalt overlays,
- HMA crack treatments,
- Microsurfacing,
- HMA ultrathin overlays,
- Paver-placed surface seal, and
- Single and double chip seals.

Projects included under the R&R program are

- New or reconstructed HMA,
- Multiple course hot-mix asphalt overlays,
- HMA placed on rubberized concrete,
- HMA placed on crush and shaped base, and
- New or reconstructed joint plain concrete pavement.

Warranty periods are 3 years for CPM projects and 5 years for R&R projects; however, specifications for CPM projects are characterized as performance-based, while specifications for R&R are method-based, materials and workmanship warranties. While this does not appear consistent with typical warranty periods for materials and workmanship and performance warranties, the logic is consistent when considered in terms of design life. CPM projects have a much shorter design life than R&R projects. Therefore, a 3-year warranty on a CPM project covers a larger percentage of the design life than a 5-year warranty on an R&R project. For example, a 3-year micro-surface warranty covers approximately 60% of the design life, whereas a 5-year HMA pavement reconstruction warranty only covers approximately 20% of the design life. Therefore, MDOT determined that CPM project warranties should be performance-based, while R&R project warranties should be method-based.

A warranty task force consisting of MDOT and industry representatives was established early in the warranty program. While MDOT had final decision authority for all aspects of the warranty provisions, the task force was consulted on durations, performance measurements, and thresholds. The warranty task force continues to meet on a semi-regular basis to discuss options for improving various aspects of the warranty program.

MDOT has scaled back DOT-performed inspection and testing since the implementation of warranties, especially on performance warranty projects. Materials and workmanship warranty projects may have one inspector assigned to five projects at a given time, while performance warranties may not be inspected until final acceptance. Approximately 3% of all projects require remedial action, and there have been relatively few documented cases of disputes. Due to the size of the warranty program, the warranty management system is maintained separately from the pavement management system.

MDOT noted that the cost increase on warranted projects is primarily attributable to the cost of the warranty bond.

FHWA has granted MDOT approval to use pass-through bonding because for 18% to 20% of MDOT projects, the prime contractor is not the paving contractor. In those cases, the prime contractor typically requires that the paving contractor carry additional bonding, and the MDOT may pay twice for the warranty bond. However, MDOT is also very interested in alternatives that would eliminate the warranty bond. MDOT noted that small- and medium-sized contractors have stopped bidding on warranty projects. It has also seen consolidation of asphalt companies, partly due to the use of warranties. With fewer companies able to participate, the bonding requirements may be reducing competition. Therefore, MDOT is looking into alternatives such as the guarantee model used in Florida and pooled risk insurance for contractors, where contractors with better quality records would pay lower rates.

MDOT does not typically include incentives for pavements that perform exceptionally well, but it is currently piloting a very small number of experimental projects where financial incentives are provided for superior pavement performance.

MDOT outlined the keys to the successful implementation of warranties. They include

- Good pavement management data,
- Proper project scoping, including any necessary preliminary engineering (soil information, traffic information, etc.),
- Pavement design method based on a widely accepted method (i.e., AASHTO) and providing for drainage of the pavement structure,
- Performance measures linked to warranty length,
- Performance thresholds based on real-life pavements,
- Proper warranty administration, and
- Contractor involvement in specification development.

Minnesota DOT (MnDOT)

MnDOT began incorporating warranties in the mid 1990s on both design–build and design–bid–build projects. MnDOT's experience under design–bid–build warranties is primarily 2-year performance warranties on bituminous mill and overlay projects, but it has also developed a 5-year performance provision for bituminous pavements. Contractors are responsible for developing the job mix formula under both the 2-year and the 5-year provisions. Under design–build projects, MnDOT has experience with both rigid and flexible pavement warranties ranging from 3 to 5 years.

MnDOT's innovative contracting summary stated that field personnel on projects with 2-year warranties identified no significant changes to the bituminous construction practices. It also stated that additional time was needed to assess the effectiveness of 5-year warranties on design–build projects (Johnson, 2004).

MnDOT performed a cost analysis on its bituminous warranty projects to determine the cost increase on warranty projects. The analysis examined projects that had both warranty and non-warranty items with the same mix design and non-warranty projects with similar bituminous bid items that were let within three months of the warranty projects in the same districts. The analysis found no apparent trends to suggest that the unit prices for warranty items increased compared to non-warranty items; however, based on information from the MnDOT estimating unit, MnDOT concluded that contractors are including costs to address the warranty in the mobilization item (Johnson, 2004).

MnDOT also considered implementing a 20-year warranty; however, it ultimately decided not to include the warranty due to several key issues that arose during the negotiation process, including the fact that the project was being constructed on excellent graded material, making subgrade failures less likely. Additionally, the maximum liability was capped at 1.5 times the warranty cost, and the warranty price included inflation of 3% to protect the warrantor against spikes in the bituminous cost. MnDOT decided that the implementation of the 20-year warranty would not be a cost effective tool.

Mississippi DOT

Mississippi DOT has experience with both HMA and PCC pavement warranties, having constructed approximately 13 HMA performance warranties and one PCC performance warranty since 2000. Mississippi DOT reported that initial bid increases on warranty projects were approximately 30%, but bid increases have leveled off at approximately 11% to 12%. Mississippi DOT developed a warranty program after receiving no bidders on a highway rehabilitation project. The project was split in half and re-bid as two projects, one as a traditional project and one as a warranty project. A case study on this project is included as Appendix C4.

Mississippi DOT's warranty projects are characterized as short-term performance warranties. Contractors are responsible for the mix design, while the DOT specifies the structural thickness. During construction, Mississippi DOT does not perform density checks in the field; however, it does verify smoothness and thickness through computerized profiling and coring. Price adjustments may be made based on the achieved smoothness and thickness. Warranty periods are 5 years for HMA and 10 years for PCC; however, Mississippi DOT noted that it plans to increase HMA warranties to 7 years, keeping the same thresholds, and it is also considering a reduced 5-year option for PCC.

Mississippi DOT developed a software program (DEDUCT) that translates different distress thresholds for pavement performance measures into a common point system for pavement distress. The software program asks the user to select a severity level for the distress based on the severity levels defined in the *Distress Identification Manual for the Long-Term Pavement Performance Program* (Miller and Bellinger, 2003). The program also asks for the extent of the distress in terms of percentage, length, surface area, or number relating the distress to the historical performance curve for that distress. The program then applies a point value for the distress based on the comparison of the distress level to the historical curve (Mississippi DOT, 2001).

Mississippi DOT is traditionally an asphalt state, and only about half of the asphalt contractors are willing to bid on warranty projects. Most contractors attributed inability to obtain bonding as the reason for not participating on warranty projects. As a result, Mississippi DOT has seen some reduced competition in the asphalt industry as a result of warranties; however, the concrete industry has been supportive of warranties since they see it as an opportunity to increase the number of contracts let for concrete pavements. Mississippi DOT noted that the likelihood of obtaining competitive bids often plays a role in warranty project selection.

Mississippi DOT conducts separate surveys for its warranty program and its pavement management program. Under the pavement management program, a survey of all roads in the DOT network is conducted every 2 years by an outside consultant. Under the warranty monitoring program, a survey is conducted every year on warranted pavements by a team from the research division. However, collection methods for the biannual survey and warranty survey are the same except for the collection of data on joint faulting. The biannual survey collects data using a laser profiler while the warranty survey collects this data using a Georgia fault meter. Mississippi DOT has not had any major disputes on warranty projects, and only one case in which the contractor was not liable for defects that occurred. In this case, a threshold for flushing was exceeded, but it was determined that the residue was actually being tracked by trucks coming from a nearby construction site.

Mississippi has not published a formal evaluation report; however, comparative data and anecdotal evidence suggest warranties have resulted in improved performance. Anecdotal evidence of improvements include contractors consulting third parties on the mix design, using higher PG grading, and using better crews and equipment on warranted projects.

Ohio DOT (ODOT)

ODOT has the second highest level of experience using warranties, having implemented more than 200 warranties since 2000. ODOT began implementing warranties as a result of a legislative mandate requiring that a minimum of 20% of all projects include a warranty. The legislation was revised the following year, deleting the minimum requirement and substituting a maximum requirement for 20% of all projects to include a warranty. ODOT warranty periods are primarily 3-year for preventative asphalt treatments, 7-year for asphalt pavement, and 7-year for concrete pavements, though the initial asphalt pavement projects were 5-year warranties. ODOT implements both materials and workmanship and performance warranties. Asphalt warranties are more performance-oriented, while concrete warranties are materials and workmanship.

Ohio's contractor association served on committees with DOT personnel to discuss and set performance indicators and thresholds; however, the legislation imposed a 6-month deadline on the timeline for the development of the warranty provision. Therefore, there was limited high-level review involved due to the time constraints. The same thresholds used to flag a road for maintenance or repair work were used as the thresholds to trigger the warranty. The committees also established the bond price, which was based on the estimation of the typical repairs costs.

ODOT stated that project selection criteria for warranty projects included simple projects with well-defined pre-existing conditions and overall consistency compared to a typical urban main-street project in a downtown area where there are many crossings, signals, and transitions. The decision to apply a warranty is made at the district level, and district construction teams are responsible for monitoring pavement warranties on an annual basis. ODOT stated that there were some inconsistencies between the districts regarding inspection processes and the level of inspection presence on-site. Unlike ODOT's contractor quality assurance specification, the warranty provisions do not require contractors to submit quality records or reports. As a result, some districts choose to maintain these records.

ODOT performed a comparison of bid prices for its pavement warranty projects. The analysis found that while there were significant increases in the initial projects bid in 2000, by 2005 the average bid increases had become insignificant. Table 8 summarizes the bid evaluation of pavement warranties.

Cost increases were attributed primarily to the warranty bond, which was paid for under a bond line item that included the total cost for the performance, payment, and warranty bond. It was difficult to isolate the cost of the warranty bond, but ODOT estimated that the bond was approximately 1% of the total cost of the work.

ODOT's quality assessments are based largely on the perceptions of the district engineers overseeing the warranty work. According to ODOT's latest report, the current perception of warranty projects is that contractors are being more conscientious about their work, but they are not necessarily producing significantly better products. In some cases, contractors were found to be more proactive in improving poor soil conditions prior to placing the pavement, but in other cases, ODOT believed that contractors improved the surface course at the expense of the underlying non-warranted base

Table 8. ODOT bid evaluation summary.

Item	Warranty Period (Years)	Avg. Bid Price Change (2000)	Avg. Bid Price Change (2005)
Asphalt (full depth)	5 and 7	+9%	+1.19%
Asphalt (overlay)	3	+8%	-1.83%
Concrete pavement (11”)	7	+7%	-7.83% (all thicknesses)
Concrete pavement (12” & 13”)	7	+15%	

Source: ODOT, 2007

course. Concern has been expressed that in these instances, defects due to a substandard base course will not arise until after the warranty period, and ODOT is considering changes in the specification to address this issue. While the use of warranties continues, the level of use has declined in recent years.

ODOT cited other concerns regarding warranty enforcement. Without comprehensive inspection records to document existing conditions and placement methods, determining the cause and enforcing the warranty may prove difficult in case of a failure. Another issue was the handling and addressing of superloads—large, one-time ESALs of 18,000 pounds or more in the warranty specification. While experience shows that the department designs are capable of handling such loads, many contractors disagree and believe such loads should void the warranty. ODOT has received letters from contractors during construction indicating problems with the base conditions and requesting that ODOT either authorize an extra work order for repairs to the existing base or void the warranty. Finally, ODOT noted difficulty in determining the start of the warranty period, especially on large, multi-phased projects. If the warranty is started upon opening to traffic, it may make monitoring an even more arduous task since there may be several different warranted segments. ODOT indicated that all of the above factors make enforcement of the warranty more difficult.

Texas DOT (TxDOT)

TxDOT has developed warranty specifications for hot-mix asphalt concrete, surface treatments, and microsurfacing, but has only implemented the microsurfacing specification. TxDOT reported issues in developing reliable thresholds for pavement warranties due to inconsistencies in its historical performance data, both in the type of pavement characteristic measured and how these characteristics were measured. This difficulty in determining thresholds has led to the slow implementation of warranties in Texas (Anderson et al., 2006). Currently, TxDOT has no plans to implement warranty specifications.

Wisconsin DOT (WisDOT)

WisDOT was the first agency to experiment with both HMA and PCC pavement warranties, each for 5-year periods. WisDOT began implementing warranties in 1995, following its implementation of a comprehensive quality control and quality assurance program. WisDOT noted in its 3-year progress report that the initial thresholds were easily achievable, which minimized the risk to contractors on the initial warranty projects. WisDOT’s long-term intention was to either tighten the threshold values or extend the warranty period once WisDOT and contractors gained some warranty experience (WisDOT, 1998).

WisDOT stated that the intention of the warranty program was to give contractors as much freedom as possible while ensuring a quality product. WisDOT does not perform inspections or testing on warranty projects, and it identifies the ability to place these resources elsewhere as the most significant advantage to using warranties.

Wisconsin contractors use their best crews on warranty projects; however, the majority of the state work is performed by a few large paving contractors. While these larger contractors have the bonding capacity necessary to support warranties, there are some small asphalt companies that have been precluded from participating in warranty contracting due to limited bonding capacity. To reduce the impact of the bonding requirement and stimulate competition, WisDOT requires a warranty performance bond for the first year of the warranty, and then requires that the warranty bond be reissued in 2-year increments for the duration of the warranty.

WisDOT published a 5-year progress report on its asphaltic pavement warranties in June 2001. WisDOT acknowledged that the limited amount of performance data available made assessing long-term trends difficult, but it offered a glimpse of comparative performance data by attempting to capture comparative cost data between warranty and non-warranty contracts over a 5-year period (Brokaw et al., 2001).

Costs evaluated under standard contracts over 5 years included mix bid prices, asphalt bid prices, tack coat bid prices, quality management bid prices, state delivery costs, and state maintenance costs. Costs evaluated under 5-year warranty contracts included warranted asphalt pavement bid prices and state delivery costs. Conflict resolution costs were found to be negligible on both project types. Additionally, distress surveys and further testing in cases of disputes were found to be negligible on warranty projects.

Table 9. WisDOT pavement performance data.

Performance Indicators	Pavement Age					
	New	1 Year	2 Years	3 Years	4 Years	5 Years
State average IRI – non-warranty	1.11	1.17	1.29	1.33	1.37	1.45
Average IRI – warranty	0.81	0.87	0.89	0.89	0.94	0.94
State average PDI – non-warranty	0	5	11	16	21	26
Average PDI – warranty	0	1	2	6	12	9

Source: Brokaw et al., 2001

The results of the cost comparison were divided into two categories based on the year the project was let. Projects let in 2000 were broken out because of the addition of ancillary pavements to the warranty provision and the large increase in asphalt price that occurred that year. The evaluation showed warranty projects averaged $24.34 per ton compared to $27.72 per ton for standard projects from 1995 to 1999, and warranty projects averaged $29.34 per ton compared to $31.25 per ton for standard projects let in 2000. In both cases, the warranted projects appeared to cost less overall compared to non-warranted projects. This cost comparison concluded that even where an initial cost was up to 7% greater, warranty pavements were still more cost effective than standard pavements.

The report also examined the comparative performance data on the warranty and non-warranty projects over the 5-year period. As shown in Table 9, the average IRI values of the warranted pavements over 5 years were improved compared to the average state IRI values. The pavement distress index (PDI) values were also significantly better than average state PDI values for non-warranted pavements.

Based on the results of the 5-year progress report, WisDOT plans to continue using warranties and to make the warranty decision earlier in the design process. Other program recommendations include

- Moving to a 7-year warranty while keeping the 5-year threshold values to tighten the requirements;
- Considering the addition of an incentive that would reduce the warranty period for above-average performance, giving contractors bonding relief and providing a resource savings for the agency by eliminating unnecessary annual monitoring;
- Investigating the use of optional warranty bidding; and
- Considering implementing warranties as a standard.

Type 3 Long-Term Performance Warranties

Only a small number of U.S. highway projects have implemented Type 3 long-term performance warranties. As noted in Table 10, these have been implemented in Virginia, Missouri, and New Mexico, using hybrid construction manager at risk or design–build–warrant contracts, but the concept of long-term performance or maintenance contracts is being developed or explored in several states using PPPs or concessionaires, including in Indiana, Texas, and Virginia. Virginia is moving forward with PPP development and long-term operation and maintenance agreements under its Public–Private Transportation Act (PPTA) program (Interstate 81, Coalfields Expressway, and U.S. Route 460). These maintenance and operation agreements are typically concessions or long-term lease agreements (50 years or more) on toll roads. For example, the Trans-Texas Corridor (SH-130) and the Indiana Toll Road include performance indicators and distress thresholds (performance standards) for HMA pavements similar to those found in long-term warranty agreements. The agreements also may require the developer to maintain the pavement at a defined level of service for periods beyond the typical service life for the pavement and include pavement turnover standards at the end of the contract period (Seiders, 2006).

Table 10. Type 3 U.S. pavement warranties.

DOT	Project	Warranty Duration
Missouri	Highway 63	25 years
New Mexico	State Route 44	20 years
Virginia	Route 288	20 years

Table 11. Project selection authority.

DOT	Project Selection Authority
California	District with headquarters
Colorado	District engineers
Illinois	Pavement warranty committee
Indiana	Central office
Louisiana	State chief engineer
Mississippi	District engineers
Ohio	District engineers
Wisconsin	District engineers

Factors in Project Selection and Implementation

Project Selection

Few DOTs have established formal guidelines for warranty selection criteria, and authority for project selection is often delegated to the district level. Therefore, project selection criteria vary from state to state, and in some cases, within states. Table 11 summarizes how several DOTs delegated project selection authority.

Caltrans, CDOT, and ODOT each established written guidelines or white papers on project selection criteria. These guidelines are included in Appendix C5. Despite the lack of formal guidelines and variations among districts, DOTs offered general comments regarding the types of projects typically warranted. Comparison of the state experiences shows that warranty application ranged from safe projects with little risk of failure to highly urbanized projects that contained a myriad of unknown variables and risks. Table 12 illustrates how various DOTs compared with respect to project selection.

DOTs interviewed acknowledged that applying a warranty to safe projects may result in little or no benefit over standard contracting practices; however, it became apparent during the interview process that while project-level criteria are an important part of the warranty decision process, programmatic-level criteria must also be considered in the project selection process. This was particularly true in states where warranty programs were initiated by legislative mandates. For example, initial legislative requirements in Ohio required warranties on a minimum of 20% of all projects let. ODOT reported that in some instances, warranties were applied simply to comply with legislation without much consideration to the project-level criteria. Legislation in Illinois required that warranties be applied to 10 projects with a 30-year design life as opposed to the standard 20-year design life. As a result, project selection was based largely on the feasibility of increasing the standard pavement thickness to comply with the legislation.

Another programmatic-level criterion that appeared to play a part in the project selection criteria was level of industry cooperation. Mississippi DOT reported that the level of competition on warranty projects varied among districts, which often plays a role in the decision to apply a warranty.

Contracting procedures can also affect project selection criteria. INDOT applies warranties in conjunction with A+B bidding with the goal of optimizing construction time and

Table 12. Criteria for candidate warranty project.

DOT	Project Selection Criteria	Warranty Description
LA	New construction only	3-year materials and workmanship
CA	Projects with solid foundations; guidelines for cracking and exclusion areas	1-year materials and workmanship
IL	Simple in scope with no unique design, materials, or other innovations	5-year materials and workmanship
FL	All projects	3-year materials and workmanship
WI	Projects with excellent subbase	5-year performance
CO	Primarily paving scope with solid foundation, predictable traffic, and significant paving scope	3- and 5-year materials and workmanship
OH	Simple, consistent scope, not highly urbanized	7-year materials and workmanship
MS	Free of severe underlying defects	5-year performance
MI	All, unless the proper repairs cannot be addressed in the scope or project is short	5-year materials and workmanship
MN	Discretion of the district engineer	2- and 5-year materials and workmanship
KY	Major traffic routes	10-year performance
IN	Major project in high traffic areas	5-year performance

quality. As a result, warranties are applied to highly visible, time-sensitive projects.

In Louisiana, while it appeared that LaDOTD used appropriate project-level selection criteria, programmatic issues such as limitations in the use of performance-based requirements resulted in dissatisfaction with warranty outcomes. LaDOTD reported that warranties resulted in an increased cost for the same performance.

Based on the information drawn during the interviews regarding project selection, it was apparent that the selection tool developed for this research project should encompass more than just project-level selection criteria. As a result, the researchers focused on the development of a multidimensional warranty decision tool that addresses both programmatic and project-level section criteria.

Furthermore, the existing project selection processes, particularly those developed by Caltrans and Michigan, led to the conclusion that the scoping of the project will be a key factor in the decision to use a warranty and will determine what warranty type can be implemented based on the risk allocation. For example, Michigan's selection process for pavement rehabilitation considers base conditions, and if repairs are needed, the scope must include repairs to the base as a condition for using a warranty. Similarly, Caltrans defines warranty exclusion areas if crack repairs are not part of the project scope. In principle, DOTs can apply a warranty on any project incorporating a scope that reduces the risk to the DOT and to the contractor. Thus, warranties are applicable to rehabilitation projects where the scope of the rehabilitation can incorporate an appropriate fix consistent with the severity level of the existing pavement.

It was also determined that in addition to addressing programmatic and project-level selection criteria, the tool must address the differences among the three types of warranties when deciding how to implement the warranty. Warranty requirements, such as the need for performance-based specifications and contractor design expertise, vary depending on the type of warranty implemented. A comparison of programmatic factors related to warranty contracting for the three warranty types is included in Appendix C6. These factors, along with the project-level selection criteria identified through interviews, formed the basis of the warranty decision tool and guidelines discussed in Chapter 3 and presented in Appendix A.

Despite the variation in reported outcomes of various types of warranties, the researchers decided to include all warranty types in the warranty decision tool. While several DOTs, including CDOT, MNDOT, and LaDOTD, have essentially concluded that materials and workmanship warranties have not proven to be beneficial over standard contracting practices, based on the collective state experience, it appears that these materials and workmanship warranties may serve as an important stepping-stone to larger warranty programs. These types of warranties give both contractors and DOTs the opportunity to gain experience with warranty contracting without placing excessive risks on either party. There is a limited risk to the contractor under a Type 1 warranty since the contractor is only guaranteeing that it has constructed the job in strict adherence to the standard specification. Consequently, the only additional cost under a Type 1 warranty should be the cost of the warranty bond. Without evidence that Type 1 warranties result in improved performance compared to standard projects, many DOTs view these warranties as an unnecessary expense. However, DOTs that forgo a warranty bond may find that Type 1 warranties can improve consistency of the overall network and act as an additional guarantee against lemon projects at no additional cost to the DOT, as reported by FDOT and Caltrans.

Several DOTs reported quality improvements as a result of Type 2 performance warranties, including Mississippi DOT, INDOT, and WisDOT. However, these DOTs admit that accurate, quantitative comparisons to support the effectiveness of warranties are difficult to achieve due to the many variables affecting project performance.

DOTs with experience using Type 3 warranties contend that it is too early to determine the cost effectiveness or utility of these long-term warranties. However, with the increased interest and use of alternative design–build–warrant contracting and PPPs, Type 3 warranties will evolve into different forms within these long-term contracts that include similar performance criteria but significantly different administrative requirements.

Implementation

The implementation of construction warranties has varied based on DOT objectives, warranty type, contracting approach, industry feedback, and other factors. DOTs have shared information and experience on the use of warranties, which to some extent has promoted consistency in how the provisions are structured. Most practitioners would agree that key technical and managerial elements must be considered in guidelines as part of implementation regardless of objectives for use or type of warranty. In addition to project selection criteria, other key considerations include selecting performance indicators, setting distress thresholds, warranty durations, bonding, and risk allocation and contracting considerations. These are addressed in the following sections.

Selecting Performance Indicators

Warranty performance indicators are distresses, or functional characteristics of the warranted component that can be measured and linked to the performance of the warranted component. Performance indicators for a pavement may include distresses or characteristics such as cracking, rutting, and ride quality.

Based on the DOT responses, a variety of sources were used to identify and select performance indicators. The majority of DOTs indicated that historical information and experience were used to identify typical criteria that are easily, accurately, and routinely measured to assess performance of the product or component over time. ODOT further reinforced the importance of historical data in a 2003 report (Hastak, Minkarah, and Cui, 2003), stating that a key criterion for evaluating warranty provisions is tracking how warranty projects are performing compared with historical data for non-warranted projects.

Several DOTs (Mississippi DOT, for example) use standardized reference manuals, such as the SHRP Distress *Identification Manual for the Long-Term Pavement Performance Program,* to identify and define performance indicators and distresses (Miller and Bellinger, 2003). CDOT and ODOT stated that the indicator selection process was a joint effort including representatives of the DOT and industry. A representative of the Materials Division for Maine DOT stated that performance indicators used by other DOTs were researched and considered during the DOT's indicator selection process. Often, DOTs use a combination of resources. For example, Illinois DOT described reviewing sample specifications from other DOTs, national reference manuals, historical performance data, and statistical analyses and using a joint DOT–industry work group to develop its performance-based warranty specifications.

Table 13 shows representative samples of performance indicators used to gauge performance on warranty contracts.

An issue to consider when selecting performance indicators is whether the monitoring process for selected indicators is consistent with established state practices for asset management. For example, distress characteristics routinely monitored through a pavement management program are relatively easy to administer under the existing program. If a performance indicator is not something that is routinely measured, the DOT must decide whether the benefit of the warranty will outweigh the burden of a separate monitoring process.

A second issue is whether causes of premature failures are easily identifiable through inspection or forensic study. For example, Table 14 shows that all the sample HMA pavement specifications collected through the literature included rutting as a distress characteristic. Rutting is an easily identifiable and measurable pavement distress that is typically one of the first distresses to appear. Typically, it is easier to identify the cause of rutting than other distress characteristics, making it a good characteristic to monitor under a warranty.

Indiana DOT selected rutting, IRI, longitudinal cracking, transverse cracking, and friction to evaluate its pavement conditions, aligning the warranty criteria with properties routinely collected under its pavement management system (PMS). INDOT did not include properties such as segregation, block cracking, flushing, and potholes in the primary evaluation because it decided that these distresses were more subjective and harder to measure or could be addressed as part of remedial action if any thresholds for the primary performance indicators were exceeded.

Setting Functional or Distress Thresholds

Warranty provisions specify threshold values for performance indicators. Threshold values are essentially measurable tolerances for the performance indicators. Warranty provisions may define maximum allowable tolerances for thresholds, which if exceeded trigger remedial action. They may also define zero-tolerance thresholds, meaning that the existence of any sign of distress requires remedial action. Thresholds are typically tracked by visual inspection, laser profiling, or individual measurements.

Survey respondents were asked to comment on the process for determining threshold values. DOTs develop benchmarks for thresholds using various resources, including statistical analysis of historical data, such as the state's pavement management system, analysis of completed model projects perceived to be performing well, collaboration with industry representatives, information from other DOTs, and the state's expectations for quality.

Table 13. Performance indicator examples.

DOT	Component	Performance Indicators	
CA	Pavement microsurfacing	Rutting Raveling Flushing	Streaking Defective areas
IN	HMA pavement	Rut depth Transverse cracking Longitudinal cracking	IRI Friction number
MI	Jointed plain concrete pavement	Transverse cracking Longitudinal cracking Map cracking Spalling	Scaling Corner cracking Joint sealant failure

Table 14. Performance indicators for HMA pavement warranties.

DOT	Rutting	Raveling/Segregation	Cracking	Longitudinal Cracking	Transverse Cracking	Block or Edge Cracking	Delamination	Depression/Shoving	Bleeding/Flushing	Potholes	Alligator Cracking	Fatigue/Reflection Cracking	Debonding	Disintegrated Area	Smoothness	Ride Quality or IRI	Patching	Friction Number
CA	x	x	x				x		x	x								
CO	x	x		x	x		x	x	x	x								
FL	x	x	x						x	x						x		
IN	x			x	x											x		x
IL	x	x		x	x	x		x	x	x		x				x		
LA	x	x		x	x	x		x	x	x		x						
ME	x			x	x	x		x	x		x						x	
MI	x	x		x	x				x				x					
MN	x	x		x	x	x			x	x	x	x						
MS	x	x		x	x	x			x	x	x	x						x
NM	x	x		x	x		x	x	x	x					x	x		
OH	x		x						x					x			x	
TN	x	x		x				x	x	x						x		
WI	x	x		x	x	x			x	x	x						x	

Factors that affect the development of thresholds include the warranty classification (materials and workmanship versus performance), the availability of reliable historical data, and the level of industry cooperation. For example, DOTs aiming to establish consistent quality of the pavement network by strict adherence to the specification may establish thresholds that are consistent with historical, statewide statistical averages, while DOTs aiming to improve quality on a particular high-profile project may establish thresholds more stringent than historical averages. Most practitioners reported that threshold establishment began with a review of historical information.

Solid, reliable historical performance data are a key to establishing thresholds consistent with the quality expectations of the DOT as well as industry standards. DOTs that struggled to establish thresholds reported that gaps or inconsistencies existed in the historical performance data. For example, when examining the feasibility of developing a pavement warranty specification in Texas, researchers reviewed historical pavement management data to determine whether accurate thresholds could be developed (Anderson et al., 2006). When examining rutting, researchers found that the method used to evaluate rutting in Texas DOT's pavement management system was to measure rutting as a percentage of the section's total wheel-path area. However, the SHRP *Distress Identification Manual for the Long-Term Pavement Performance Program* defines rutting severity as rut depth in inches (Miller and Bellinger, 2003). Furthermore, a survey of warranty provisions used in other states showed that rutting threshold values were always expressed as rut depth. Because the Texas DOT pavement management system did not record rut depth, researchers were not able to establish a threshold consistent with industry-established terms and measurements of distress. Such inconsistencies in pavement data have hindered the implementation of pavement warranties in Texas and can act as a gap to implementation in other states (Anderson et al., 2006).

DOTs that collaborated with industry throughout the developmental processes established reasonable thresholds for both the DOT and the industry. Some DOTs worked with industry representatives to familiarize the industry with different levels of performance. For example, the Indiana DOT invited a group of industry representatives to participate in a demonstration of IRI values. The demonstration involved taking rides with these representatives on roads of varying IRI values to give them a better understanding of what the IRI is and how it relates to the warranty requirements. Other DOTs, including those of Wisconsin and Mississippi, started out with relatively easy-to-obtain threshold values to gain support and build experience within the industry. Wisconsin DOT is now considering modifications to either the threshold values or the warranty length as parties become more knowledgeable and comfortable with the application of warranties. Mississippi DOT reported that it initially chose a 5-year threshold for HMA and a 10-year threshold for PCC, but after letting two HMA projects, it decided to increase the HMA term to 7 years, with the same thresholds, on subsequent projects.

Threshold values are structured several different ways. Some performance indicators use a single, minimum threshold value, while others may specify levels of thresholds with different remedial procedures that correspond to the severity of the distress. Other thresholds are expressed in terms of percentages of the overall segment or a predetermined length or surface area of the warranted component.

Mississippi DOT developed the DEDUCT software program, which translates different distress thresholds for pavement performance measures into a common point system for pavement distress. DEDUCT asks the user to select a severity level for the distress based on the severity levels defined in the *Distress Identification Manual for the Long-Term Pavement Performance Program* (Miller and Bellinger, 2003). The program also asks for the extent of the distress in percentage, length, surface area, or number to relate it to the historical performance curve for that distress. The program then applies a point value for the distress based on the comparison of the extent of the distress to the historical curve. Table 15 illustrates how thresholds for the same HMA pavement distress are defined differently by various DOTs.

Maine DOT indicated that the threshold values should account for both the number of defects and the dimensions of the defects. The comment was in reference to an issue arising on an HMA warranty project in Houlton. The warranty provision called for remedial action if two or more transverse cracks were found in a single pavement segment. A segment was defined as a 100-meter (328-ft) portion of the pavement surface. During monitoring, the DOT found that many segments of the project had one transverse crack, one of which was more than 50 mm (1.9 in.) wide, but these segments did not require remedial work because there was only one crack in the segment.

Another potential issue with thresholds is determining whether to specify a distinct minimum threshold or a graduated scale or performance curve during the warranty period. In other words, if the warranty period is 5 years, the DOT must determine whether the threshold should be set at the anticipated 5-year value or be based on a performance curve with differing values for years 1 through 5. A report prepared for the Montana DOT concluded that performance thresholds should be the minimum thresholds, as opposed to graduated thresholds over the warranty period, citing the disadvantage that the performance curve can be modified once remedial action is performed.

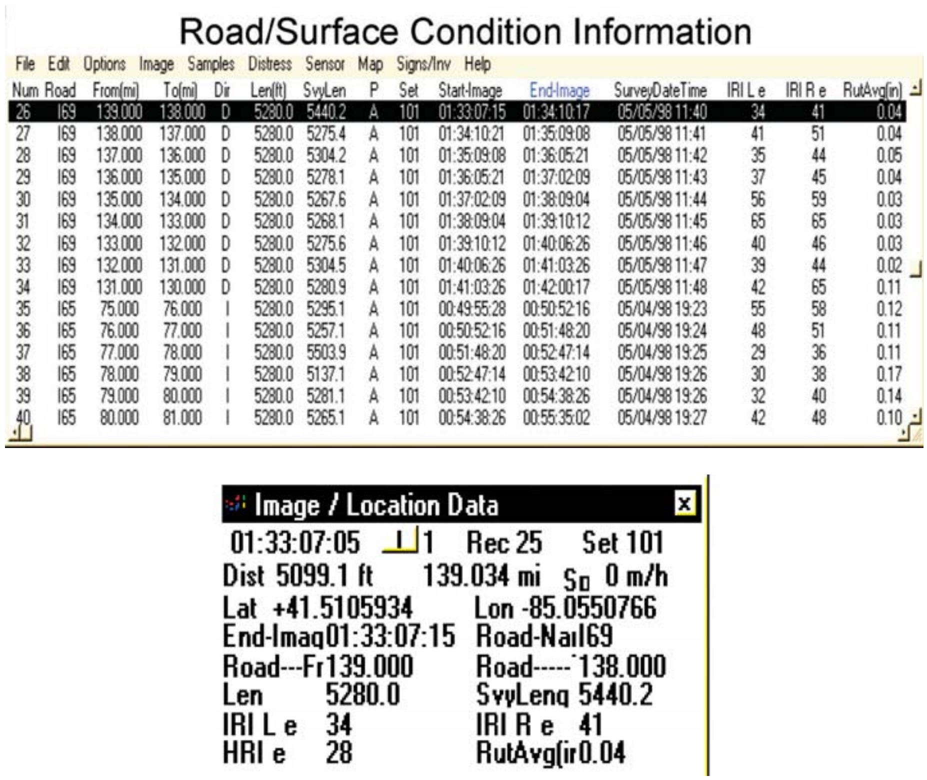
The manner in which performance data is tracked and evaluated should be considered when setting threshold values. Selecting performance indicators similar to distresses tracked under the standard pavement management system is useful for developing comparative performance data; however, consideration should be given to the length of the segment over which data points are measured when setting thresholds. If the evaluation segments are too long, a localized area of poor performance can be diluted. Distresses on warranty projects are typically measured over shorter segment lengths than the segment lengths measured during typical pavement condition surveys to ensure that localized areas are not diluted. The effect of differences in segment length should be evaluated when considering thresholds or comparing data points.

To illustrate how a baseline performance threshold might be developed, the following steps provide an approach for establishing baseline IRI thresholds using PMS project data based on age and functional classification.

1. Review existing PMS data. For this example, PMS data is taken from an Indiana DOT 10-year HMA pavement using high-speed data collection methods (inertial profiler). Segments are typically 1.0 mile in length, as shown in Figure 6. These PMS segments are typically too long to accurately evaluate warranted pavement condition for shorter warranty segments.
2. To develop IRI thresholds for shorter warranty segment lengths, typically 0.1 mile, reprocess the existing PMS data for shorter sections by eliminating the data from areas with expected localized extremes caused by bridge approaches or other transitions in the pavement.
3. For an evaluation length of 0.1 mile (520 ft), use the reprocessed PMS data to compile the IRI and rutting data

Table 15. Threshold values.

Indicators	Measurement Basis and Thresholds		
	Mississippi Deduct Points	Wisconsin Segment = 0.1 mi	Minnesota Segment = 500 ft
Rutting	>5.0 points >7.0 points	≥0.25 in. <0.50 in. ≥0.50 in.	≥0.375 in. (25 ft of the segment length)
Transverse cracking	>3.0 points >5.0 points	>25 cracks that average 0.5 in. wide per segment (granular base)	3 cracks per segment with minimum length of 6 ft (med. severity)
Longitudinal cracking	>4.0 points >6.0 points	>1,000 linear ft of cracks that average 0.5 in. wide	None allowed



Road/Surface Condition Information

File Edit Options Image Samples Distress Sensor Map Signs/Inv Help

Num	Road	From(mi)	To(mi)	Dir	Len(ft)	SvyLen	P	Set	Start-Image	End-Image	SurveyDateTime	IRI L e	IRI R e	RutAvg(in)
26	I69	139.000	138.000	D	5280.0	5440.2	A	101	01:33:07:15	01:34:10:17	05/05/98 11:40	34	41	0.04
27	I69	138.000	137.000	D	5280.0	5275.4	A	101	01:34:10:21	01:35:09:08	05/05/98 11:41	41	51	0.04
28	I69	137.000	136.000	D	5280.0	5304.2	A	101	01:35:09:08	01:36:05:21	05/05/98 11:42	35	44	0.05
29	I69	136.000	135.000	D	5280.0	5278.1	A	101	01:36:05:21	01:37:02:09	05/05/98 11:43	37	45	0.04
30	I69	135.000	134.000	D	5280.0	5267.6	A	101	01:37:02:09	01:38:09:04	05/05/98 11:44	56	59	0.03
31	I69	134.000	133.000	D	5280.0	5268.1	A	101	01:38:09:04	01:39:10:12	05/05/98 11:45	65	65	0.03
32	I69	133.000	132.000	D	5280.0	5275.6	A	101	01:39:10:12	01:40:06:26	05/05/98 11:46	40	46	0.03
33	I69	132.000	131.000	D	5280.0	5304.5	A	101	01:40:06:26	01:41:03:26	05/05/98 11:47	39	44	0.02
34	I69	131.000	130.000	D	5280.0	5280.9	A	101	01:41:03:26	01:42:00:17	05/05/98 11:48	42	65	0.11
35	I65	75.000	76.000	I	5280.0	5295.1	A	101	00:49:55:28	00:50:52:16	05/04/98 19:23	55	58	0.12
36	I65	76.000	77.000	I	5280.0	5257.1	A	101	00:50:52:16	00:51:48:20	05/04/98 19:24	48	51	0.11
37	I65	77.000	78.000	I	5280.0	5503.9	A	101	00:51:48:20	00:52:47:14	05/04/98 19:25	29	36	0.11
38	I65	78.000	79.000	I	5280.0	5137.1	A	101	00:52:47:14	00:53:42:10	05/04/98 19:26	30	38	0.17
39	I65	79.000	80.000	I	5280.0	5281.1	A	101	00:53:42:10	00:54:38:26	05/04/98 19:26	32	40	0.14
40	I65	80.000	81.000	I	5280.0	5265.1	A	101	00:54:38:26	00:55:35:02	05/04/98 19:27	42	48	0.10

Figure 6. PMS data for IRI and rutting for INDOT 10-year HMA using a high-speed inertial profiler and rut bar based on 1.0 mile segment lengths.

for 520-ft (0.1-mile) sections. Figure 7 shows a sample IRI and rut data strip for a 501-ft section.

4. Determine the statistical distribution of the data and calculate the standard deviation (σ) of IRI, as shown in Figure 8.

As shown in Figure 8, σ is a measure of dispersion. Assuming a normal distribution, approximately 68% of the data would fall within 1 σ, and 95% of the population would fall within 2 σ. As a starting point, the DOT may set the threshold at 2 σ (where only 5% of measured sections would exceed the threshold) to reduce the risk to the contractor for a 10-year warranted pavement. With additional experience or improved consistency, the DOT may decide to tighten the threshold (to between 1 σ and 2 σ) or extend the warranty.

If one considers the variability or dispersion of distress values on the warranty versus the non-warranty projects, the consistency of the warranty projects is likely to be consider-

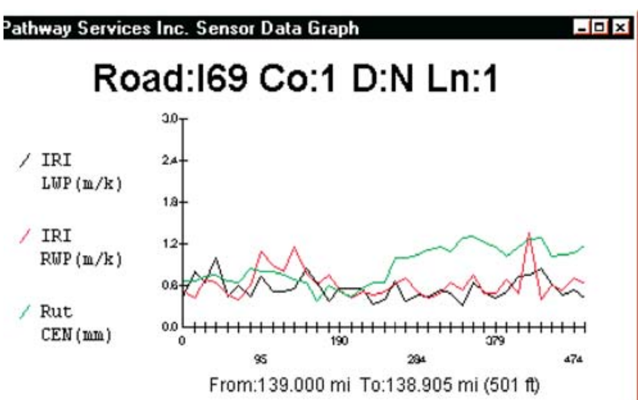


Figure 7. INDOT IRI and rut data for a 0.1 mile segment length.

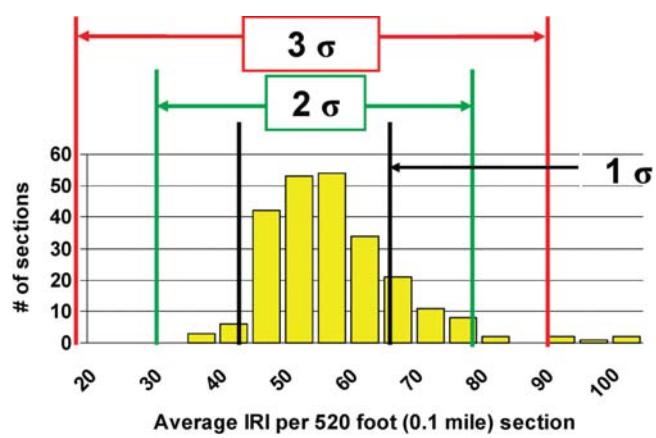


Figure 8. Distribution and standard deviation (σ) for IRI over a 0.1 mile segment.

ably better than that of the non-warranty projects. Therefore, the consistency, and thus quality, of the warranty projects is improved, even if a comparison of the averages shows performance to be about the same. These factors should be considered when setting thresholds or comparing data.

Setting the Warranty Period

Warranty periods vary by state but are typically much shorter than the service life of the component. Based on the literature and interview responses, warranty durations for projects that do not include planned maintenance typically cover 10% to 30% of the overall design life of the component being warranted. Table 16 summarizes the range of durations that have been implemented on pavement warranties in the United States according to the literature and interview responses.

Long-term performance warranties or maintenance agreements (greater than 10 years) that include planned maintenance or major rehabilitation for pavements can cover from 60% to 100% or more of the overall design life. These are the exception rather than the rule in the United States, but the number of these projects is growing as DOTs turn to the private sector for long-term maintenance and operation of transportation assets.

Survey respondents stated that warranty periods for shorter-term warranties were developed based on factors such as percentage of design life, historical performance data, experiences of other states, cost of bonding, and input from industry and sureties. In Illinois, legislation mandated specific warranty periods (5 and 10 years) for pavement.

If a DOT is interested in setting warranty durations or supporting a proposed duration using a more analytical approach, it could analyze performance data for a particular pavement type and roadway classification and develop deterioration curves for key distresses over time (e.g., IRI and rutting from the PMS). An example of deterioration curves using regression analysis for data from different aged HMA pavement from the Indiana DOT's Interstate highway system is shown in Figure 9.

A DOT could then evaluate these curves to determine the expected IRI and rutting thresholds (from the PMS) that would trigger major maintenance or rehabilitation of the pavement. If, for example, the thresholds triggering maintenance were reached at approximately 12 years and DOT was considering a Type 2 warranty, it would not want the contractor to assume the risk (cost) of planned maintenance and might use a factor of safety setting the warranty duration at somewhat less than the age that would trigger major planned maintenance, say 8 years or 66% of the expected threshold. Alternatively, a DOT could analyze the dispersion of the data at the 15-year threshold and set the warranty duration based on standard deviation, as noted in Figure 8.

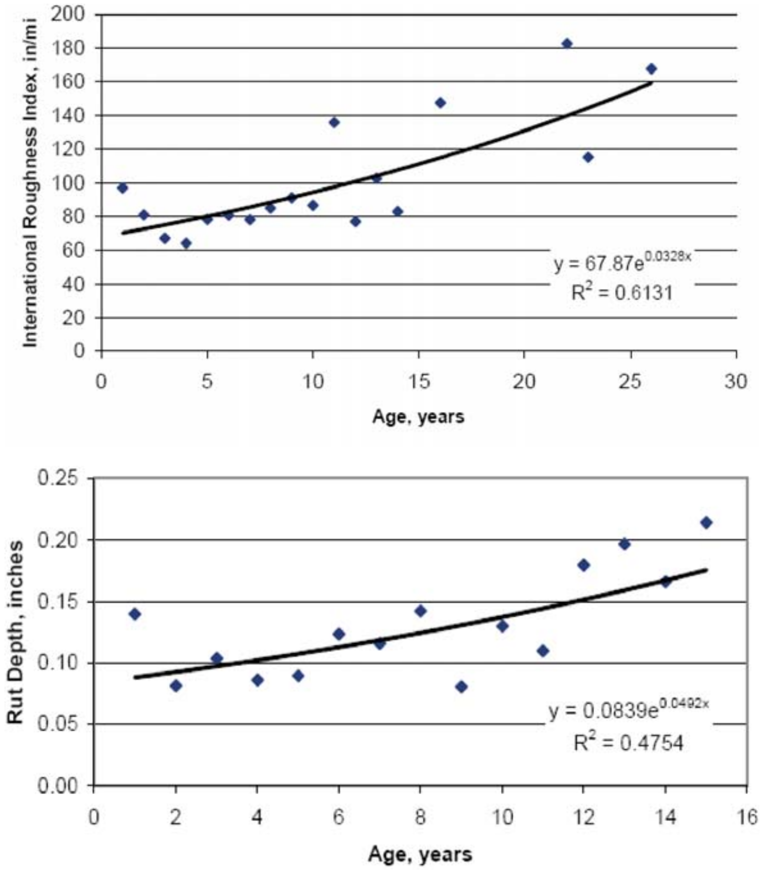
In practice, DOTs apply a combination of analysis and practical knowledge gained through experience to determine the warranty length. Caltrans reported that, based on its experience, if a pavement preservation project did not show distress within the first year after construction, it had a higher potential for maintaining performance during the expected life of the surface treatment. Therefore, the benefit of a warranty period longer than 1 year did not justify the added cost. Minnesota DOT responded that economics played a factor in determining the length of its design–build warranties. Design–build warranties were cut from 5 to 3 years because of a significant increase in bonding cost for the longer warranty period.

A common concern raised about warranties is that durations of 10% to 30% of the design life are often not enough to ensure improved quality and adequate performance over the design life of the component (if that is the DOT's primary objective). For example, 5-year warranties on pavements and 10-year warranties on bridges provide some measure of quality assurance but not enough to guarantee performance over the design life of these warranted components. The findings indicate that warranties are often limited by bonding and other economic considerations, reducing their perceived benefit.

An additional concern raised by practitioners in Minnesota and Mississippi was setting the effective start date for the warranty. Projects that involve multiple phases or lane shifts have the potential for disputes if the start date of the warranty is not clearly defined in the contract. The contract should define whether the warranty will start upon substantial completion or upon the opening of each of the warranted sections to traffic. As a disadvantage to pavement warranties, Minnesota DOT listed difficulty defining warranty start dates when the projects had multistage construction. Mississippi DOT commented that pavement warranties should start once the pavement has been accepted rather than waiting for the final maintenance release, which is often delayed by unrelated issues such as grass growth.

Table 16. Warranty periods.

Component	No. States	Durations (years)	
		Range	Typical
HMA pavement	23	1–25	3–5
PCC pavement	15	3–20	5–10
Pavement preservation	9	1–3	2



Source: Flora, 2003

Figure 9. Average IRI and rutting versus age of HMA pavement sections.

Bonding Requirements

In the United States, the cost of the warranty is typically factored into the unit price of the component being warranted; thus, the contractor collects payment for the warranted item upon completion of the construction. U.S. DOTs typically require a bond to cover contractor warranty obligations during the warranty period. A warranty bond is secured through a surety, which guarantees contractor performance throughout the warranty term. Should the contractor fail to perform, the surety is responsible for the cost of remedial work to the limits of the bond. DOTs vary significantly on the value of the bond, depending on the component being warranted.

Bond values are typically determined by one of the following methods:

- Total dollar value of the warranted item (construction value),
- Percentage of the total dollar value of the warranted item,
- Lower value between a percentage of the contract value and a set dollar amount (i.e., 5% or $1 million), or
- Estimated cost to perform a full repair or preservation technique, as noted in the Indiana example in Figure 10.

Because carrying a warranty bond reduces the contractor's overall bonding capacity, many contractors have expressed concern that warranty projects will reduce their capacity

> The warranty bond is $2,000,000.00 for the warranted HMA/SMA pavement. The bond is intended to insure completion of required warranty work, including payments for all labor, equipment, materials, and closure periods used to remediate any warranted pavement distresses.

Source: Indiana DOT HMA Warranty Specification

Figure 10. Specification excerpt: warranty bond.

to take on future work, and sureties have set limits on bond durations based on their assessment of warranty risk. These bonding concerns have in some cases precluded contractors from bidding and contributed to lower numbers of bidders on warranty projects.

Sureties are often reluctant to take on the risk of a longer-term bond, particularly for smaller or first-time contractors. Kansas reported that contractors could not find a bonding company that would warrant a project element beyond 5 years and discontinued PCC pavement warranties after deciding 5 years was not a significant enough percentage of the design life to make the warranty worthwhile. To avoid such obstacles, the warranty bond is often obtained for a shorter period (1 to 2 years) and then renewed for the life of the warranty. Many DOTs with warranty experience have invited representatives of industry and sureties to discuss options during the specification development process that would balance the risk for all parties involved, but bonding remains a gap to implementation for many DOTs examining warranties.

Because of the issues related to the use of bonds to ensure performance during the warranty, several states have explored alternatives to single-term warranty bonds, including the following:

- Extended-performance bond;
- Letter of credit, certificate of deposit, U.S. currency, or other form of security approved by the department;
- Warranty performance tied to the prequalification process for future work (guarantee); and
- Pay-for-performance or retainage.

Some of these alternatives have roots in European practice. For example, not all European agencies use warranty bonds. Instead of requiring a bond, the British Highways Agency uses prequalification to ensure that its contractors will correct defects in their work. Denmark uses a graduated bond for its 5-year warranties, reducing the bond to 2% of construction costs in the final 4 years to balance risk and reduce cost (Bower et al., 2003).

Florida has moved from a warranty bond to prequalification for future work. If the contractor fails to perform the required remedial work, the contractor is precluded from bidding on future state work for 6 months or until the remedial work is completed, whichever is longer. Florida has coined this alternative a "guarantee."

While Florida has stated that its guarantee process is an effective alternative to bonding, certain factors in Florida may not transfer well to other states. For example, the risk of being precluded from bidding on future work motivates contractors in Florida because most do not typically perform work outside of Florida. This concept would not be ideal in areas where it is feasible for contractors to bid on work in multiple states. For example, Michigan DOT is considering implementing a similar guarantee process, but is concerned about its effectiveness in areas where work is readily available should a contractor be precluded from bidding on future work in Michigan. Legislative changes would also be necessary for Michigan to implement a guarantee in place of a warranty bond.

Minnesota has also expressed interest in the guarantee model. Minnesota has previously used a pay-for-performance specification. The pay-for-performance concept is similar to retainage, in which the contractor is paid a portion of the costs at the time the item is placed and then is paid on a graduated scale over time if the item performs to expectation. Minnesota implemented this alternative for warranties on its I-494 design–build project.

For warranties of 1 year or less, DOTs have also extended the performance bond to cover the warranty period, making a separate warranty bond unnecessary. This is the case in California and North Carolina, which require standard 1-year warranties on most projects.

Risk Allocation and Contracting Considerations

Material and construction requirements vary depending on whether DOTs are implementing a materials and workmanship warranty or a performance warranty. When transitioning from materials and workmanship to performance warranties, progressively more responsibility is shifted to the contractor and they are typically given more freedom to control aspects of design or construction.

Most materials and workmanship warranties require the contractor to conform to the standard method specifications. The contractor may have some choice over mix design and material selection, but the contractor is typically restricted to choosing materials from a state-approved list. Under performance warranties, the contractor is typically given greater control over material selection and mix design. The contractor may or may not be restricted to a list of state-approved materials. Some performance warranty provisions also give contractors control over the methods used to construct the work. Based on the interview responses and an examination of specifications, it was difficult to classify some of the pavement specifications as material and method versus performance because of subtle differences in responsibility for mix design. Contractors are typically given greater design responsibility under a design–build–warrant type of contract. Lack of clear definitions of rights and responsibilities between materials and workmanship warranties and performance warranties can be a risk in the successful implementation of warranties.

Quality Control, Inspection, Testing, and Acceptance During Construction

Implementation of warranties often involves changes in traditional roles and responsibilities for quality control, inspection, and testing during construction. Warranty provisions differ on responsibility for these duties. For example, Indiana DOT implemented a hands-off approach, shifting responsibility for inspection, quality control, and testing to the contractor. Louisiana DOT, on the other hand, maintained traditional roles and responsibilities for these duties on its warranty projects. Typically, the contractor takes on greater responsibility for these tasks, with the DOT maintaining a quality assurance or verification role. DOTs in Indiana, Mississippi, Michigan, and Wisconsin reported resource savings benefits on warranty projects. Florida reported that the benefit of its resource saving was comparable to the benefit achieved through the use of a contractor QC specification.

Based on the comments provided in the survey and evaluations performed at the state level on warranty contracting, DOTs differ on the role the DOT should maintain in inspection and testing on warranty projects. Colorado DOT responded that better quality control and more oversight by state forces are needed. Indiana DOT responded that the owner should not oversee contractor operations to avoid disputes over responsibility because the state witnessed the operation. Indiana DOT also responded that if inspection is performed, it should consist of a spot-checking process, not a full-time inspector. These different perspectives among warranty programs are driven in part by the comfort level DOTs have with shifting the responsibility for quality management to the contractor. Again, the warranty provisions should clearly define the roles and responsibilities of each party for inspection and testing in the warranty provisions.

Alternative Contracting

Design–Build–Warranty

Recent international scan studies have reported that European agencies routinely use warranties in conjunction with design–build contracting and rely more on the private sector to maintain and operate highways. The European agencies also have increased the use of maintenance contracts and pavement performance contracts (FHWA, 2005). These trends toward greater private-sector responsibility are evident in the U.S. highway industry but are not as common. Based on a 2005 FHWA-sponsored design–build effectiveness study, about 30 DOTs have used design–build contracting on public works projects (FHWA, 2006). Among these, a smaller percentage of DOTs have implemented design–build–warranty contracts or entered into agreements with the private sector for long-term maintenance or operation of highways and bridges under a PPP agreement or performance-based maintenance contract.

Because performance warranties shift progressively more responsibility for quality and performance to the private sector, contractors have expressed concerns that they cannot take on this performance risk without greater control of the design. Contractors from Ohio DOT's 2003 warranty study expressed these concerns (Hastak, 2003), and they were also expressed in Michigan Local Technical Assistance Program workshops in 2005 (MDOT, 2005). When asked which factors would hinder contractors from bidding on warranty projects, the Ohio contractors cited the absence of design–build contracting, followed by the duration of the warranty and availability of bonds. In this vein, Maryland and Alabama solicited bids for warranted HMA pavement on design–bid–build contracts, but they failed to receive any bids and have no plans to use warranties on similar contracts.

While the majority of DOTs use warranties with traditional design–bid–build contracts, some DOTs have combined design–build contracts with performance warranties to ensure quality in a design–build environment of reduced owner inspection and accelerated construction. Minnesota has combined short-term performance warranties with design–build projects to achieve these goals (MNDOT, 2005). Missouri and Virginia have also combined design–build contracts with the long-term performance warranties noted in Table 10.

Given that design–build contracting shifts more control to the contractor for design and project performance, in the event of a failure the contractor is less likely to be excused from the warranty obligations because of design- or performance-related issues. Disputes documented in the literature and interview responses typically occurred on design–bid–build projects. Minnesota DOT did report that one of its 5-year design–build–warranty pavement projects was experiencing excessive transverse cracking and rutting, requiring corrective action by the contractor to rout and seal cracks. The contractor did not contest responsibility for the corrective action, but has contested the start of the warranty period, which affected the cost of the repairs (MNDOT, 2005). Virginia DOT also reported one case in which a contractor negotiated out of the warranty for a design–build job during construction.

Public–Private Partnerships and Concessionaires

In parallel with a long-standing and growing use in Europe, PPPs or concessions have been applied to a handful of high-profile projects in the United States, but their use has recently gained new momentum as transportation owners struggle to find resources to fund and deliver critical transportation projects. Some of the earliest examples of privately funded PPP projects in the United States were the Route 91 express lanes in California and the Dulles Greenway toll road in Virginia, both completed in 1995. More recent examples include the Virginia DOT Public–Private Transportation Act program, the Florida DOT Port of Miami Tunnel project, the Indiana Toll Road, and the Trans-Texas Corridor (Seiders, 2006).

Texas DOT established operational and maintenance performance standards for the Trans-Texas Corridor that the concessionaire must meet for the operation and maintenance (O&M) of the facility. The pavement performance standards define the minimum standards (thresholds) the concessionaire will be required to meet during the O&M period for the facility. Corrective action will be made if these thresholds are exceeded. The performance standards include the following (Seiders, 2006):

- **Pavement condition score.** Measurements and inspections necessary to derive a pavement condition score in accordance with Texas DOT procedures.
- **Ruts—mainlanes, shoulders, and ramps.** Depth measured using an automated device in compliance with Texas DOT standards. Straightedge used to measure rut depth for localized areas.
- **Ride quality.** Measurement of IRI according to Texas DOT standard Tex-1001-S, operation of inertial profilers, and evaluation of pavement profiles.
- **Failures.** Instances of failures exceeding the failure criteria set forth in the Texas DOT *Pavement Management Information System Rater's Manual,* including potholes, base failures, punchouts, and jointed concrete pavement failures.
- **Edge drop-offs.** Physical measurement of edge drop-off level compared with adjacent surface.
- **Skid resistance.** ASTM E 274 Standard Test Method for Skid Resistance Testing of Paved Surfaces at 50 miles per hour (80.4 kilometers per hour) using a full-scale smooth tire meeting the requirements of ASTM E 524.

These PPP performance standards and thresholds are very similar to performance characteristics and distress thresholds specified for warranty contracts, but they extend the performance period in some cases well beyond the service life of the pavement, which would entail major rehabilitation during the O&M period. They also do not include the typical exclusions that may void the agreement. To achieve these standards, PPP specifications are performance-oriented. In other words, Texas DOT in theory will not specify pavement design and type and will limit its review and approval functions under these types of contracts.

Performance-Based Maintenance

An alternative to using warranties to guarantee post-construction performance is the use of performance-based maintenance contracts, such as in Virginia and the District of Columbia where a private entity enters into a long-term agreement with the DOT. The DOT typically pays the contractor a set amount each year to maintain a specified performance level. These contracts primarily cover routine maintenance, but often include limited preventive maintenance duties for pavements such as the repair of potholes and joints.

Multiparameter Bidding

Several DOTs have combined warranties with cost-plus-time or A+B bidding and incentive–disincentive provisions to motivate contractors to balance time and quality goals. For example, Indiana uses pavement warranties in conjunction with A+B bidding and has reported improvements in quality and time with this approach. While the state has not substantiated it, Indiana believes that contractors receiving an incentive for accelerated project completion are motivated to apply greater resources and attention to quality than contractors not receiving an incentive. Kentucky piloted an A+B+C formula, asking contractors to bid, in addition to cost and time, a C duration for the warranty worth a $500,000 credit for each year offered. The results were advantageous to the state because it received 5 additional warranty years in conjunction with a shorter schedule.

Exclusions

A review of the warranty provisions collected for this report shows that most DOTs define specific exclusions limiting contractor liability under the warranty. For example, warranties on traffic signal and lighting posts typically include exclusions for conditions outside the contractor's control, such as damage from lightning or vehicular accidents.

Common exclusions include damage to warranted products resulting from the following:

- State-controlled operations, such as routine maintenance or destructive testing,
- Vandalism,
- Vehicular accidents and hazardous material spills,
- Military action, and
- Acts of God and natural disasters.

Some warranty provisions define design-related exclusions. For example, a materials and workmanship warranty for HMA pavement may exclude defects caused by existing base conditions or drainage design errors. As shown in Figure 11, pavement warranties also typically specify a maximum ESAL value or maximum number of heavy trucks that, if exceeded by a certain percentage, voids the warranty.

Some pavement warranties also define one-time, heavy-load ESAL values. DOTs that have used ESAL exclusions for pavement warranties, including Florida, Ohio and Michigan, do not uniformly specify weigh-in-motion devices to monitor ESALs because of the significant up-front cost and instead rely on average daily traffic counts to estimate ESALs.

Exclusions

Remedial work will not apply if any one of the following factors is found to be beyond the scope of the contract:

a. Determination that the pavement thickness design is deficient. The department will make available a copy of the original pavement thickness design package and design traffic report to the responsible party upon request.

b. Determination that the accumulated ESALs (number of 18 kip equivalent single axle loads in the design lane) have increased by 25% or more over the accumulated ESALs used by the department for design purposes for the warranty period. In calculating ESALs, the average annual daily traffic (AADT) will be obtained from the department's traffic count data and the T24 (percentage of heavy trucks during a 24-hour period) will be obtained from the department's traffic classification survey data.

c. Determination that the deficiency was due to the failure of the existing underlying layers that were not part of the contract work.

d. Determination that the deficiency was the responsibility of a third party or its actions, unless the third party was performing work included in the contract.

Source: Florida DOT Section 338, Value-Added Asphalt Pavement Specifications

Figure 11. Specification excerpt: exclusion language.

Monitoring and Remedial Action

Warranty clauses always provide for condition surveys of warranted items, either at periodic intervals or, for short-term items such as pavement preservation, at the end of the warranty. For pavements, this survey may be conducted in concert with the DOT's annual pavement condition survey or through an independent warranty program. This survey may be conducted with the contractor or unilaterally.

If the survey shows that the thresholds established in the warranty provision are exceeded at any time during the warranty period and the cause does not fall under a defined exclusion, then the contractor is notified and called back to perform remedial action.

Based on a review of the sample specifications gathered for this report, DOTs have developed different approaches for establishing the required remedial action. Several require or suggest a remedial procedure when a given threshold is exceeded. Some specify degrees of severity for the threshold distresses and require or suggest different remedial procedures based on the severity of the distress. For example, Minnesota DOT's warranty for bituminous pavement suggests that contractors rout and seal transverse cracking of medium severity and mill and resurface transverse cracking of high severity. The severity of the cracking is determined by the number of cracks in a pavement segment. Most if not all of these warranty provisions require that the contractor submit for approval a remedial work plan detailing the proposed fix.

If the contractor does not agree with the survey results or the scope of the remedial work or believes that the cause of the distress was beyond its control, it can dispute the results and refer the matter to a dispute resolution team or board to render a final or independent decision.

Dispute Resolution Procedures

Most warranty provisions establish measures for settling disagreements for potential disputes over remedial action. Responsibility for settling disputes is typically delegated to a conflict resolution team (CRT) or a DRB.

CRTs are typically set up on a project-by-project basis. They consist of an equal number of representatives from the contractor and the DOT who may or may not be directly involved in the project, plus one outside representative mutually agreed on by the contractor and the DOT. Costs associated with the outside representative are shared by the contractor and the DOT. CRTs have also been called dispute resolution teams and pavement evaluation teams.

DRBs are formal committees set up to resolve disagreements before they can delay or disrupt construction projects. DRBs typically consist of one to three members and can be set up for specific projects or on a district or statewide basis. DRBs can be responsible for settling all project-related disputes or only disputes related to warranties. Florida has established a three-member, statewide DRB dedicated to settling pavement warranty disputes that cannot be resolved at the project level. Florida's DRB panel is drawn from the state, industry, and academia.

Chapter Summary

As evidenced by the experience of the workshop attendees, the DOTs surveyed, and the available literature, there is a significant range of opinion regarding the effectiveness of warranties, but the more-experienced DOT practitioners report that warranty projects will result in improved performance (cost and quality) if implemented for appropriate projects. There is also

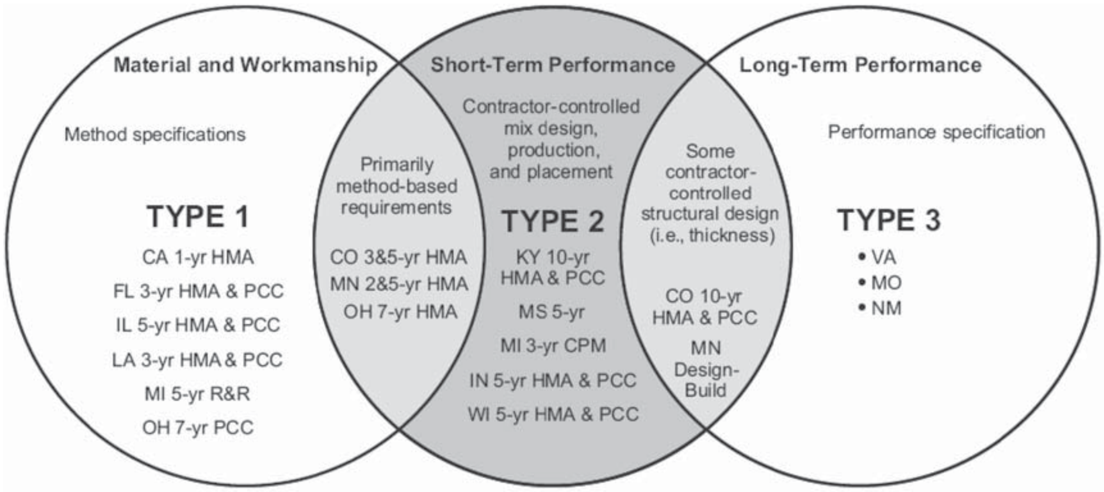


Figure 12. DOT warranty provisions—comparison by type.

significant variation in the way DOTs have defined and implemented warranties, contributing to a grey area or overlap in defining the types of warranties. Figure 12 uses a Venn diagram to illustrate how several existing warranty provisions align with respect to the definitions used in this report.

The research team has adopted definitions of the warranty types generally based on the specifications that fall outside of the overlapping areas within Figure 12.

While several DOTs have established that there is no tangible benefit to short-term Type 1 materials and workmanship warranties (3 years or less), based on collective state experience, it appears that these Type 1 warranties achieve a specific objective, namely to prevent early failures, and may also serve as an important stepping-stone to implementing longer-term warranties. This approach gives both contractors and DOTs the opportunity to become accustomed to warranty contracting while limiting the risk to either party. Theoretically, there is a very limited risk to contractors under a Type 1 warranty since they are only guaranteeing that the project has been constructed in strict adherence to the standard specifications. Consequently, the additional cost to the project for a Type 1 warranty should be limited to the cost of the bond. Given this perspective, the research team decided to address all warranty types in the guidelines for project selection, project implementation, and model specifications.

While DOT selection criteria were limited in scope, the few examples of systematic selection tools used by Caltrans and MDOT have led to the conclusion that the project scoping is a key factor in the decision to use a warranty, and the decision process must align the project scope and project objectives with the selection of an appropriate warranty type to achieve a successful result.

This chapter addressed the other key considerations for warranty implementation discussed in the literature, workshop, and surveys. Warranty implementation varies significantly, depending on whether DOTs are using short-term materials and workmanship or longer-term performance warranties, or in the context of traditional-versus-alternative contracting. This chapter also discussed how DOTs with experience have addressed these key implementation elements based on their internal goals and lessons learned.

Finally, this chapter identified a number of issues raised by practitioners and discussed potential strategies to address these issues. These strategies include developing systematic project selection criteria and guidance for applying materials and workmanship versus performance warranties; setting performance thresholds based on historical data or quality goals; exploring alternatives to warranty bonds; appropriately allocating risk related to warranty types, contracting method, and exclusions; and establishing responsibility for pass-through warranties.

Guidelines and sample specifications have previously been developed and used for implementing pavement warranties, particularly for asphalt pavements. These guidelines and specifications have been updated in this report to reflect the current state of practice for warranties, including project selection criteria for warranty types, risk allocation based on contract type, and model specifications for both HMA and PCC pavements covering both materials and workmanship and performance warranties. The next chapter discusses the approach to developing these guidelines. Appendix A includes standalone warranty guidelines, a selection tool, and model specifications for HMA and PCC pavements.

CHAPTER 3

Development of a Pavement Warranty Decision Tool, Best Practice Guidelines, and Model Technical Provisions for HMA and PCC Pavements

Chapter 2 summarizes the findings of the comprehensive investigation performed under NCHRP Project 10-68's Phase I research effort. Task 2 of Phase I required the development of a systematic method or decision process for evaluating candidate pavement warranty projects. The original intent of this task was to develop this decision process based on project-level criteria such as project type and existing conditions. It was determined early in Phase I that few DOTs documented a systematic decision process for identifying candidate warranty projects. It was also determined that many DOTs considered very few variables in their warranty decision processes. Additionally, the research team found that key decision factors were not limited to project-level decision criteria. Rather, the decision process often included broader, programmatic considerations such as contractor familiarity with QA-type specifications and limitations of DOT resources. Finally, it was determined that the decision criteria would vary depending on the type of warranty being applied. Therefore, the decision process for evaluating candidate warranty projects developed under Task 2 is a multilevel tool that enables the user to evaluate both program-level and project-level criteria in addition to evaluating different types of warranties. Furthermore, the guidelines and model specifications developed under Tasks 5, 6, and 7 must address these multiple levels of decision criteria as well. The following sections discuss the approach that was used to address these multilevel considerations in the development of the warranty decision tool, the guideline document, and the sample provisions.

Warranty Decision Tool

A systematic decision tool for applying pavement warranties to highway construction projects is presented in Appendix A2. During the Phase I research, several DOTs using pavement warranties indicated through interviews that potential warranty projects were often applied to a limited pool of projects with good existing base and soil conditions. In other words, projects with a high probability of success were often selected as candidate warranty projects. This tool was designed for selecting warranty projects beyond just the safe projects. Instead it was designed to evaluate various levels of risk based on program- and project-level criteria with respect to warranty type and to include suggested strategies for mitigating risks.

During the one-on-one interviews with DOTs that have warranty experience, DOTs were asked to assess whether the application of the warranty resulted in an overall benefit to the DOT. Through these discussions, the research team determined that the single most important factor in determining the measure of a project's success or failure was the project's ability to achieve a goal or expectation such as to improve quality or compensate for limited agency resources. Because materials and workmanship warranties are designed to satisfy different expectations than performance warranties, it was determined that the first step of the warranty decision process should be to identify the motivation or objective of using the warranty. The likelihood of success in applying warranties involves choosing the right type of warranty to achieve the stated goals of the project. Success also requires an understanding of project-level conditions, such as base conditions and ability to predict traffic volumes, and program-level conditions, such as the level of cooperation of industry and the ability to develop performance-based specifications. Figure 13 summarizes the steps in the decision tool contained in Appendix A2. Each of the steps is discussed in the guidelines and the decision tool.

The warranty decision tool is composed of three parts to assist DOTs through the decision process identified above. Part 1 asks DOTs to identify their objectives or motivations for using warranties and to weigh those objectives by applying a total of 10 points across various possible objectives, which

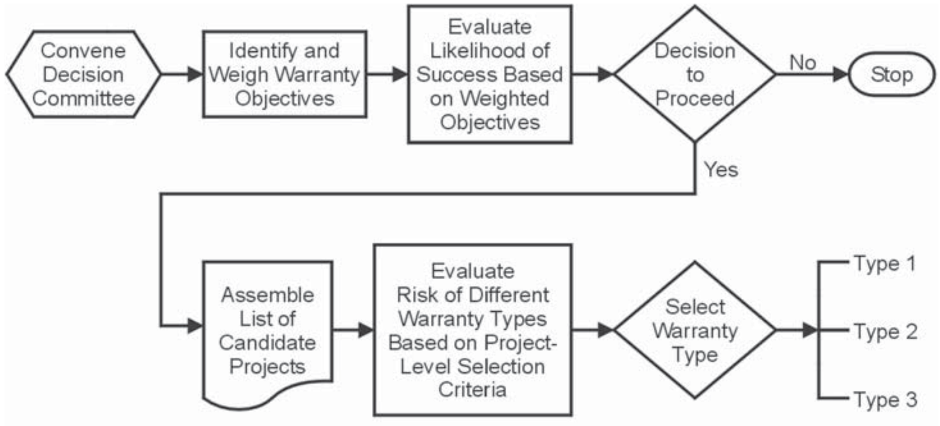


Figure 13. Decision process for selecting a warranty project and warranty type.

were identified and compiled through the Phase I research and refined by vetting the process using DOTs with warranty experience.

Each possible objective in Part 1 has a corresponding list of criteria in Part 2. These criteria focus on the program-level conditions determined to be necessary or desirable for achieving the stated objective for using a warranty as determined by the Task 1 research. All of the criteria listed in Part 2 are structured in the form of statements that, if true, contribute to successful warranty implementation. Users are asked to rate the statements on a scale of 1 to 10, with 10 being extremely true and 1 being very false. The statements are weighted evenly, and the ratings entered by the user for each statement are averaged to determine the average criteria rating. This rating is then combined with the weighting of the objectives in Part 1 to return a percentage score ranging from 0 to 100. DOTs can then use this scoring to evaluate the likelihood of success of the warranty from a programmatic standpoint. DOTs can then identify what program-level conditions, if any, require change or further development before applying a warranty program. The criteria used in Part 2 were revised and refined through the vetting process, which is described in detail in the following section.

Part 3 prompts the user to assess the level of risk associated with using different types of warranties based on project-level criteria. Part 3 consists of three different sections of multiple choice questions. Each section pertains to one of the following types of construction: preservation, rehabilitation, or new construction. It was necessary to separate these sections out because the type of construction can affect the risk associated with applying a warranty. Each answer to the questions in Part 3 carries an associated risk factor for each warranty type. Risk factors are based on an adjectival rating system of low, medium, and high risk. These risk ratings were designed to steer the user to a specific type of warranty based on project-level criteria and were developed and refined though the vetting process described in the following section.

Vetting Process

The warranty decision tool was sent to several representatives with experience using warranties. Representatives were asked to test the tool on actual projects and return comments on the validity of the results and the structure of the tool itself. The following DOT personnel reviewed the warranty decisions tool and participated in the vetting process:

Caltrans	Lance Brown, Shakir Shatnawi
CDOT	Jay Goldbaum
FDOT	David Sadler
MNDOT	Pat Schafer, Kevin Kennedy, Curtis Bleech
WisDOT	Irene Battaglia

Commentary and results on test run applications of the tool were provided by Lance Brown, Jay Goldbaum, David Sadler, and Irene Battaglia, and a summary of the results follows. Comments on the structure and content of the tool were provided by Lance Brown, Shakir Shatnawi, Pat Schafer, Kevin Kennedy, Curtis Bleech, and Irene Battaglia, and are summarized following the results of the test applications.

Results on Test Applications of the Tool

Caltrans

Caltrans tested the tool on a thin blanket overlay project. Caltrans identified and weighted objectives as follows:

Prevent early catastrophic failures	6
Promote quality/consistency of the overall network	2
Reduce life-cycle costs	2

After rating the statements in Part 2, the decision tool returned a 74% rating for likelihood of success in achieving stated objectives. After answering questions in Part 3, the risk matrix results showed an overall low risk rating for a Type 1 warranty and an overall medium risk rating for a Type 2 warranty. Applying a Type 1 warranty to this type of project is consistent with the manner in which Caltrans applies its warranties.

CDOT

CDOT tested the warranty decision tool on three existing pavement warranty projects to determine if the project produced accurate results. CDOT reported that overall, the tool works well and accurately matches the objectives of the project and the administration in charge at the time these projects were advertised.

The first project tested was CDOT's pilot 10-year PCC warranty project on Interstate 70 in Kit Carson County. The project scope included a 9.1-mile stretch along the four-lane highway. Colorado reported that the tool determined an 85% success rate and a favorable risk matrix output for a Type 2 warranty.

The second project tested was CDOT's 5-year HMA rehabilitation warranty project on U.S. Highway 36, east of Byers. The project is located in Arapahoe and Adams counties and is 10 miles long. The rehabilitation strategy used was a 4-in. cold recycle overlay. Colorado reported that the tool determined a 90% success rate for a Type 2 warranty.

The third project tested was a proposed urban, new construction, 5-year HMA pavement project through Denver that is currently in its preliminary design phase. CDOT selected improving performance on a particular project as the primary objective of the warranty. The tool initially returned a low success rate of 52%, causing CDOT to re-evaluate the statements in Part 2. Statement 2.E.4 (the agency is willing to consider design–build or to allow the contractor greater flexibility in mix design and other areas of control) was rated low since CDOT intended to use design–bid–build contracting. However, CDOT saw that by increasing the rating for this statement, the success rating improved to 80%.

FDOT

FDOT reported that the decision tool produced acceptable results assuming the typical types of pavement projects implemented by FDOT. Florida applies Type 1 warranties with the objective of preventing premature catastrophic failures. FDOT stated that the risk ratings established under Part 3 were acceptable as drafted, and proposed no changes.

WisDOT

WisDOT reported that the risk assessment results returned appeared fairly accurate for two project tests, but a few changes in risk determination were noted. These recommended changes were incorporated in the revised tool.

Comments Regarding Structure and Content of the Tool

Caltrans

One of the two reviewers from Caltrans commented that overall the tool is difficult to understand and that the intent of all questions is not clear. The reviewer commented that engineers selecting projects need to fully understand the purpose of each question and understand how these questions fit into the risk matrix. The reviewer agreed that the use of a committee team for selection of a warranty project is a good plan. The second reviewer from Caltrans commented that the report describing the seven-step decisions is well written and easy to follow. Comments about specific sections of the warranty selection tool are summarized as follows:

Part 1: Caltrans suggested adding the objective of transferring accountability from the agency to the contractor in Part 1. Because this objective was integral to the other objectives, the research team edited the existing Part 2 statements to address the transfer of accountability to the contractor.

Part 2: Caltrans suggested that Statement 2.A.1 be divided into two separate statements. Statement 2.A.1 reads: "One or both of the following conditions exist:

- A primary goal of the agency is to ensure strict adherence to the standard method specification
- There is a need for a technique to act as a counterbalance for time pressures that may affect compliance with the specification."

This statement is aligned with the objective of preventing early, catastrophic failures. The researchers did not divide it into two separate parts because doing so would imply that both conditions are required to be true in order to accomplish the objective. However, in this case, if either condition exists, the application of a warranty is consistent with the objective.

Part 3: Caltrans noted that the assigned risk factors for questions on mix design, phasing and traffic management, and project expectation differed in Parts 3A, 3B, and 3C. This was an intentional variation because it was determined that the risk associated with these variables is dependent on both the type of warranty (e.g., Type 1, 2, or 3) and the kind of project (e.g., preservation, rehabilitation, or new construction).

Caltrans recommended expanding the question on existing conditions, and they provided a matrix showing guidelines on existing conditions used to determine excluded areas for warranty projects. Caltrans operates under the premise that good existing base conditions are essential criteria for warranty projects. The risk assessment of existing conditions is addressed in Part 3 of the tool. The research team decided not to expand this criterion in order to avoid adding more complexity to the tool.

Caltrans also commented that traffic control not be shifted to the contractor on its warranty project. Rather, the contractor must conform to the DOT's traffic management plans. This item was deleted from Section 3A (pavement preservation), but it was not removed from Sections 3B and 3C (rehabilitation and new construction/reconstruction) because it was determined that traffic management responsibility should be considered on these types of projects.

Finally, to reduce the complexity of the tool, Caltrans recommended consolidating warranties into two types: 1- to 5-year short-term warranties and 10-year warranties. The reviewer conveyed that in his experience materials and workmanship warranties do not provide benefit and, therefore, should not be used. The reviewer recommended that the tool should focus on performance-based warranties that allow the contractor to make decisions. The reviewer agrees that the level of contractor input may vary depending on the warranty length and that for longer-term projects, the condition of the base condition will play a key role.

MNDOT

In general, MDOT commented that the tool was very useful as a means of investigating the use of warranties. MNDOT stated that they have streamlined the decision process into qualifying projects categorically (i.e., CPM and R&R) rather than individually. Thus, the warranty design process focuses more heavily on categorizing fixes rather than looking at individual projects, and the design of the project plays a major part in determining the type of warranty that will be applied. Comments to specific sections of the warranty selection tool are summarized as follows:

Part 3: MDOT recommended revisions to questions 3.A.2, 3.B.2, and 3.C.2 regarding the scope of the project. The questions on base and foundation conditions were reevaluated based on these comments.

MDOT also commented that ESALs should only apply if the warranty includes an ESAL escalation clause, which would imply that the design and performance used for the warranty thresholds has been verified with actual ESALs; also, this would only apply to long-term warranties. MDOT commented that phasing and traffic management control would only be beneficial to shift to the contractor in a Type 3 situation. The research team believes that ESALs and shifting phasing and traffic management control can be part of a Type 2 warranty. The research team removed this criterion for Type 1 warranties but retained these criteria for Types 2 and 3.

Finally, MDOT commented that it does not believe that the manner in which thresholds are established affects the risk rating, regardless of the warranty type. Based on information gathered through literature and interviews, particularly with TxDOT, the research team believes that the level of accuracy of the historical performance data does play a factor in the risk of the warranty. Accuracy of the threshold is determined by the reliability of the historical data and the ability of the DOT to translate the historical data into performance curves. The more accurate the thresholds, the less risk the contractor must build into the bid. However, the research team attempted to clarify the intention of this question in the revised tool.

WisDOT

WisDOT commented that overall the tool appears to be a useful aid for DOTs looking to start a warranty program. There were no issues taken with Part 1 of the decision tool.

Several of the programmatic issues identified in Part 2 are issues that WisDOT considered during the development of its warranty program, but other issues were addressed along the way, and WisDOT continues to address some of the issues today. Therefore, while WisDOT agrees it is important to consider these issues, WisDOT does not believe all these issues have to be resolved before constructing a warranty project. Programmatic issues in Part 2 that WisDOT identified to be of particular importance include

- Addressing the learning curve,
- Addressing bonding,
- Creating the paper trail, and
- Managing internal administrative costs.

WisDOT suggested adding a section that addresses whether a method to resolve conflicts has been established. While it is agreed that this is an essential aspect of a warranty provision that must be addressed in the development of the warranty specification, the research team does not believe that it is a deciding factor in whether to apply a warranty. However, the establishment of a conflict resolution team is an administrative cost, which can be a deciding factor. Since managing the administrative cost of warranties is addressed in the tool, the research team did not add a question to specifically address dispute resolution.

WisDOT noted that a flowchart used to aid project selection focuses entirely on foundation conditions, and there should perhaps be more focus on this in Part 3. WisDOT noted that there is an important distinction in risk between an overlay that is applied directly to an existing concrete pavement versus an overlay applied on a milled asphalt surface. Questions 3.B.2 and 3.C.2 were revised to address this comment.

WisDOT noted that it has struggled with how to deal with legal and/or undocumented ESAL overloads. WisDOT suggested modifying a question or adding an additional question regarding the potential of seasonal or undocumented overloads in Part 3. The questions on ESALs have been revised to include overloads accordingly.

Finally, WisDOT recommended that the tool include commentary on how the risk output matrix is evaluated and what the acceptable range is for L, M, and H ratings when choosing a warranty type. The research team added instructions to the tool in response to this comment.

Vetting Summary

Reviewers from the four DOTs that provided results on test applications of the tool reported that the results on the type of warranty suggested by the tool were consistent with the type of warranty ultimately applied by the DOT.

The majority of comments on the structure of the tool were directed at Part 3 on questions related to foundation conditions, mix-design, traffic management, and ESALs. The following revisions were made to address these comments:

- Added the concept of transferring accountability from the DOT to contractors in Part 2;
- Revised the multiple-choice answers to questions 3.A.2, 3.B.2, and 3.C.2 related to foundation conditions;
- Revised multiple-choice answers to questions on mix-design control;
- Deleted questions on traffic control and ESALs under Section 3A on pavement preservation; and
- Revised multiple-choice answers to address seasonal/undocumented overloads in questions on ESALs.

Development of Warranty Implementation Guidelines and Model Technical Provisions for HMA and PCC Pavements

Chapter 2 used a literature review and workshop and interview results to identify and discuss a number of key issues related to the implementation of pavement warranties. Related issues included warranty objectives or rationale, project selection, performance indicators and distress thresholds, warranty durations, bonding practices, and risk allocation in terms of contract type, responsibility for quality control, inspection, testing, remedial work, and exclusions. In the existing literature addressing warranty implementation, recent guidance from FHWA recommended that DOTs, particularly when implementing pavement warranty projects for the first time, engage the industry in the development of specifications and discuss bonding with the surety industry before attempting to implement a warranty to clarify the warranty coverage and roles and responsibilities. It also recommended that DOTs not attempt to implement a warranty program without a mature QA process in place for acceptance of materials and construction (FHWA, 2008).

Based on the observations and lessons learned from DOTs that have developed sustained warranty programs, the research team created a framework including seven generic topic elements that should be addressed in steps to successfully develop and implement pavement warranties. These elements are discussed in the following sections and are reflected in the pavement warranty guidelines shown in Appendix A1.

Rationale for Warranties

The Appendix A1 guidelines start by addressing the common drivers or objectives for using pavement warranties. Regardless of whether the decision to use warranties is driven internally by the DOT or externally, as in a legislative mandate, it is imperative to understand the rationale behind the warranty. The objectives for using a warranty can include improved quality, innovation, reduced inspections, transfer of accountability, and extended service life. Identifying and articulating the objectives must come first because they guide the follow-on decisions of what warranty type to implement and how it should be implemented.

For example, the quality objective can mean setting the target acceptance criteria higher than the historic average or based on a lower standard deviation. In one case, the quality goal could be to extend service life. In another, the goal could be to improve contractor consistency and attention to detail when constructing the work. The differences in these will affect what type of warranty to implement and how to implement it. In theory, improved contractor performance leads to improved quality; however, the link between performance and quality is not guaranteed. Therefore, these two objectives should be distinguished when determining the rationale behind warranties.

Program Considerations

The Appendix A1 guidelines next address various programmatic considerations necessary for successful implementation of pavement warranties. The inclusion of programmatic considerations as a screening step was not part of the initial scope of this research, but it became apparent after obtaining the findings from practitioners that programmatic issues must be addressed as part of the decision tool and guidelines, particularly for the first-time implementation of pavement warranties. Programmatic prerequisites include the need for both owner and industry warranty concept buy-in, some level of DOT and industry experience with QA specifications, surety support, and reliable historic performance data. The more that these programmatic conditions are ingrained or in place, the greater the likelihood that the implementation of pavement warranties will be successful or that the DOT will be able to transition from materials and workmanship to performance warranties.

Project Considerations

The next step in the Appendix A1 guidelines is project considerations. The DOT must determine whether a specific project is suitable for a warranty and what type of warranty would best serve the goals or needs of the project. Project characteristics to consider that may affect the implementation of a warranty include

- Project scope;
- Material type, quality, and availability;
- Foundation conditions;
- Pavement remedial work anticipated;
- Structural design;
- Contracting method;
- Traffic projections;
- Construction phasing and work sequence; and
- Exclusions.

The project-specific considerations shown in Appendix A1 address whether a warranty is appropriate for the project scope, whether existing base or pavement conditions or traffic loads might limit the warranty or trigger exclusions, and what warranty type would be the most appropriate for the project in the context of scope, contracting method, and risk allocation.

The last step in the decision process is to assess, based on programmatic and project-specific inputs, whether to implement a warranty and what type to implement. The warranty decision tool described in this chapter and presented in Appendix A2 is integrated with these guidelines.

Developing Warranty Provisions

If a DOT already has an established pavement warranty program or provisions and is interested in improving existing practices or transitioning to a longer-term performance warranty, then the DOT would focus primarily on project-specific considerations and the contents of warranty provisions themselves. Key considerations in the development of warranty provisions are the selection of appropriate performance indicators, establishing appropriate thresholds, and determining the most appropriate monitoring and evaluation plan for the roadway classification and warranty type.

Performance Indicators and Thresholds

Important to the implementation of warranty provisions are selecting the right performance indicators and setting thresholds that achieve the desired quality or pavement performance based on the project objectives. The logical steps in establishing indicators and setting thresholds are

1. Select pavements of target age,
2. Establish evaluation section length,
3. Evaluate PMS or other performance data, and
4. Establish performance indicator threshold values.

The research findings indicated that the choice of indicators was derived from a number of sources, but the most reliable basis is historic pavement management data from similar previously constructed pavements. Tables 14 and 15 in Chapter 2 compare common performance indicators and thresholds used in warranty specifications for HMA pavement. In general, the findings suggest that a DOT developing a warranty provision should focus on distresses or functional characteristics that can be measured routinely and objectively (as part of a PMS or other test roadway), directly affect the safety of the facility and the performance of the pavement, and relate to elements of the pavement or the project that are under the control of the contractor.

While many performance indicators or measurable distresses have been identified in the literature and affect performance, some indicators are less critical, are subsumed by other indicators, or as a practical matter do not justify the resources required to evaluate them on a routine basis. Appendix A1 includes HMA and PCC pavement performance criteria summarizing the range of common indicators, measurements, potential causes, and fixes applicable to pavement warranty types based on the *Distress Identification Manual for the Long-Term Pavement Performance Program* (Miller and Bellinger, 2003) and other sources (Washington State DOT, 2008 and FHWA, 2001). The guidelines recommend that the DOT should choose distress indicators for HMA and PCC pavements where the cause of distress is relatively straightforward to identify and is related to scope of work under the contractor's control. The guidelines also recommend that, if practical, DOTs should use high-speed computer-automated evaluations of HMA pavements for ride quality (IRI), rutting, and longitudinal and transverse cracking, and should evaluate other distress indicators only if required.

As in the case of performance indicators, it is necessary to set thresholds based on pavement age and expected traffic conditions and determine whether the pavement condition during the warranty period is consistent with the expected distress thresholds for the age and service life of the pavement. As discussed in the Appendix A1 guidelines, the key to establishing appropriate threshold values lies in consistent, reliable historical performance data gathered through a DOT's PMS. Figures 6, 7, and 8 in Chapter 2 and the guidelines in Appendix A1 discuss how a DOT might use data output from its PMS to develop thresholds for IRI and rutting for a typical HMA warranty pavement segment.

Warranty objectives, warranty duration, and dependability of information derived from historical or model data are important factors that shape how a threshold is structured and established. The evaluation interval or section length will affect the threshold levels. The threshold may also be affected by how the pavement is constructed. For example, the more opportunities to achieve smoothness through constructing multiple pavement layers or surface milling, the tighter the smoothness tolerance could be.

Based on existing warranty specifications, distress threshold values vary significantly with geographical region, roadway classification and design standards, materials used, and the warranty objectives. The distress thresholds for cracking among other surface distresses used in some of the warranty specifications define multiple thresholds based on levels of severity of distresses described in the *Distress Identification Manual* (Miller and Bellinger, 2003). Each level, if exceeded, will trigger different remedial actions.

If the objective of the warranty is to dramatically improve quality over the warranty duration, then thresholds should be set tighter than the expected distress values (or dispersion) to achieve this warranty objective. If the objective is to maintain a roadway to a defined level of service for its expected service life or beyond, as in the case of a long-term Type 3 warranty provision, the thresholds may be structured to meet graduated or tiered values based on the age of the pavement or to meet a minimum acceptable standard based on a defined pavement age. In some of these cases, particularly for PPP agreements or lease agreements, DOTs are also experimenting with pavement hand-back requirements based on a residual life requirement (translated to thresholds) that would be determined at a stage close to the end of the warranty or maintenance period. The model specifications shown in Appendices A3 and A4 include hand-back language to illustrate the current thought process regarding this type of requirement.

Monitoring and Evaluation

Guidelines and specifications must also address cost-effective approaches to monitoring and evaluating a warranty provision. The type of warranty implemented will factor into how the warranty is monitored and evaluated. Other contributing factors will include the performance indicators and thresholds specified in the warranty provisions and the frequency of the monitoring effort. Monitoring may occur on a regular interval, at random, or as the result of a trigger or alert flagged during standard PMS inspections, as determined by the warranty specification. Monitoring may be conducted as a formal process or as an informal process. It may be witnessed by a representative of the contractor.

Distresses on warranty projects are measured and evaluated as a function of average distress per segment length. The segment length, or lot, must be carefully considered. If evaluation segments are too long, a localized area of poor performance can be diluted. However, segments must be long enough to allow a practical means of data processing. Based on the research findings, typical segment lengths used in the United States range from approximately 300 ft to 500 ft (100 m to 167 m). However, these segments are much different from the segment length, typically 1 mile (1.6 km), used to process network data under the standard pavement management system. Therefore, if using standard network data for comparative purposes to determine the effectiveness of warranties, an appropriate adjustment should be made to thresholds to correlate the warranty and the network data. Considerations for monitoring and evaluation are discussed in the Appendix A1 guidelines and in the commentary included in the model specifications in Appendices A3 and A4.

Specification Content

In addition to selecting the right indicators and thresholds, remedial actions, and monitoring and evaluation plan, the warranty provisions must address the other key administrative elements of warranty specifications. These include bonding, conflict resolution, exclusions, quality control, measurement and payment, and acceptance. The organization and content of warranty provisions will vary considerably based in part on the choice of warranty (i.e., Type I materials and workmanship versus Type II or III performance) and the contracting strategy (i.e., design–bid–build or design–build). Warranty provisions also may be formatted as stand-alone special provisions or aligned with the standard specifications for flexible and rigid pavements (typically AASHTO Divisions 400 and 500).

The recent FHWA guidance for pavement warranties recommends that the specifications address the following core elements for pavement warranty specifications (FHWA, 2008):

1. Description;
2. Warranty bond/guarantee requirements;
3. Conflict resolution team;
4. Permit requirements;
5. Pavement distress indicators, thresholds, and remedial action;
6. Elective/preventive actions;
7. Agency maintenance responsibilities;
8. Method of measurement;
9. Basis of payment;

10. Quality control plans;
11. Verification and evaluation; and
12. Final warranty acceptance.

The FHWA guidance also notes that the content of these elements will vary considerably based on whether the DOT is implementing a materials and workmanship or a performance warranty, an HMA or PCC pavement, or is using an alternative contracting method. For example, the responsibility for quality management activities will shift based on the warranty type and contracting method. The performance criteria and thresholds will change based on the pavement type and warranty objectives.

The research team compared this suggested approach with current warranty specification content, expanding its content analysis of HMA and PCC specifications to determine what core elements were addressed in the specifications and how they were drafted. The research team compared performance indicators and thresholds for PCC pavement, bonding requirements, exclusions, conflict resolution, measurement and payment, and acceptance requirements among other elements. The complete list of the warranty specifications reviewed as part of this effort is included in Appendix B.

Based on this initial review, the research team selected and compared a representative sample of these warranty specifications representing the range of possible formats and contents. Table 17 includes this comparison of six DOT pavement warranty specifications to determine the most common organizational structure and content of these specifications.

Based on the content analysis of these existing specifications, the research team found that the organizational structure was in part dictated by the type and the term of the warranty, which was consistent with the recent FHWA guidance (FHWA, 2008). As noted in Table 17, the sections used in virtually all of the specifications reviewed included the following core elements:

- Description,
- Warranty bond,
- Conflict resolution,
- Pavement performance evaluations (distress indicators, thresholds, monitoring, and remedial action),
- Warranty work/permit requirements,
- Exclusion,
- Measurement, and
- Payment.

The elements that were less-frequently used in the warranty special provisions or included elsewhere in the specifications for a project were

- Definitions,
- Contractor QC plan,
- Initial acceptance,
- Elective/preventative action,
- Agency maintenance,
- Final acceptance, and
- Release from warranty.

The research team determined that the model warranty specifications shown in Appendices A3 and A4 should at a minimum include the core elements and the less frequently

Table 17. Comparison of warranty specification sections.

Specification Section	PA	IN	MS	FL	WI	MI
Description	√	√	√	√	√	√
Definitions						√
Warranty (bond/guarantee)	√	√	√	√	√	√
Contractor QC plan (Documentation)		√	√		√	
Initial Acceptance		√				
Conflict Resolution	√	√	√	√	√	√
Pavement performance criteria (distress indicators and thresholds)	√	√	√	√	√	√
Warranty evaluations (monitoring, and evaluation of distress)	√	√	√	√	√	√
Warranty exclusions	√	√	√	√	√	√
Warranty (remedial) work/ permit requirements	√	√	√	√	√	√
Elective/preventative action		√	√		√	
Agency maintenance/emergency repairs	√	√				
Measurement	√	√	√	√	√	√
Payment	√	√	√	√	√	√
Payment adjustments			√			
Final (inspection) acceptance	√					
Release from warranty	√					

used agency maintenance and final acceptance language. The DOT could then add optional language depending on agency practices and whether the specification was a Type 1 (materials and workmanship) warranty or a Type 2 or 3 (performance) warranty. For example, for a Type 2 or 3 performance warranty, the specification may include responsibility for planned maintenance and the contractor may be required to submit a QC plan. Suggested language for the content of these elements was adapted from the representative sample of warranty specifications and edited to achieve a consistent style and format.

The research team decided that the model specifications shown in Appendices A3 and A4 would be most useful structured as special provisions/standard supplements to Divisions 400 and 500, but could also be drafted as stand-alone AASHTO-formatted standard pavement specifications. This would allow the flexibility to modify the model warranty specifications based on agency practices, whether the warranty is a Type 1 materials and workmanship or a Type 2 or 3 performance warranty and whether it is written as a special provision or as a standard specification. Recommended inserts or optional language, based on the specification structure or type of warranty (materials and workmanship versus performance), are noted in the commentary in italics as appropriate. Where applicable, standard language was adopted from the AASHTO *Guide Specifications for Highway Construction.* Some sections of the model specifications are written in a manner to appear as absolute or definite. This was not intended to be the only approach to the content of the section but provides examples based on current practices. Bracketed items are suggested options or suggested values and should be changed as needed to meet the specific requirements of the project or program.

CHAPTER 4

Conclusions and Recommendations

Pavement warranties for roadway construction have been used in the United States for more than 100 years. Since the passage of a 1995 federal rulemaking on warranties, however, warranty use on DOT construction projects has accelerated dramatically, and the use of pavement warranties for HMA and PCC has grown significantly in the past 10 years. The majority of these are relatively short-term materials and workmanship warranties used in conjunction with the traditional low-bid method of contracting. However, a few DOTs have used or experimented with long-term performance warranties in conjunction with design–build or alternative contracting methods or maintenance agreements in line with practices common in Europe and other parts of the world.

Literature, survey, and workshop findings indicated that the primary objectives for warranty use are to improve product performance and enhance project quality. Other important objectives are to ensure compliance with specifications, increase contractor responsibility for the work, promote innovation or new technologies, and improve life-cycle performance. The findings also revealed that there were three types of warranties currently in use, each with unique objectives and considerations for a project. Additionally, few agencies had developed formal guidelines for project selection or warranty implementation. DOTs that did refer to formal detailed guidelines, such as Caltrans, used guidelines designed for a specific type of warranty (materials and workmanship) and category of project (pavement preservation). Additionally, several states delegated authority for the application of warranties to the district level, resulting in variations within the DOT organization in terms of how pavement warranties are applied.

With a limited number of formal guidelines, the research team performed content analyses of pavement warranty specifications to better classify the type of warranty typically applied by the DOTs using pavement warranties. Types of warranties applied ranged from 1-year materials and workmanship to 25-year performance warranties. The decision to use a specific type of warranty was often determined by programmatic considerations such as the DOT's ability to use alternative contracting, the DOT's ability to develop and implement performance specifications, the availability of bonding, and the expected level of competition. Additionally, the research team categorized the types of projects in which DOTs typically applied warranties as part of the project selection criteria. Results showed that warranted projects ranged from rural to urban and included preservation applications, rehabilitation projects, and new construction.

It was apparent based on the literature review and target interviews with experienced DOTs that the decision to apply a warranty involved a combination of programmatic issues and project-level selection criteria. A three-part warranty decision tool was developed to address both the programmatic and the project-level selection criteria. It was determined that warranties can be applied to a wide range of projects with successful results as long as the DOT aligns its stated goals or objectives with the type of warranty that would have the greatest likelihood of or least risk in achieving those stated goals or objectives.

DOT experience with developing warranty provisions was further summarized and issues or lessons learned that affected the implementation of warranties were outlined. These included selecting appropriate performance indicators aligned with warranty type, determining minimum thresholds or ranges based on DOT objectives and experience, and determining how remedial or corrective actions are defined and handled. As a preferred practice, joint industry–DOT work groups have developed performance thresholds using historical experience or model projects. With more experience, some DOTs plan to refine thresholds to better reflect actual performance. In some cases, contractors have proactively performed elective maintenance to avoid callbacks and remedial work, and there is evidence that contractors are more willing to improve the initial quality of work to avoid potential remedial action in the future.

The implementation of warranties often changes risk allocation and traditional roles and responsibilities, particularly those related to inspection, quality control, and testing. DOTs have different views on shifting this responsibility to the private sector. The DOTs that have shifted greater responsibility for inspection and quality management to the contractor have reported significant savings in resources. This reallocation appears more likely to occur when warranties are used in conjunction with design–build or other alternative contracting systems that shift greater control to the contractor for design and construction.

The use of warranty bonds to secure performance during the warranty period has been a standard industry practice in the United States, but in some states this practice has resulted in reduced competition or lack of bids. Sureties have also not provided bonds for longer-duration warranties, limiting their effectiveness and leading some DOTs to explore alternatives to bonding. These alternatives include extensions to the performance bond, warranties tied to prequalification, graduated payment, and other strategies designed to reduce the cost to and burden on the contracting community.

The specific outcomes of this research project were (1) to develop a project-level selection tool for DOTs to aid in the selection of candidate projects for warranty application, (2) the development of best practice guidelines incorporating the selection tool and various other programmatic and project-level considerations for the implementation of pavement warranties, and (3) the development of model technical provisions for both HMA and PCC pavements. The selection tool, guidelines, and model technical provisions developed as a product of this research are intended to address issues in the development and implementation of warranties for highway construction and strategies that will garner greater support from the industry and improve the overall implementation and effectiveness of warranties. Recommended actions to improve warranty implementation are

- Development of definitions and guidance for understanding and applying warranty types;
- Development of a decision tool for project selection and warranty application;
- Use of consistent, reliable historical data to set performance thresholds and balance risk;
- Alignment of key performance indicators with PMS data to streamline the warranty monitoring and evaluation process;
- Clarity on exclusions and remedial actions, such as the level of repair expected for remedial actions and the materials and techniques that may be used;
- Further development of and experimentation with alternatives to bonding to promote competition;
- Use of alternative contracting in conjunction with warranties to allocate contractor responsibility for performance, to promote innovation, and to implement long-term warranty durations; and
- Use of model pavement warranty technical provisions to promote consistency in how specifications are drafted, and suggested language to promote clarity in terms of contractual obligations and roles and responsibilities based on warranty type.

In the larger context of performance specifications, short-term Type 1 and 2 warranties represent a transition between prescriptive or material and method specifications and performance specifications in the sense that warranty provisions do not encompass the pavement life cycle or include all the factors that contribute to performance. These warranty provisions for pavements typically exclude subbase, drainage, and embankment features or other factors related to pavement design or construction methods that may affect performance. However, as DOTs gain experience with long-term performance warranties or maintenance provisions found in design–build–maintain or PPP agreements, most if not all of the pavement features and factors that affect pavement performance will fall under contractor control. This will require a fundamental shift in risk allocation, contracting and surety practices, and business culture before it becomes more commonplace in the United States. Research is needed to better understand life-cycle costs, predict the factors affecting long-term performance, and change contracting and business models before Type 3 performance warranties will be more commonplace and widely implemented in the United States.

Warranties have a long history of use for maintaining and enhancing quality on highway construction projects in the United States and elsewhere. By improving where and how pavement warranties are implemented, owners, contractors, and highway users can realize tangible and long-lasting benefits from their use.

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Glossary

Design–Bid–Build: The traditional contract delivery system where the owner contracts with separate entities for design and construction services. The construction contract is awarded based on the low bid, and the project is constructed using method specifications. Using a warranty under this system, the contractor may take responsibility for the mix design, but the owner retains the majority of the performance risk.

Design–Build: A delivery system in which a single entity designs and constructs a project based on conceptual plans, design criteria, and performance specifications established by the owner. The procurement approach may range from low bid to best value where price and other factors are considered in the selection. Using a warranty under this system, the contractor takes responsibility for design, both mix and structural within certain parameters, and assumes greater risk for performance.

Design–Build–Operate–Maintain (Public–Private Partnership): A contract delivery system where a single entity designs, constructs, maintains, and operates (and finances) a project for a specified duration, usually the life cycle of the pavement or longer, based on technical criteria and performance requirements established by the owner. The procurement process may entail a qualifications-based selection and a negotiated process to reach agreement on price and other commercial terms. Under this system, the contractor (or developer/concessionaire) takes primary responsibility for the pavement performance.

Equivalent Single Axle Load (ESAL): A type of load quantification that converts wheel loads of various magnitudes and repetitions (mixed traffic) to an equivalent number of standard or equivalent loads based on the amount of damage they do to the pavement.

Hot Mix Asphalt (HMA): Refers to flexible pavements. The terms "bituminous" and "asphalt" are used interchangeably.

International Roughness Index (IRI): A worldwide standard for measuring pavement smoothness. The index measures ride comfort in terms of road roughness using the number of inches per mile that a laser, mounted in a specialized van, jumps as it is driven on the roadway.

Longitudinal Cracking: A pavement distress in which cracks are predominantly parallel to pavement centerline.

Method Specification: Also called recipe specifications, or prescriptive specifications, method specifications require that the contractor use specified materials in definite proportions and specific types of equipment and methods to place the material (*Transportation Research Circular E-C074,* 2005).

Pavement Distress Index (PDI): A combined index of pavement surface distress combining IRI and other roughness distress indices.

Portland Cement Concrete (PCC): Refers to rigid pavements placed on a subgrade or underlying base course.

Performance Indicators: Distresses, properties, or functional characteristics of a warranted pavement that can be measured and are linked to the performance of the pavement.

Performance Specification: Performance specifications state requirements in terms of the required results with criteria for verifying compliance, without stating the methods for achieving the required results. In the broadest terms, a performance specification defines the performance characteristics of the final product and links them to construction, materials, and other items under the contractor control (FHWA, 2004).

Performance Warranties: Specifications that hold the contractor fully responsible for product performance during the warranty period. Under performance warranties, the contractor guarantees that the pavement will perform at a desired quality level. The contractor assumes some level of responsibility, depending on the specific project, for structural pavement or mix decisions (*Transportation Research Circular E-C074,* 2005).

Potholes: A pavement distress in which bowl-shaped holes of various sizes develop in the pavement surface.

Raveling: A pavement distress in which the pavement surface is worn away by the dislodging of aggregate particles and the loss of asphalt binder.

Reflective Cracking at Joints: A pavement distress in which cracks in asphalt concrete overlay surfaces that occur over joints in concrete.

Rutting: A pavement distress in which a longitudinal surface depression develops in the wheel path.

Threshold: Measurable tolerance or limit for performance (distress or functional) indicators.

Transverse Cracking: A pavement distress in which cracks are predominantly perpendicular to pavement centerline.

Type 1 (Materials and Workmanship) Warranty: A warranty implemented in conjunction with standard, method specifications. Type 1 warranties require the contractor to correct early defects in the pavement caused by elements within the contractor's control, namely the materials and workmanship of construction. The DOT uses a traditional low-bid contract where the contractor assumes minimal performance risk. The warranty durations are relatively short-term, typically three years or less.

Type 2 (Short-Term Performance) Warranty: A warranty that shifts more responsibility to the contractor for certain aspects of pavement performance during the warranty period. Type 2 warranties are implemented under traditional low-bid or alternative design–build contracts. They are the broadest category of warranties, as the amount of responsibility shifted to the contractor can range from design of the mix to design of structural aspects of the pavement, particularly when combined with an alternative design–build contract. Their provisions typically include elements of both method and performance specifications but can vary between method-based or performance-based. Type 2 warranty durations generally fall within the range of 5 to 10 years.

Type 3 (Long-Term Performance Warranty): A warranty that shifts the responsibility for the long-term pavement performance to the contractor. Type 3 warranties typically use high-level performance criteria establishing pavement performance standards or thresholds that the contractor must maintain for the service life of the pavement or beyond, and include planned and unplanned maintenance. They are implemented under alternative design–build–warrant, performance-based maintenance, or public–private partnership agreements, and are typically 20 years or longer in duration.

Warranty: A guarantee of the integrity of a product and of responsibility for the repair or replacement of defects by the contractor (Hancher, 1994).

Abbreviations and Symbols

AADT	Average annual daily traffic
AGC	Associated General Contractors of America
ASR	Alkali silica reactivity
σ	Population standard deviation
CRT	Conflict resolution team
CPM	Capital preventative maintenance
DOT	Department of transportation
DRB	Disputes Review Board
ESAL	Equivalent single axle load
HMA	Hot mix asphalt
HBP	Hot bituminous pavement
IPFS	Illinois Pavement Feedback System
IRI	International roughness index
IRIS	Illinois Roadway Information System
LCCA	Life-cycle cost analysis
LTPP	Long-term pavement performance
O&M	Operation and maintenance
PET	Pavement evaluation team
PCC	Portland cement concrete
PCCP	Portland cement concrete pavement
PDI	Pavement distress index
PMS	Pavement management system
PPP	Public–private partnership
PPTA	Public–Private Transportation Act
QA	Quality assurance
QC	Quality control
R&R	Rehabilitation and reconstruction
WIM	Weigh-in-motion

APPENDICES

Appendices A through C are available on the CD-ROM that accompanies this report.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation