Determinants of Industry Acceptance for Highway Warranty Contracts: Alabama Case Study

Qingbin Cui[1]; Philip W. Johnson[2]; Deepak Sharma[3]; and Mehmet Emre Bayraktar[4]

Abstract: There is an increasing demand from state DOTs to explore alternative ways to provide adequate oversight on construction projects. As one of the innovative contracting techniques encouraged by the Federal Highway Administration, warranties in highway construction hold contractors accountable for potential maintenance for a given period of time after project completion. The warranty practices in many states indicate that such provisions would benefit the state DOTs by improving quality, reducing life-cycle costs and project duration, and encouraging contractor innovation. However, the successful implementation of warranty contracting needs widespread industry acceptance and collaboration. This paper presents the findings of a recent research on the industry acceptance of warranty contracting in the state of Alabama. The paper identifies several major concerns and the needs of the construction industry with respect to the subject matter. More importantly, the paper reports a learning process in using warranties in highway construction. Results shows that factors like leniency in specifications, tort liability, and contractors' past experience on warranty jobs help achieve a significance level of industry acceptance. The findings presented in this paper would help those state highway agencies that have limited experience in integrating warranties effectively into their contracts.

DOI: 10.1061/(ASCE)1076-0342(2010)16:1(93)

CE Database subject headings: Warranties; Highways and roads; Construction; Alabama; Contracts; Case studies.

Author keywords: Warranties; Highway construction; Contracting; Industry acceptance; Alabama.

Introduction

In the United States, warranty provisions were first used in transportation projects in the early 1990s to protect public agencies' initial investment by holding contractors accountable for potential maintenance after project completion. Since the early warranty applications under the Special Experiment Project Number 14 (SEP-14) established by the Federal Highway Administration (FHWA) in 1990, there has been a marked increase in the inclusion of warranty provisions in highway construction. By the end of 2003, more than 30 state DOTs had incorporated warranty provisions into their construction contracts (Bayraktar et al. 2004). The warranty practices in many states indicated that warranty contracting could benefit state DOTs by improving project quality, reducing overall life-cycle cost, and accelerating construction as well as encouraging contractor initiated innovations. On the other hand, associated challenges could be substantial, including higher initial costs, a reduction or even elimination of small contractors from the bidding process, and an increase in contract disputes and litigation, in addition to skepticism from contractors and sureties (Anderson and Russell 2001; Hastak et al. 2003; Wang and Park 2004).

Some recent research focused on the influence of warranties on project success. Hancher (1994) first defined warranty contracting in highway construction. Based on the initial experience in Wisconsin, Russell et al. (1999) developed a warranty implementation guide for state highway agencies. Bayraktar et al. (2004) documented the state-of-practice of warranty contracting in the United States and summarized the related benefits and shortcomings from the DOT, contractor, and surety perspectives. Two important investigations regarding the cost-efficiency of warranty contracting were conducted in the states of Wisconsin and Indiana. Krebs et al. (2001) compared the cost performance of warranty projects from 1995 to 1999 with the historical data in Wisconsin and concluded that warranted projects cost 13% less than standard projects in terms of life-cycle project cost. Based on a comparison analysis in Indiana, Singh et al. (2007) estimated that warranty contracts represent more than 70% cost reduction over the entire service life when both agency and user costs are included in the analysis. It should be noted that the conclusions from Krebs et al. (2001) and Singh et al. (2007) were obtained by extrapolating results for short-term performance. Long-term pavement performance data should be collected to verify the life-cycle cost reduction effects due to warranty contracting. Furthermore, early research also showed that cost-efficiency can be improved through a delayed warranty purchase decision, especially under uncertainty. Cui et al. (2004) presented an alternative practice in the Utah I-15 Project where the state agency locked in the warranty cost at the early stage but kept the flexibility to delay the warranty purchase decision until the end of the construction. The

[1]Assistant Professor, Dept. of Civil and Environmental Engineering, Univ. of Maryland, College Park, MD 20742. E-mail: cui@umd.edu

[2]Associate Professor, Dept. of Civil, Construction, and Environmental Engineering, Univ. of Alabama, Tuscaloosa, AL 35487. E-mail: pjohnson@eng.ua.edu

[3]Graduate Assistant, Dept. of Civil and Environmental Engineering, Univ. of Maryland, College Park, MD 20742. E-mail: dksharma@umd.edu

[4]Assistant Professor, Dept. of Construction Management, Florida International Univ., Miami, FL 33174. E-mail: bayrakm@fiu.edu

Note. This manuscript was submitted on February 15, 2008; approved on August 22, 2009; published online on February 12, 2010. Discussion period open until August 1, 2010; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Infrastructure Systems***, Vol. 16, No. 1, March 1, 2010. ©ASCE, ISSN 1076-0342/2010/1-93–101/$25.00.

flexibility allowed the agency to purchase a warranty only when the performance on site warranted it.

Given the potential to significantly reduce overall life-cycle cost, an increasing number of state highway agencies have incorporated warranties into their programs. But integrated analyses of warranty contracting that include the perspectives of contractors and surety companies are needed since the use of warranties affects state DOTs, contractors, and surety companies differently. As such, an advantage to one party (state DOT, contractor, or surety company) may be a disadvantage to other stake holders. Although, as the owner of the project, a state DOT itself is able to initialize the use of warranty contracting, the successful implementation of warranty provisions requires partnering of many sectors of the industry with the state agency. The state DOT needs to have "buy in" since warranties increase quality, reduce failures, and reduce life-cycle cost. Furthermore, the contracting industry must also buy in and accept the risks and rewards of warranty implementation. The bottom line is that ignorance of the industry perspective can lead to failure.

With an increasing demand in Alabama for alternative ways to provide adequate oversight on construction projects, Alabama DOT (ALDOT) initiated several innovative contracting techniques encouraged by the FHWA, including warranties. However, the first warranty trial project in late 2003 could not be let due to lack of industry involvement. Thereafter, the state supported a research program through the University Transportation Center for Alabama to evaluate the industry acceptance, legal viability, and cost effectiveness of warranty contracting in Alabama (Cui et al. 2007). While the legal and economical viability is the theme of another paper, this paper presents the results of a survey regarding industry acceptance of warranty contracting. The paper first explains the concept of warranty contracting briefly followed by a detailed discussion of the survey results.

What Is Warranty Contracting Anyway?

Simply speaking, a warranty is the "assurance" given by the "seller" to the "purchaser" that the "product" will be delivered as promised in the "contractual agreement." If, in this definition, product is replaced with "roadway," seller with "contractor," the purchaser with "state DOT," and contractual agreement with "warranty clause," then the assurance can be said to be equivalent to "warranty provision" in a road project.

Aschenbrener and DeDios (2001) classified highway warranties with respect to contractor's responsibility into workmanship and material warranties, and performance warranties. A workmanship and material warranty holds a contractor responsible for correcting deficiencies caused by bad workmanship and material but exempts the contractor from deficiencies caused by faulty design and other reasons beyond the contractor's control. The workmanship and material warranty is compatible with the low bid system and usually has a short-term period, from a few months to 5 years. The contractor is given the responsibility for material selection and undertakes the risk for bad workmanship and early failure of the selected material. On the other hand, the performance warranty approach gives the contractor the flexibility to design and even modify contract details in addition to material selection and workmanship. Thus, he assumes the responsibility for correcting defects that are caused by workmanship and material as well as design. The contractor may also choose a rehabilitation strategy or undertake preventive maintenance during the warranty period. To provide the state investment with adequate protection from design defects, the performance warranty usually has a longer period, from 5 to 20 years, which under certain conditions may also be a biddable item. North Carolina became the first state to implement warranty provisions on its highway projects in 1987. Since then, testing of warranty contracting has been widespread among state highway agencies and regular use has become popular in many of the states (Russell et al. 1999).

As the use of warranties increased, more and more advantages and disadvantages were recognized. NCHRP report 451, *Guidelines for Warranty, Multi-Parameter, and Best Value Contracting*, by Anderson and Russell (2001) lists 10 critical warranty issues that have a significant effect on state DOTs and the contracting industry including compatibility with the low bid system, impact on open competition, reduction of agency human resources, reduction in project cost, improvement in quality of the constructed project, reduction of project completion time, shifting risk from agency to contractor, ease of implementation with respect to resources, contractor innovation, and project applicability.

As mentioned earlier, critical issues that may be an advantage or opportunity to state DOTs may become a serious disadvantage or threat to contractors or surety companies. Just as an example, transfer of the risk of early failure from the state DOT to the contractor using warranty provisions is an advantage to the DOT, but the contractor and the surety company may be very concerned about assuming the sole responsibility in such cases. This reduces the chances that smaller contractors that do not have the leverage of spreading the assumed risk over other projects will bid for such projects. Similarly, surety companies may refrain from bonding contractors with relatively small working capital in warranty work. As a result, this pattern eventually may eliminate small contractors from competition.

Many conflicting issues similar to the one described earlier surfaced with the increased use of warranty provisions on highway projects. Therefore, it is essential that the needs of the private sector are addressed when state DOTs plan to incorporate warranties into their project delivery process.

Research Approach

Questionnaire Design

A survey was conducted to collect industry opinion on warranty contracting. The questionnaire was designed to be specific and easy to administer to encourage wide industry participation. The development of the questionnaire involved a cooperative effort between the research team at the University of Alabama and the project advisory committee, including representatives from the ALDOT, Alabama Road Builders Association, and surety companies. Two research meetings were held at ALDOT headquarters in Montgomery to discuss, draft, and finalize the questionnaire. The final questionnaire included twelve questions covering the responding company background information, acceptance of and concerns about warranty contracting, and the expected impact of warranty provisions.

In addition to respondent's contact details, four questions were asked regarding company background information, including annual dollar revenue, years in the highway construction business, percentage of revenue in each type of highway project, and warranty project experience in other states. These questions were used to categorize responding companies into several groups in accordance with size, highway construction experience, warranty project experience, etc.

Another group of four questions were designed to collect contractors' opinions on warranty contracting in Alabama. Respondents were asked what type of warranted highway projects they would consider bidding on, how long a warranty period they would accept, what they would request in return for the warranty, and what are their concerns about warranty work. Additional questions addressed the availability of and length of the warranty bond they can obtain.

A third group of questions regarding the expected impact of warranty contracting was also asked. Those questions included: what type of roadway projects would achieve a life-cycle cost benefit from warranties and what measures of roadway performance they would accept. Additional questions, such as the impact of warranties on construction quality and owner-contractor relationships were also included in the questionnaire. For additional details on the questionnaire, readers are referred to Cui et al. (2007).

Sampling

The success of a survey depends largely upon the sample size and the representativeness of the sample. To obtain a representative sample, the survey population must be defined and examined. In most states, a contractor must be prequalified before submitting a bid proposal for highway and bridge construction. In Alabama, the state DOT qualifies a contractor based on the company's financial statement, equipment fleet, and construction experience. There are currently 360 companies on the list of prequalified contractors that are allowed to bid on Alabama transportation projects. These contractors can be divided into two groups using company size, state residency, or experience in warranty jobs as a criterion. In another words, we can define several dichotomous variables with the value of 0 and 1 to describe the characteristics of any prequalified contractor. For example, residency variable x is defined as the state residency of a responding company. If a responding company takes residency in Alabama x equals to 1, otherwise x equals to 0 for non-Alabama resident companies. The characteristics of the survey population are represented by the group distributions of prequalified companies. However, these distributions are generally unknown.

While sampling from the finite population, the survey requires sufficient responding companies from each group, or a typical sample with statistically indifferent group distributions. Consider a finite population of size N from which a simple random sample of size n is drawn, without replacement. Let $\bar{x}$ be the sample mean and let $\bar{X}$ and $\bar{S}$ be the population mean and variance. For a dichotomous group variable with a value of 0 or 1, $\bar{x}$ and $\bar{X}$ are denoted by p and P, respectively, and the sample variance can be found as, $S^2=(NPQ)/(N-1)$, where, $Q=1-P$. It is known that

$$\mathrm{Var}(\bar{x}) = \left(\frac{N-n}{Nn}\right)S^2 \tag{1}$$

By imposing the constraint $\mathrm{Var}(\bar{x}) \leq V^*$ for a prechosen margin of error V^*, the required sample size to satisfy this inequity is determined (Desu and Raghavarao 1990) as

$$n^* = \frac{NS^2}{S^2+NV^*} + 1 \tag{2}$$

or

$$n^* = \frac{N}{1+\dfrac{(N-1)V^*}{P(1-P)}} + 1 \tag{3}$$

Since P is usually unknown and somewhat difficult to guess, a conservative approach is to take $P=0.5$ which yields the highest value for n^*. Thus, with $N=360$ prequalified contractors, the required sample size for $V^*=(0.1)^2$ is

$$n^* = [360/\{1+(359 \times 0.01)/(0.5 \times 0.5)\}] + 1 = 24$$

Based on the preceding calculation, if 100 questionnaires are sent out, the required sample size (24 responses) needs at least a 24% response rate. Given that the average response rate from construction companies on earlier similar research was within 10–20% (Hastak et al. 2003), the research team decided to send the prepared questionnaire to all 360 prequalified contractors with a target minimum response rate of 7% to achieve the required number of 24 total responses needed for a sound statistical analysis.

Survey Implementation

A list of the prequalified contractors was obtained from the ALDOT office of engineering. ALDOT also provided a cover letter to the questionnaire which explained the purpose of the research. The questionnaire was sent out by mail to all 360 contractors on August 4, 2006. Twenty-eight contractors responded within the first two weeks, the required return period for the questionnaire. Within the next 2 weeks, after a reminder was sent out on August 21, 2006, 15 more questionnaires were received. Of the 43 responses, three were discarded because the companies were specialty contractors for roofing, ITS, etc., with no experience in the research area. Also, one company responded twice with conflicting answers. The research team contacted the respondent and confirmed that the latest response reflected their current opinion on warranty contracting. Thus the research team counted 39 usable responses, which represented a 10.8% response rate and satisfied the minimum sample size requirement for the survey design.

Of the 39 responding contractors, 18 were local companies in Alabama, while 12 were from the southeastern states including Mississippi, Tennessee, Georgia, and Florida. The remaining seven contractors had their head offices in Texas, Minnesota, Indiana, Kentucky, Pennsylvania, Virginia, and Connecticut. After a discussion with the ALDOT engineers and Alabama Asphalt Pavement Association, the research team categorized contractors with over $20 million annual revenues as large, contractors with annual revenues from $5 to $20 million as medium-size, and contractors with annual revenues less than $5 million as small contractors. Based on this criterion, 48.7% of the respondents were categorized as large contractors, while 51.3% were in the small and medium-size groups. Responding companies were also divided into five specialty contractor groups according their work focus and experience. Seventeen out of 39 (44%) of the responding contractors had done asphalt pavement projects, 10 (or 26%) had done portland cement concrete (PCC) pavement jobs, 16 (or 41%) had done bridge work, and 15 (or 38%) had done pipework (Fig. 1).

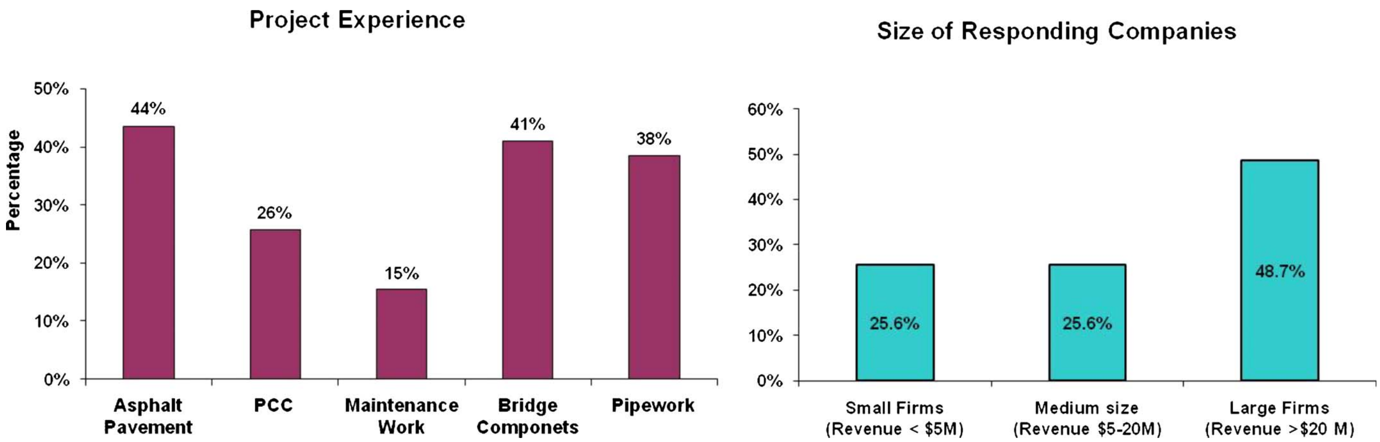

Fig. 1. Profile of the responding companies

View of Highway Contractors on Warranty Projects

Warranty Duration and Project Types from the Industry Perspective

The successful implementation of warranty contracting depends on buy in by the construction industry. Without cooperation from contractors, a state DOT would not be able to shift maintenance responsibility. In several states, where highway departments intended to let projects with warranties, few contractors would bid on these jobs. A preinvestigation of the industry acceptance of alternative contracting could help state DOTs predict potential backlash from the industry and develop creative solutions. This research showed that a majority of highway contractors in Alabama accept short-term warranties, typically for defective materials or workmanship, on highway projects. Around one-quarter of the responding contractors will not consider bidding on warranty projects in Alabama no matter what the type, term, and performance indicators of warranties are. The survey also found out that there is a significant difference between the acceptance of new construction and of resurfacing jobs. The contractors were more willing to offer warranties on new construction projects than on resurfacing work. Within the group accepting warranty contracting, 80% (24 out of 30) preferred to bid on new construction, especially performance warranties. This correlates well with earlier findings that contractors wish to reduce risks on warranty jobs and prefer to warrant design-build contracts (Bayraktar et al. 2004). It should be noted that on an early warranty pilot project in Alabama, the acceptable pavement conditions at the end of the warranty period were defined based on the average performance values from its pavement management system.

Although most contractors would consider bidding on warranty jobs, their decisions also depend upon the term of the warranty period and the type of the project. Asphalt pavement and PCC pavement are the top two types of construction projects on which most contractors would offer warranties. 41% (7 out of 17) of asphalt paving contractors would bid on asphalt pavement projects with 1 to 3 year warranties. However, when the warranty period goes up to 4 to 5 years, less than one-quarter of contractors would take warranty risks. Only 6% (1 out of 17) of asphalt paving contractors would offer a warranty of more than 5 years. The longest term acceptable on an asphalt pavement job was found to be 8 years. No contractor in Alabama would bid on a warranty of over 8 years on asphalt pavement projects. On PCC projects, the longest acceptable warranty period was found to be 10 years. However, as the warranty period goes over 3 years, a very limited number of contractors would like to bear the associated risks. Three out of all 10 PCC contractors would offer warranty of 1 to 3 years, while only 20% (2 out of 10) would consider bidding on a 4–5 year warranty job. Only about one contractor would offer a warranty of more than 5 years on PCC projects. Similarly, in case of the other types of highway projects, the majority of contractors suggested a warranty period of 3 years or less. In return for accepting a warranty contract, contractors would request an increased cost on top of the total installed cost, as well as leniency in the construction specifications. Fig. 2 provides a consolidated view of industry acceptance of warranties in Alabama. The bars in the figure show the percentage of contractors within the specialty groups accepting certain warranty terms, while the numbers above the bars indicate actual responses for each project group and warranty term.

Concerns of the Industry

Previous research has identified state DOTs' major concerns regarding the use of warranties in highway construction (Bayraktar et al. 2004). This paper reports major concerns of the construction industry (Fig. 3). In rank order, the major concerns included risks and liabilities, availability of warranty bonds, warranty cost estimating, warranty duration, and legal issues. By far, the most serious concern indicated by the respondents was the risks and liabilities associated with warranties. A total of 46% (18 out of 39) of the respondents ranked this as the most important factor

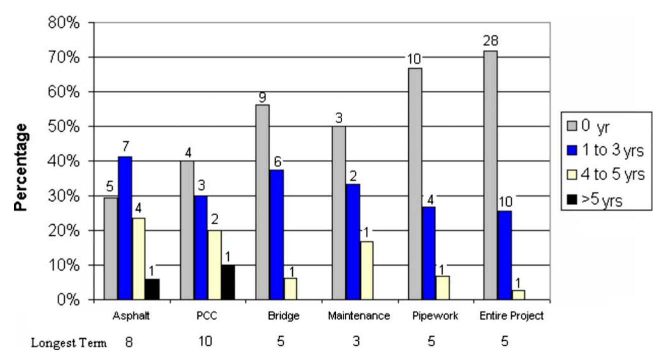

Fig. 2. Industry acceptance of warranty contracting

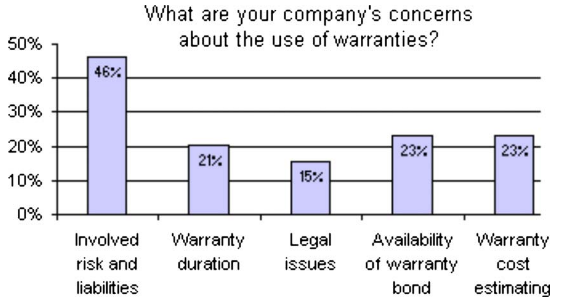

Fig. 3. Industry concerns regarding warranty contracting

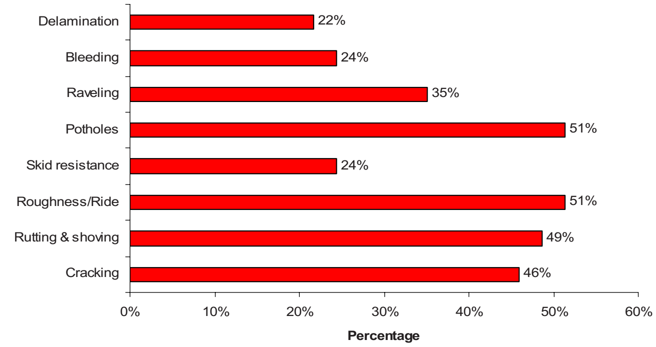

Fig. 4. Contractor acceptance level for pavement performance indicators

when warranty jobs are considered. The risks mentioned by the industry included high traffic loads, environmental impact, and uncertain geotechnical conditions.

The concerns about the unavailability of warranty bonds to relatively small contractors were introduced in earlier work (Bayraktar et al. 2006). The survey showed that 21 out of 39 responding companies could obtain a warranty bond of 3 years or less with no major problem, while none of the respondents expected a 5-year or longer warranty bond to be available to them. For short-term warranty periods, this research indicated a statistically insignificant impact of company size on the availability at a 5% level of significance. If a warranty bond of more than 3 years is required, neither large contractors nor small firms were capable of finding a surety to bond their projects. Therefore, bonding availability was found to be not a problem in short-term warranties (less than 3 years), whereas it was the most serious obstacle to long-term warranty projects (5 years or more) in Alabama.

In return for providing a performance guarantee along with the final product, most of the contractors requested a line item to be added to the bid schedule allowing them to estimate the warranty cost under a worst case scenario. One-third of these contractors willing to bid warranty jobs also requested leniency in designing the warranty and specifications. They claimed that the degree of the contractor's control of the specifications dictates success in warranty projects.

Some contractors had also comments about other issues. One contractor was willing to warrant his paint work for up to 5 years but mentioned that the sureties would not issue a warranty bond for more than 3 years. Another contractor was concerned about the state DOTs controlling and inspecting the specification, and then asking for warranted performance. This contractor indicated that the state DOTs should allow contractors to take full control of their work and thus be fully responsible for their work.

The survey responses on concerns also included some extremes. One contractor responded that warranties are creating a negative impact on the relations between the owner, the contractor, and the taxpaying people of Alabama. To support his position, he attached photographs showing uncontrolled and excessive loads traveling on the sections of Alabama highways completed by his company. But another contractor mentioned that though 90% of his work is warranted, he has experienced no negative effects.

Performance Indicators and Quality Issue

One major concern that prevents contractors from bidding on warranty projects is the lack of useful historical data. The survey included a question asking about the contractors' opinion on the parameters that can be used as evaluation criteria for project compliance. The acceptance level for each performance indicator is shown in Fig. 4. State DOTs may be able to use these evaluation criteria for successfully implementing warranty contracting in highway projects.

The last two concluding questions of the survey were to document industry opinion about the effect of warranties on the quality of construction and on the relationship between the state DOT and the contractors. 36 and 37 respondents answered the questions respectively. One-half of the 36 respondents thought warranties would improve quality, while three (or 8%) respondents indicated reduced quality, and 15 (or 42%) indicated no effect on quality. With regard to the state DOT-contractor relationship, 13 out of 37 contactors believed that warranties would have a positive effect, 14 negative effect, and 10 no effect. Readers should bear in mind that while the opinions of the contractors about the potential effect of warranties on quality are important for the study of the factors that would make the use of warranties easier. With respect to the actual effect, it would be more important to quantify the improvements with actual data.

Impact on Open Opportunity

Industry acceptance of warranty contracting needs to be further evaluated in terms of the opportunity offered to all construction companies. As public agencies, the state DOTs are expected to provide equal opportunities to all construction companies. However, it is widely believed that the inclusion of warranties in highway projects makes it difficult for small contractors to bid on due to involved risks and bonding availability. In another words, warranty contracting has been generally recognized to be favorable to large contractors rather than small ones. This paper, however, presents an opposite argument on the equal opportunities offered by warranty contracting, especially for short-term warranties. The argument is based on the ANOVA with company size as the independent variable (Table 1).

Given the null hypothesis that the groups are all the same, it is obvious from Table 1 that all P values are too big and hence the null hypothesis cannot be rejected. Therefore, it is statistically reasonable to conclude that there is insignificant difference across the groups in terms of every dependent variable. As to the warranty contracting in highway construction, this means that small, medium-size, and large contractors have similar warranty experience, share similar concerns associated with warranty contracting, and make similar bidding decision on warranty projects. It should be noted however that contractors usually have extremely opposite opinions about warranty contracting as shown by the large

Table 1. Analysis of Variance with Company Size as between Group Factor

	Size of contractor							
	Small		Medium		Large		Test	
	μ	σ^2	μ	σ^2	μ	σ^2	F-value	P-value
Warranty project experience	0.40	0.27	0.30	0.23	0.37	0.25	0.11	0.90
Acceptable warranty term	1.10	2.10	1.80	2.18	2.37	7.02	1.16	0.32
Acceptance of warranty projects	0.90	0.10	0.80	0.18	0.68	0.23	0.87	0.43
Acceptance of DBW projects	0.20	0.18	0.30	0.23	0.42	0.26	0.72	0.49
Impact on construction quality	0.33	0.50	0.50	0.72	0.41	0.26	0.15	0.86
Impact on owner-contractor relationship	0.22	0.69	−0.20	0.84	−0.06	0.76	0.57	0.57
Concerns								
Involved risks and liabilities	2.50	5.61	3.70	4.68	3.32	3.78	0.86	0.43
Warranty duration	2.00	4.89	2.20	4.62	2.26	3.65	0.05	0.95
Legal issues	1.30	3.79	1.90	5.21	2.47	3.82	1.11	0.34
Availability of warranty bond	1.70	5.57	1.90	4.54	2.32	3.78	0.32	0.73
Warranty cost estimating	1.10	2.77	2.20	5.96	2.11	4.10	0.95	0.39

Note: Small contractors with annual revenue below $5 million, medium-size contractors with revenue between $5 million–$20 million; and large contractors with annual revenue above $20 million. Sample size is 39, with 10 small contractors, 10 medium-size, and 19 large contractors. F-test criteria using $P < 5\%$ is 3.26.

variances in each group. For example, the acceptable warranty term indicates the maximal warranty duration that contractors would bid on. The mean value in the small contractors group is 1.1 year, with a variance of 2.1. This indicates most small contractors will accept less than 1 year warranty, while several would consider longer warranty contracts. Similarly, large contractors on an average accept 2.37 years warranty contracts. The large variances of 7.02 indicate a big difference about the acceptable warranty term. One contractor was found to warrant his work for 8 years while several others wanted to warrant for much lesser years. These extremely opposite responses cause large variations.

Table 1 also shows a very interesting observation regarding the impact of warranty contracts on the long-term relationship between contractors and the DOTs. It was largely believed that warranties would eliminate the small contractors from bidding and are favoring the large contractors. But the results obtained during the research gave a very different picture. It was observed that the small contractors believed that warranty contracts will improve relationship but the medium and large contractors believed that warranties will create a negative impact on relationship. This implies that the small contractors are more positive about warranty contracts as compared to the medium and large-sized contractors given that they are considering bidding for the state of Alabama. This can be observed from the signs reversals of the means in Table 1. This result provides a convincing evidence to counter the widespread belief that small contractors do not want the warranty contracts to be implemented and warranty contracts do not give equal opportunity. Statistically, no matter large or small, contractors hold the same opinions on the impact of warranty contracting on construction quality and owner-contractor relationship. Furthermore, there is no significant evidence to state that more large contractors prefer design-build-warranty (DBW) projects than small contractors. Additionally, there is less evidence to reject the hypothesis that no significant difference exists across the groups regarding the concerns associated with warranty contracting. There is an increasing trend in the means from small contractor group to large contractor group, which may indicate increasing concerns in large contractor group regarding the risks associated with warranty contracting. However, this trend is not statistically significant.

Determinants of Industry Acceptance

Correlation Analysis

Another objective of this research was to identify and understand the determinants of industry acceptance of warranty contracting on highway projects. This would help state DOTs better design or fine-tune their existing systems and practices to achieve a wide acceptance of long-term warranties among highway contractors. In this research, a correlation analysis was performed to assess the significance level of influence caused by various factors such as company size, age, experience in highway projects, requirements for taking warranty risks, and bonding availability with respect to the acceptance of warranty contracting by the construction industry. Considering the characteristics of the data collected in the survey, the Pearson's correlation procedure was used to make inferences about the association between industry acceptance and the factors mentioned earlier. Pearson's correlation coefficient is used when the data are categorical and has several ties (Stockburger 1998).

To perform the Pearson's correlation analysis, all the responses were coded as categorical data with "1" in case of a positive answer representing the selection of a choice in the survey response, and with "0" in case of a negative answer representing the nonselection of a choice in the survey response. Then the responses to every factor (or variable) were expressed in ranks. By calculating the difference between the ranks of each pair of variables, i.e., industry acceptance variable and a factor variable, the Pearson's correlation coefficients, r, can be calculated as (Triola 2005)

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\left[\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right)\left(\sum y\right)^2}\right]} \tag{4}$$

where x and y represent the coded response of industry acceptance variable and a factor variable, respectively. n is the rank order which is 39 in this research. To test whether there was a relationship between the industry acceptance variable and a factor variable, i.e., whether their correlation was significantly different

Table 2. Pearson's Correlation Analysis

Description	Pearson's correlation	P-value
Warranty experience in other states	0.410[b]	0.010
Legal issues	−0.333[a]	0.038
Leniency in specifications	0.322[a]	0.046
Company size	—	0.230
Risk and liabilities	—	0.267
Availability of bonds	—	0.492
Warranty duration	—	0.554
Industry experience	—	0.554
Warranty cost estimating	—	0.604
Addition of funds	—	0.650

Note: Sample size=39.
[a]Significant at the 0.05 level (two tailed).
[b]Significant at the 0.01 level (two tailed).

from zero, the identified Pearson's correlation coefficients can be used in the test statistic (Weiss 2005)

$$t = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}} \tag{5}$$

which is based on the t-distribution with (N-2) degree of freedom. The analysis was conducted using SPSS 14.0 for Windows. As shown in Table 2, the levels of influence of three factors on the acceptance of warranties by the industry were identified as significant. As discussed in detail in the following sections, these factors included past experience in warranty projects, legal issues, and leniency in specifications.

Past Experience in Warranty Projects and Contractor's Learning

The most important determinant of warranty acceptance lies in a company's past warranty experience in other states. It shows that warranty experience of contractors significantly increases the acceptance probability of warranty contracting. The Pearson correlation analysis indicated that it is significant even at the 99% confidence level. The positive coefficient indicates a positive influence on warranty acceptance, i.e., the more warranty experience, the higher is the acceptance of warranty contracting. This is partly due to the change in warranty concerns and opinions generated by warranty experience. The survey showed that as a contractor becomes more experienced in warranty projects, he/she will better understand the risks associated with warranties and that in turn alleviates the concerns about the risks and liabilities, but raises the concerns about bonding availability, which is beyond his/her control. Furthermore, an experienced contractor would be more likely to request flexibility in design and construction to reduce the warranty costs and risks. The bottom line is that contractors learn from warranty projects and then show increasing tendency to accept warranty contracting. Another significant difference between with warranty experience and without warranty experience groups lies in the concerns about bonding availability. It seems that experienced contractors in warranty contracting regard bonding availability as one of the biggest barriers to retaining the use of warranty contracting. And this issue has not been sufficiently realized by those who have no warranty experience before (Table 3).

State DOTs can encourage contractors' learning by implementing pilot projects. In a pilot project, an experienced contractor will serve as an example to the local industry. His success in the warranty project will increase the confidence and knowledge of other contractors to accept warranty contracting. Simultaneously, they will learn the best practices and lessons and become aware of the possible pitfalls in warranty contracting. It is interesting to identify that company size and the state residency do not contribute to the warranty learning process. So the perception that warranty contracting favors large firms is likely not true. The survey also shows no statistical correlation between company size and acceptance of warranty contracting. Combined with the finding that the company size does not affect the availability of bonds, it is safe to draw the conclusion that warranty contracting does not impede competition in the highway construction market.

Legal Issues—Tort Liability

With a p-value lower than 0.05, "legal issues" is another significant determinant of the industry acceptance of warranty contracting. The major legal issue concerning the contractors in warranty projects is the increased tort liability. Torts in highway projects are injuries resulting from defective highways. In case of traditional contracting, when a state agency performs maintenance work, the doctrine of sovereign immunity prevents a third party from suing the state highway agency in tort for negligence if the cause of the injury is within the scope of the agency's general

Table 3. Analysis of Variance with Warranty Experience as between Group Factor

	Warranty experience in other states						
	Without warranty		With warranty		Test		
	μ	σ^2	μ	σ^2	F-value	P-value	
Acceptance of warranty projects	0.64	0.24	1.00	0.00	7.47	0.01	*
Acceptance of DBW projects	0.24	0.19	0.50	0.27	2.78	0.10	*
Impact on construction quality	0.38	0.51	0.50	0.27	0.29	0.59	
Impact on owner-contractor relationship	0.00	0.70	−0.08	0.91	0.06	0.80	
Concerns							
Involved risks and liabilities	3.68	3.06	2.36	6.09	3.81	0.06	*
Warranty duration	1.96	3.62	2.57	4.73	0.84	0.37	
Legal issues	2.28	3.96	1.57	4.57	1.08	0.31	
Availability of warranty bond	0.32	0.23	0.93	0.07	19.31	0.00	*
Warranty cost estimating	2.08	3.99	1.50	4.73	0.71	0.40	

Note: Sample size is 39, 25 of them without warranty experience and 14 with warranty experience. An asterisk indicates value significant at the 0.10 level.

functions. When maintenance duties are shifted to contractors, they are normally not protected by the same immunity as public agencies. As a result, injured parties often choose to sue the contractor responsible for the construction or maintenance of the roadway itself. The risk of a lawsuit to contractors is great and has led to difficulties in obtaining not only the required level of liability insurance but any extra the contractor needs to obtain. Above all, with a warranty, not only will the contractor be responsible for injuries caused by defective maintenance, but will also be required to carry on liability insurance for a longer period of time for a specific project.

In accepting a warranty contract, contractors may expect consideration for taking on these additional risks. Reducing contractors' tort liabilities will definitely increase their willingness to accept warranty contracting. In some states, such as Kansas, a contractor is protected under the same immunity as the agency once the project is completed and accepted by the state. Additionally, some states, such as California and Montana, may abrogate this immunity to expose an agency to liability under certain conditions. The final decision on how to best allocate the liability in warranty contracts should be decided between contractors, insurance company representatives, and the state agency.

Leniency in Specifications

Industry acceptance of warranty contracting is also significantly influenced by contract specifications. At a 95% confidence level, the analysis showed that the more lenient the specifications become, the more contractor willingness there is to bid on warranty jobs. The leniency in specifications, however, should not be equated to reduced quality requirements. On the contrary, it often leads to an improvement in performance throughout the life cycle of highway infrastructure. The performance improvement is primarily attributable to the shift from the existing prescriptive specifications to performance specifications.

Prescriptive or method specifications have been a mainstay in transportation construction for many years. They place maximum control and responsibility in the hands of the state agencies. Typically, prescriptive specifications provide a "cookbook" with specific "recipes" for contractors to follow, while the state agencies monitor and ensure contractor compliance through inspections, sampling, and testing during construction. Instead of "tell contractors how to do the job," performance specifications use "tell contractors what the agency wants and let them go" [Federal Highway Administration (FHWA) 2004]. In theory, performance-based specifications allow contractors more freedom to implement innovative materials, choose cost-efficient methods, and conduct site-specific process control programs. The state agencies, on the other hand, define desired performance characteristics of the final product and link the performance to the construction and material items under the control of contractors.

A warranty is essentially a performance-based contract that guarantees the integrity of highway infrastructure. The incorporation of performance specifications in warranty contracting is generally welcomed by the construction industry, and therefore would improve the acceptance of this new contracting method. A detailed comparison of opinions between small, medium, and large contractors also reveals that large and medium-size contractors are more excited about the use of performance specifications. Small contractors, however, still prefer traditional prescriptive specifications, partly because of the lack of needed knowledge and workforce.

Conclusions and Recommendations

Warranty provisions hold contractors accountable for failures and maintenance after construction completion. Along with the expected benefits, the state DOTs need to evaluate industry acceptance before implementing alternative contracting methods. This paper reported that there is very less difference between the small, medium, and the large contractors in terms of availability of opportunity offered by the warranty contracting. More importantly, the research observed a learning process in the construction industry when using warranty contracting. Past warranty project experiences in other states improve the level of industry acceptance for warranty contracting. The readers should be cautious, however, before generalizing these findings derived from a limited number of cases in Alabama. The analysis in this paper greatly depended on a self-selected sample, i.e., contractors who chose to respond in the survey, which could be a misrepresentation and bias the result. On the other hand, this paper illustrated a procedure to evaluate industry acceptance in Alabama. Other state DOTs could slightly modify the procedure according to their local legal environment and industry capacity, and implement similar evaluation of industry acceptance before introducing innovative project procurement. The findings from the survey are able to establish a guide for the state of Alabama and beyond to select appropriate projects, warranty terms, and specifications.

In the state of Alabama, widespread industry acceptance exists for short-term (less than 3 years) warranties in highway construction. There is a sufficient degree of acceptance for 4–5 year warranties in pavement projects. However, the local industry is not prepared to accept warranties for over 5 years. If substantial benefits from warranty contracting are expected, the state DOT is encouraged to consider warranties of less than 5 years for new pavement construction and less than 3 years for other projects. To achieve a significant level of market acceptance, a better strategy is to implement pilot warranty projects. The pilot projects must be carefully selected to ensure success. They will serve as both a test bed for evaluating the effectiveness of warranty contracts and an educational platform for the local contracting industry. The development of the pilot projects will strengthen cooperation and partnership among the state DOT, the contracting industry, sureties, and beyond. Two other issues need careful attention including tort liability and specifications. It is recommended that the state DOT increase industry acceptance through limiting contractor's tort liabilities and developing performance-based specifications.

Before the agency initiates the new program, the state must be ready for possible cost increases. The state DOT should be prepared to allow contractors more freedom in the selection of materials, construction technologies, inspection methods, or even mix design and structural design. Considerable effort should be devoted to developing detailed specifications and guidelines. The state DOT may have to identify alternative solutions if no surety is willing to provide a bond in pavement projects with over 5-year warranties. Alternative methods used in other states, including renewable bonds (Wisconsin) and letters of guarantee (South Carolina), should be evaluated. Performance indicators should be further examined and carefully selected to insure performance and quality.

Local construction companies may need to adjust their strategies and opinions on warranty contracting. Moreover, this research highlighted the fact that warranty contracting may not be as risky as it appears. Many contractors learn from past experience and are able to control the risks well. When the concept of "get in, stay in, get out, and stay out" becomes a new objective of the FHWA, the construction industry will see warranties becoming integral components in more and more transportation projects, especially in design-build projects. To maintain a competitive position, contractors need to consider providing operation and maintenance services. Participation in the policy discussion and cooperation with the state DOT in pilot projects would help improve their competitive advantage in today's changing construction market.

Acknowledgments

The writers thank the University Transportation Center for Alabama for providing financial support for this study. The writers are also in debt to Don Arkle, Ronald Baldwin, Walter Dowdy, Terry McDuffie, Terry Robinson, and Dr. Rocky Durrans for their valuable insights. The opinions and findings expressed here, however, are those of the writers alone. Finally, the writers acknowledge the anonymous reviewers for their valuable comments and suggestions for the revision of this paper.

References

Anderson, S. D., and Russell, J. S. (2001). "Guidelines for warranty, multi-parameter, and best value contracting." *NCHRP Rep. No. 451*, Transportation Research Board, Washington, D.C.

Aschenbrener, T., and DeDios, R. (2001). "Material and workmanship warranties for hot bituminous pavement." *Rep. No. CDOTS-DTD-2001-18*, Colorado DOT, Denver.

Bayraktar, M. E., Cui, Q., Hastak, M., and Minkarah, I. (2004). "The state-of-practice of warranty contracting in the US." *J. Infrastruct. Syst.*, 10(2), 60–68.

Bayraktar, M. E., Cui, Q., Hastak, M., and Minkarah, I. (2006). "Warranty bonds from the perspective of surety companies." *J. Constr. Eng. Manage.*, 132(4), 333–337.

Cui, Q., Bayraktar, M., Hastak, M., and Minkarah, I. (2004). "Use of warranties on highway projects: A real option perspective." *J. Manage. Eng.*, 20(3), 118–125.

Cui, Q., Johnson, P. W., and Sees, E. (2007). "Long-term warranty on highway projects." *USDOT-UTCA Rep. No. 06109*, Univ. of Alabama, Tuscaloosa, Ala.

Desu, M. M., and Raghavarao, D. (1990). *Sample size methodology*, Academic, San Diego.

Federal Highway Administration (FHWA). (2004). *Performance specifications strategic road map: A vision for the future*, FHWA, Washington, D.C.

Hancher, D. (1994). *NCHRP synthesis 195: Use of warranties in road construction*, Transportation Research Board, Washington, D.C.

Hastak, M., Minkarah, I., Cui, Q., and Bayraktar, M. E. (2003). "The evaluation of warranty provisions on ODOT construction projects." *Rep. No. FHWA/OH-2003/019*, Ohio DOT, Columbus, Ohio.

Krebs, S. W., et al. (2001). "Asphaltic pavement warranties, five-year progress report." *Rep. Prepared for Wisconsin DOT*, Madison, Wis.

Russell, J. S., Hanna, A. S., Anderson, S. D., Wiseley, P. W., and Smith, R. J. (1999). "The warranty alternative." *Civ. Eng.*, 69, 60–63.

Singh, P., Oh, J. E., Labi, S., and Sinha, K. C. (2007). "Cost-effectiveness evaluation of warranty pavement projects." *J. Constr. Eng. Manage.*, 133(3), 217–224.

Stockburger, D.W. (1998). "Introductory statistics: Concepts, models, and applications." 3rd Ed., Atomic Dog, Cincinnati.

Triola, M. F. (2005). *Elementary statistics*, 9th Ed., Pearson Education, New York.

Wang, L., and Park, J. (2004). "The effectiveness of pavement management databases to capture essential data to monitor the performance of projects under warranty." *Federal Highway Administration Rep.*, FHWA, Washington, D.C.

Weiss, N. A. (2005). *Introductory statistics*, 7th Ed., Pearson Education, New York.