RESEARCH

Utah Department of Transportation - Research Division
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udot.utah.gov

Report No.UT-13.16

LESSONS LEARNED – PAVEMENT MARKING WARRANTY CONTRACT

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Final Report Date
December 2013

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1. Report No. UT – 13.16	**2. Government Accession No.**	**3. Catalog No. NA**
4. Title and Subtitle LESSONS LEARNED – PAVEMENT MARKING WARRANTY CONTRACT	**5. Report Date** December 2013 **6. Performing Organization Code**	
7. Author Milan Zlatkovic, Richard J. Porter	**8. Performing Organization Report No.**	
9. Performing Organization Name and Address University of Utah 110 Central Campus Dr. Room 2000 Salt Lake City, UT 84112	**10. Work Unit No.** 8RD1324H **11. Contract No.** 13 8354	
12. Sponsoring Agency Name and Address Utah Department of Transportation Research Division 4501 South 2700 West Salt Lake City, Utah 84114-8410	**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code** AM13.003	

15. Supplementary Notes
Prepared in cooperation with the Utah Department of Transportation.

16. Abstract

In 2012, UDOT implemented a performance-based warranty on a portion of an I-15 pavement marking project. The awarded contract requested a contractor warranty on the implemented markings for a total duration of six years. This is the first time that UDOT has requested a warranty on pavement markings, and also the first time that Interstate Maintenance (IM) funds were used for pavement markings. This report documents lessons learned from the preconstruction, construction and post-construction phases of this project, collected through surveys of key involved UDOT personnel. It also includes a literature review on pavement marking warranty contracts in general, a review of the I-15 performance-based warranty contract, and reviews of previous, materials and workmanship warranty based pavement marking contracts of similar size. The estimated life-cycle and suggestions for benefit-cost analysis are also included.

17. Key Words Pavement marking warranty, risk mitigation, IM funds, performance-based warranty		**18. Distribution Statement** Not restricted. Available through: UDOT Research Division 4501 South 2700 West P.O. Box 148410 Salt Lake City, Utah 84114-8410 www.udot.utah.gov/go/research		**23. Registrant's Seal**
19. Security Classification (of this report) Unclassified	**20. Security Classification (of this page)** Unclassified	**21. No. of Pages** 63	**22. Price - NA**	

ACKNOWLEDGEMENTS

The authors thank UDOT personnel Russ Scovil, David Stevens, Ken Berg, Dan Betts, Kevin Griffin, Lloyd Neeley, George Lukes, Phil Peterson, Bryan Chamberlain, Troy Peterson, Rob Wight, Abdi Fatemi, Bryan Adams, Steve Poulsen, and Philip Ellsworth for their assistance and contribution to the research.

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EXECUTIVE SUMMARY

In 2012, UDOT awarded a first of its kind performance-based warranty contract on a portion of an I-15 pavement marking project. The awarded contract requested a contractor's warranty on the implemented markings for the total duration of six years. This is the first time that UDOT has requested such a warranty on pavement markings, and also the first time that Interstate Maintenance (IM) funds were used for pavement markings. This report documents lessons learned from the preconstruction, construction and post-construction phases through surveys of key UDOT personnel involved in the pavement marking warranty contract. It also includes a literature review on pavement marking warranty contracts in general, a review of the I-15 warranty contract, and reviews of previous, non-warranty based pavement marking contracts of similar size. In addition, the report includes life cycle estimation for the new markings, based on the degradation models obtained through the literature review, as well as an approach to estimate the benefit-cost ratio.

An increasing number of DOTs in the U.S. have started to implement performance-based warranties for pavement marking projects. The duration of the warranties implemented by those agencies varies between 180 days and six years. Performance specifications are also different. The highest-levels of performance specifications were implemented by Missouri and Utah DOTs. Studies that looked into previous warranty projects found that most of the agencies, about 70 percent, were satisfied with their warranty programs. Agencies viewed benefits in terms of improved pavement marking performance and quality, protection against premature failure, reduced lane occupancy for repairs or reapplication, and attendant savings in recurring and life-cycle costs. Potential disadvantages of pavement marking warranties recognized by the agencies were a perceived greater administrative burden, potentially higher bid prices, and possible increases in disputes or litigation with contractors.

The analysis of the pavement marking warranty contract implemented by UDOT shows a total estimated length of implemented markings of more than 2.23 million linear feet (approximately 423 miles), over the 17.4 miles of segments along I-15 and I-215. Based on the contract amount, the estimated cost per linear foot is $1.77 in 2012 USD for the entire 6-year warranty period, or

approximately $0.3 per linear foot per year. This is close to or even a slightly a lower price per linear foot when compared to previous material and workmanship warranty contracts implemented by UDOT for projects along I-15 and I-80, but the performance specifications are much higher than in previous contracts. Based on models for analyzing life cycles of pavement markings, it is estimated that the pavement markings will probably need to be reapplied during the third year of warranty to meet the performance specifications.

The most significant expected benefit is increased safety, expressed through estimated reduction in the number of crashes after the implementation of the new pavement markings with stricter retroreflectivity requirements. However, the benefit-cost analysis cannot be performed at this point due to the lack of data. The researchers propose a safety evaluation of the new pavement markings once at least two years of crash data on these sections become available, since the costs of safety are the highest. Considering the change in crash frequency for different crash types and costs associated with those types, as well as the known costs for pavement marking implementation, the benefit-cost analysis can assess the rate of return of pavement marking implementation.

Results of the surveys covering the preconstruction, construction and post-construction phases of the I-15 project show a consensus that this type of pavement marking warranty contract is a more effective option than traditional, non-warranty contracts. Although some disadvantages are recognized (e.g., higher initial cost, a more complex bidding process, difficulties in risk assessment), the advantages of this contract type appear to outweigh the challenges. Initial opinions of UDOT staff indicate that this contracting option is more cost effective. The most frequently recognized advantages identified in the survey responses were:

- Risk is reallocated to the contractor,
- Contractor is responsible to keep everything within defined specifications,
- Contractor is free to choose materials and processes as long as the final product meets given specifications,
- UDOT does not need to perform maintenance for the six-year warranty period,

- No additional pavement marking contracts during the warranty period will be needed at the project location, and
- Impacts to the traveling public (resulting from maintenance and/or replacement) are minimized.

The assessment of risk in the preconstruction process was cited as the most difficult task. The first bidding process failed because of this challenge. After UDOT reassessed the risks and provided more favorable terms for the contractor, the second bidding process succeeded and the contract was awarded in June 2012. The use of the Interstate Maintenance (IM) funds was proven very beneficial in this case. Those funds helped achieve the desired contract. According to survey results, survey respondents suggest that IM funds should be used in the future for performance-based pavement marking warranty contracts.

Despite the issues at the beginning of the process, the performance-based warranty pavement marking contract was a success according to the survey results. Performance-based warranty contracts should be used for projects where performance can be clearly defined and measured; pavement marking projects are seen as belonging to this group. UDOT should pursue this type of contracting for the major pavement marking projects. Risks in the preconstruction process should be handled more carefully in the future projects to avoid any issues during the bidding process. Respondents agree that the contract was well-handled and expect to get the full six-year performance period out of the new markings.

Respondents also concluded that it still may be too early to efficiently outsource pavement marking warranty projects, and assess the full performance and benefits of this warranty project, since this is still the initial phase. A similar study should be performed further down the life of the contract to provide more fact-based details and conclusions.

1.0 INTRODUCTION

UDOT contracts out some of the pavement marking (striping and messages) work that is routinely needed on roadways that are constructed and maintained. These contracts have typically been based on a materials or method specification with no warranties. The non-warranty contracts have often been maintenance service contracts using waterborne paint, applied annually in some cases. In recent years, UDOT has explored the possibility of including a warranty specification in the pavement marking contract. The contractor would then be responsible for monitoring performance and repairing the pavement markings as needed for a period of time after the main pavement marking work is completed. This type of contract is considered a warranty- or performance-based contract. There is potential with this new type of contract for longer lasting pavement markings, resulting in less impact to the traveling public and cost savings to both UDOT and the public.

UDOT's first performance-based warranty contract for pavement markings was awarded in June 2012. The contract covered pavement marking installations on portions of I-15 with a total length of 17.41 miles. The base bid called for a four year warranty with two additional years under "additives" to the bid. UDOT expected to get a six year warranty on the new pavement markings. This is the first time that a pavement marking warranty specification was part of a new contract for UDOT. It was also the first time that the supplier was also the Prime Contractor on a pavement marking contract, and the first time that IM funds were approved by FHWA to be used solely for pavement markings. The contract does not allow waterborne paint, and grooving is not required. The contractor had the freedom to choose materials and processes, as long as they were within the required specifications.

The warranty that the contractor provides covers the required minimum retroreflectivity during the duration of the contract. The required minimum retroreflectivity should be no less than 200 $mcd/m^2/lux$ for white and 125 $mcd/m^2/lux$ for yellow striping. The surface area presence of the striping should also be maintained to a minimum of 90 percent per mile long segment, and the surface area presence of the messages to a minimum of 95 percent per message. The contractor is

paid 90 percent of the contract sum after the initial acceptance of the installation, and 10 percent at the end of the warranty period. The contracted sum for this project was $3,951,349.

A team of UDOT personnel consisting of representatives from Region 2, Central Maintenance, Central Construction, Central Preconstruction and consultants was assembled to execute and manage the contract. The goal of this study is to collect and document experiences and lessons learned from this process. The findings of the study will ultimately lead to recommendations to UDOT on the use of performance-based pavement marking warranty contracts in the future. This report summarizes findings from surveys of UDOT personnel regarding the preconstruction, construction, and post-construction phases of the I-15 pavement marking project. It also includes a literature review on pavement marking warranty contracts, as well as a review of the UDOT's contract for location, specifications, quantity, costs and warranty terms. Life cycle estimation for the new markings is also included, and is based on the degradation models obtained through the literature review. A review and analysis of past UDOT warranty contracts that were not performance-based is included for comparison purposes. These contracts include the I-15 Reconstruct and I-15 Reassignment contracts, and the I-80 Wasatch to Wyoming State Line Pavement Markings contract.

2.0 LITERATURE REVIEW

Warranties for roadway construction in the United States have been used for more than 100 years. State transportation agencies have accelerated the use of innovative contracting methods and procedures, including roadway warranties, over the past 20 years (*1*). The current federal-aid warranty policy generally allows for the use of warranties on National Highway System federal-aid projects with two important qualifiers (*2*):

- The warranty must apply to a specific product or feature.
- The warranty should exclude ordinary maintenance items or features outside the contractor's control.

Warranties have been used for a number of features on U.S. highway construction projects including (*1 – 3*):

- Pavements
- Pavement Preservation
- Bridge Painting and Bridge Components
- Signalization, Lighting and Intelligent Transportation Systems
- Pavement Markings
- Roadside Facilities

Warranty applications differ from state to state, but most warranties are classified as materials and workmanship warranties, and performance warranties. Material and workmanship warranties cover early or catastrophic defects in the materials and/or workmanship of the warranted components. The material and workmanship warranty generally covers a small percentage of the overall design life of the warranted product. Material and workmanship warranties are generally prescriptive and do not require contractors to work outside the standard specification. The driving principle behind material and workmanship warranties is that the contractor has control over material and workmanship in accordance with specifications, but has no control over design and is not responsible for failures due to design defects. Performance warranties place more responsibility on contractors for the performance of a specific project component. The contractor is typically given more flexibility over certain aspects of the component design and construction, such as mix design, material or product selection, construction methods, equipment, traffic

control, and in some cases structural design or alternative designs. Performance warranties are sometimes further classified into the subcategories of short-term performance warranties and long-term performance warranties. The length of the warranty is generally related to the level of control and responsibility given to the contractor, and in the longer warranty projects more control is given to the contractor. Performance warranties generally allow some contractor discretion to maintain or repair actual or potential defects. Contractor responsibility, however, is still limited to defects resulting from aspects within the contractor's control. It is this apparent conflict that has led to slow acceptance of performance specifications in the United States (*1*). The driving principle behind a performance warranty is to motivate contractors to focus on quality to improve the intended performance of the product and to minimize early or premature maintenance.

Identifying objectives for warranty use and understanding risk allocation issues are key factors in developing warranty provisions and implementing warranties. Key components of a warranty provision include:

- Warranty Term
- Performance Indicators
- Threshold Values
- Bonding Requirements
- Exclusions
- Monitoring and Remedial Action
- Dispute Resolution

The top objectives for warranty use for any highway construction or related project can be classified as follows:

- Improve product performance and enhance quality
- Shift performance and quality assurance responsibility to contractor
- Promote innovation and new technology
- Reduce DOT administrative and inspection costs
- Improve public relations or minimize impacts on the public

- Lower life-cycle and maintenance costs
- Protect against early or catastrophic failures.

Performance Specifications

The trend over the last several years has been towards greater accountability of resources used by public agencies. Typically, specifications that contractors must meet are placed on materials and workmanship to assure a quality product. However, these specifications do not address the important question of how the final product will perform over time. One method to address the long-term performance issue is through the use of performance specifications (*3*).

Performance specifications address the issue of product performance over time. They are simply an assurance on the part of the contractor that the warranted item performs in a manner that has been pre-determined and agreed to in advance by all the parties to the contract. Several contract items are convenient for the use of performance specifications: landscaping, bridge painting, pavement striping, and paving. Regardless of the work item covered, the establishment of performance specifications and their implementation can be approached in the same manner.

The following are elements desirable to any performance specification (*3*):

- Acceptance criteria – quality control plan and a certification process for the materials used on the project.
- Performance criteria – engineering properties to be used to evaluate the performance of the warranted elements and the procedures for evaluating those properties. Also included would be the length of time that the contractor would warrant the performance of the elements.
- Evaluation Process – explanation of how the measurement of performance criteria will be accomplished and how often.
- Dispute Resolution – a pre-defined process for the parties to get together and settle any disputes that occur during the construction process, the warranty process, or its mitigation.

Some of the expected benefits for the contractor and the contract owner gained from the performance specifications are as follows (*3*):

- Defined success – since the performance criteria and the monitoring of the performance are pre-defined, it is easy to know when a successful product has been achieved.
- Balanced risk – the risk and responsibility for the contract elements are allocated to the party that has control over those elements. This contributes to innovation and increased efficiency.
- Innovation rewarded – placing the responsibility for the long-term with the contractor and allowing him the ability to control many aspects of the construction process contributes to innovation, increased quality, and greater potential reward for the contractor.
- Non-confrontational construction – by having a well defined and agreed to procedure for sharing responsibility and resolving conflict, the relationship between the parties is transformed from confrontation to one of cooperation and trust between the partners.
- Improved quality – by allowing the contractor more control over the construction process and placing the responsibility for the long-term performance with the contractor, the result is a better quality of the warranted elements. The motoring public is the ultimate winner in this process with improved satisfaction with the final product and reduced operating costs.

Pavement Marking Warranties

Pavement marking warranties are one form of highway construction warranty. Construction warranties transfer the risk inherent in maintaining acceptable asset performance to a private sector firm, either a contractor or materials manufacturer, in exchange for a potentially higher bid price. Additional benefits may attend to warranty use, particularly in improved product quality and performance. To date, state DOT experience with pavement marking warranties varies among agencies, but warranty acceptance, use, and willingness to experiment with longer-duration specifications appear to be increasing. Successful U.S. and Canadian firms have been developing production, procurement, and application practices that enable them to meet performance requirements even when faced with demanding traffic, wintertime conditions, or other challenging road characteristics (*4*).

Pavement markings are often warranted through manufacturer warranties, where the manufacturer is responsible for repair or replacement of defects instead of the contractor (*1*). Manufacturer warranties may be passed directly to the DOT or they may be assigned to the contractor and then passed through to the DOT upon completion of construction. This warranty may require that the construction contract remain open for a short observational period in case

defects arise in the installation of the warranted component that are not attributable to the manufacturer. When the manufacturer holds the warranty, the DOT typically contacts the manufacturer directly if the warranty is invoked. However, there are also several examples of contractors warranting pavement.

Kansas, Maryland, Utah, Texas, and Mississippi have been using manufacturer warranties on pavement markings that pass through the contractor. Connecticut (1-year warranties), Florida (5-year), Colorado (2-year), Kentucky (1- and 2-year), Minnesota (3-year), Montana (3-year), Ohio (2- and 3-year), Oregon (7-year), Pennsylvania (3-year), Tennessee (2-year), and West Virginia (1- year), on the other hand, have implemented construction warranties for pavement markings, holding the contractor directly responsible for the warranty. Kentucky developed a standard warranty specification for pavement markings that is applied to all paving projects. The warranty provision is renewable for up to 2 years and includes incentives and disincentives tied to retro-reflectivity. Pavement marking warranties are also a standard practice in Oregon. West Virginia awards annual contracts in each of its 10 districts for the placement of pavement markings, and these contracts include a 1-year material and workmanship warranty for markings.

The main pavement marking warranty elements recognized by state transportation agencies that use this type of warranty include (*1*):

- **Warranty Structure and Timeline**. Most agencies start the warranty evaluation period after installation or after initial acceptance of the marking application. Typical warranty durations are one to six years, although some agencies apply warranties of 180 days that are timed to encompass one winter season.
- **Variations in Evaluation Periods**. Some agencies impose additional time periods, referred to respectively as observation periods and performance periods, to evaluate pavement marking performance through a lengthier period before initial acceptance or to serve as a further evaluation after initial acceptance but before onset of a multi-year warranty.
- **Warranty Concepts**. Pavement marking warranty specifications used by the agencies represent a blend of methods-based and performance-based warranty concepts. A very small number of agencies are using true performance-based specifications, in which contractors are given full latitude to select pavement marking materials and installation techniques to meet agency requirements for pavement marking performance.
- **Pavement Marking Performance**. The performance criteria specified in warranties typically include durability or presence, retroreflectivity, and color retention. The

minimum acceptable threshold values of these measures through the warranty performance period differ among agencies.

- **Responsible Party**. Some agencies regard the contractor as the warrantor responsible for fulfilling the requirements of the warranty specification. Others either hold the materials manufacturer responsible, or employ a dual or discretionary assignment of responsibility.
- **Cost Impacts**. Most assessments of costs are based on subjective judgments or perceptions by parties engaged in the warranty process, with little supporting quantitative information.
- **Issues in Administration**. Several issues in administering pavement marking warranties were identified by the agencies, contractors and materials manufacturers. The most common topic is the scheduling of partial payments through a multi-year warranty period, with questions surrounding what is a reasonable amount for initial payment and what should be the amounts of subsequent annual payments through the duration of the warranty. A balanced approach is needed to ensure that agency expectations of quality and performance are met, while providing contractors and materials manufacturers with fair, timely payment for work accomplished in initial installation of markings.

Measures of Performance

Measures of the pavement marking performance that are often specified in the warranties include:

- **Retroreflectivity and visibility.** The visibility of pavement markings is critical to safety and the orderly movements and interactions among motor vehicles, bicyclists, and pedestrians. Retroreflectivity is the ability of marking materials to reflect light back to its source and can be measured quantitatively by instruments. Warranties typically specify minimum retroreflectivity requirements (under dry, wet, or rainy conditions) through the warranty period, but may also allow for visual inspections in daytime or nighttime. Allowable minimum retroreflectivity levels are usually specified separately for white and yellow markings and, depending on individual agency practice, may or may not vary during the warranty period. The minimum level of reflectivity has been a subject of continuing research and agencies have adopted different approaches and threshold values. For roads other than two lane roads with centerline markings only with posted speed limits of 55 mph or more, FHWA recommends minimum maintained retroreflectivity levels of 100 millicandelas per square meter per lux (mcd/m2/lux) (*5*).
- **Durability.** Durability, also referred to as presence, refers to the resistance of a pavement marking to physical damage that causes the marking to appear worn out or unsightly. The durability of a pavement marking depends on the marking material, and on traffic, weather and resulting maintenance activity, the quality of materials, preparation, installation, and the type and condition of the pavement surface. An issue in assessing durability is defining when a marking has degraded to the threshold that requires replacement. Agencies have adopted different approaches and threshold values for evaluating durability.

- **Color.** Color retention or stability may be specified with reference to standardized color chips and color tolerance charts, or by providing chromaticity coordinate limits for use with a colorimeter. In addition to these color-related requirements, specifications may also call for minimum daytime reflectance values separately for white and yellow markings.

Practices in Payment Scheduling

Payments and monetary penalties to contractors can reinforce the objective of quality work. Different agencies have implemented different payment schedules and requirements in their pavement marking warranty contracts. For example, the Missouri DOT performance specification incorporates payment adjustments based on the performance of individual one-mile segments covered by the contract. If more than 10 percent of pavement markings have failed in any one evaluation period, the contractor is regarded as in default and required to submit a remedial plan to correct these failures, which must be approved by the DOT. The specification of the West Virginia DOT provides an example of liquidated damages applied to pavement marking projects.

Some examples of the payment schedules for multi-year warranty contracts are as follows (*4*):

- Idaho's 2-year warranty: Initial payment, 60%; end of year 1, 5%; end of year 2, 35%.
- Idaho's 4-year warranty: Initial payment, 60%; payments at end of years 1, 2, and 3, 5% respectively; end of year 4, 25%.
- Missouri's revised payment schedule for 4-year performance specification: initial payment, 60%; payments in each of years 1 through 4 of the warranty period, maximum 10% annually.
- Texas' 1-year warranty for raised pavement markers (RPMs): initial payment, 80% following written acceptance; at end of performance period including satisfactory replacement of deficient markers, 20%.
- Kansas' 180-day warranty: initial payment, 90% following initial acceptance; 10% at successful completion of the warranty period.
- Alaska is now using 2-year warranties, but is considering a 5-year warranty period with step payments.

Pavement Marking Warranty Benefits

About 70 percent of agencies that use pavement marking warranties expressed satisfaction with their warranty program (*4*). Agencies with successful warranty programs have often refined their individual practices based on experience, incorporating lessons learned into longer term, more ambitious pavement marking contracts. About 13 percent of agencies reported mixed results, with concerns primarily surrounding timely response by contractors to concerns about observed performance.

Most agencies that use pavement marking warranties viewed their benefits in terms of improved pavement marking performance and quality, protection against premature failure, reduced lane occupancy for repairs or re-application, and attendant savings in annual (or recurring) costs and life-cycle costs (including road-user cost savings resulting from reduced lane occupancy through the warranty period). Agencies use several mechanisms to promote quality in their warranty specifications, such as:

- stipulated meetings among all parties
- required contractor submittals
- materials manufacturer's training, certification, onsite representation during installation, and technical assistance
- contractor provision of test stripes or sections
- use of qualified products lists.

Benefits that were cited included the potential for greater contractor innovation, warranties as a logical component of comprehensive departmental outsourcing, reduced administrative and staffing burden for the agency, a mechanism for generating performance measurement data for pavement markings (which could also be used for product performance comparisons), and a perceived benefit of risk sharing. The distribution of these and other identified pavement marking warranty benefits obtained through agency surveys (*4*) is given in Figure 2.1.

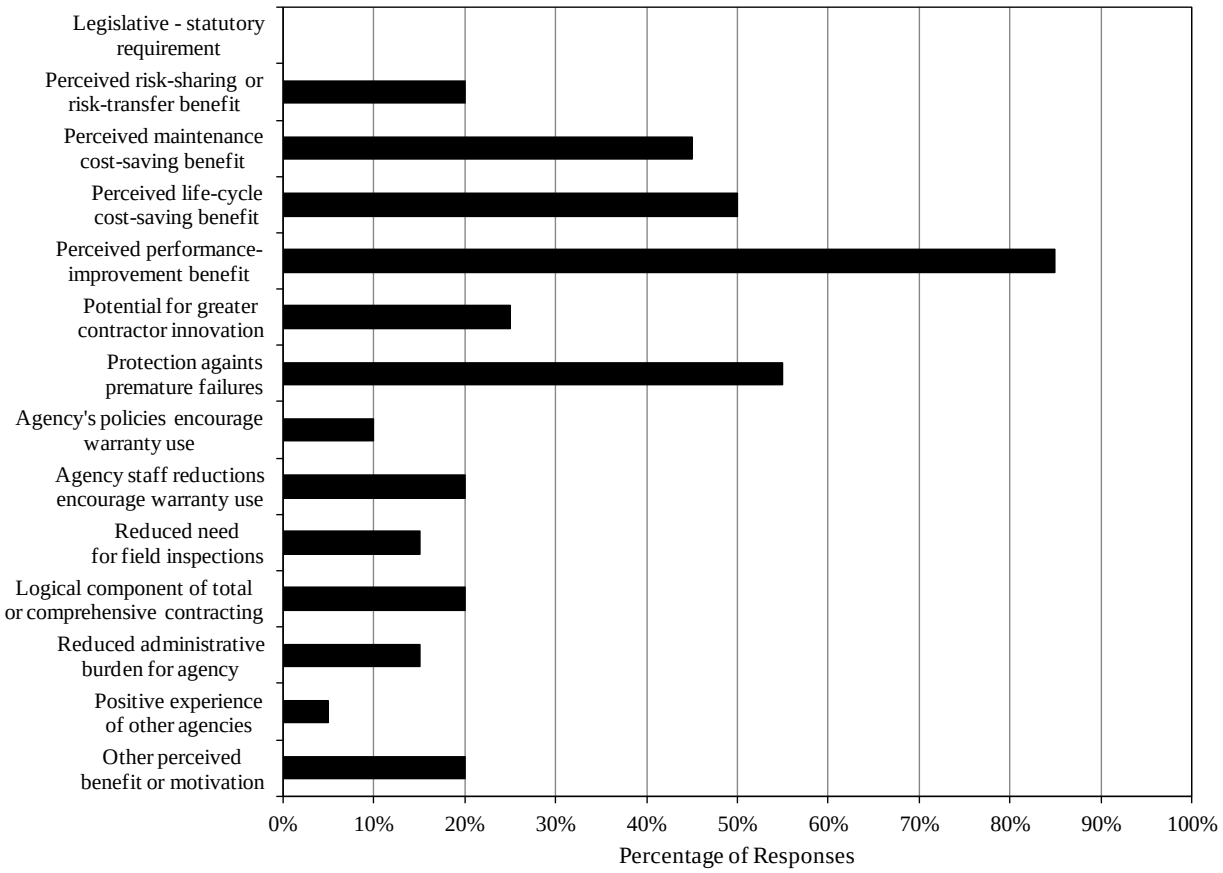

Figure 2.1: Recognized Pavement Warranty Benefits

Pavement Marking Warranty Disadvantages

The major disadvantages of pavement marking warranties as reported by agencies that do not use them were the perceived greater administrative burden, potentially higher bid prices, and possible increases in disputes or litigation with contractors. Some other potential problems that were cited included: 1) administrative difficulties associated with using U.S. federal-aid funding if sole sourcing pavement marking work; 2) keeping contracts open on federal-aid projects while the warranty remains in force; 3) the perception that an agency's management philosophy and culture discourage more frequent use of warranties. Possible disadvantages of using pavement marking warranties obtained through agency surveys (*4*) are shown in Figure 2.2.

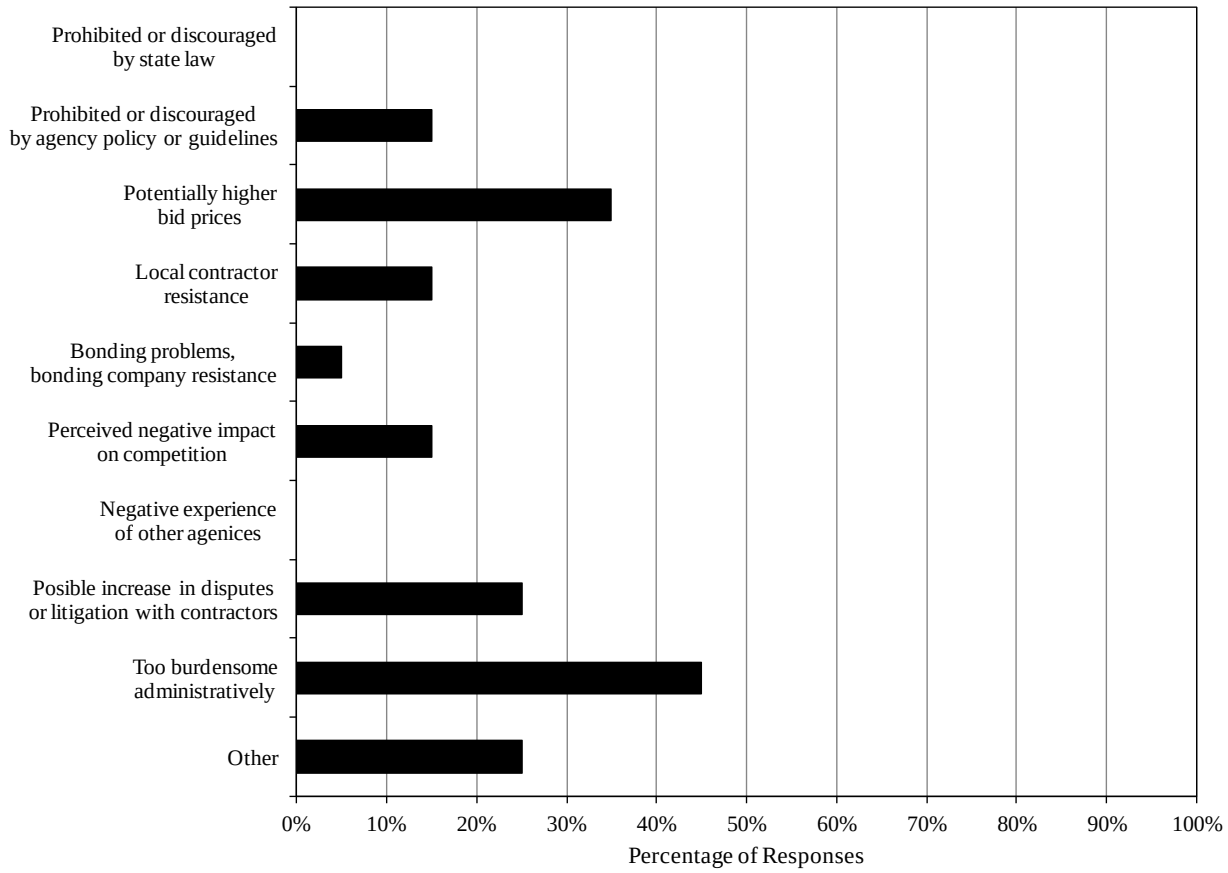

Figure 2.2: Possible Pavement Warranty Disadvantages

Risks and Risk Mitigation

The implementation of pavement marking warranties includes certain risks. The major categories of risk recognized by the agencies are technical risks, administrative risks, financial risks, and business reputation risks.

Technical Risks

Technical risks appear with the failure to use the right material and installation method for a given project. Mitigating these risks involves understanding road operating conditions, the pavement surface, and geographical and environmental site conditions; knowing the correct installation method and performing it correctly with a trained crew; and maintaining good communications between all parties.

Well-specified warranties promote higher quality workmanship and materials. The absence of warranties can have some competitors implementing pavement markings of a lower quality, particularly if the highway agency lacks sufficient resources to conduct proper inspection and jobsite monitoring. There is also a question as to who will monitor in-place markings and how deficient materials and lengths will be identified along with the corresponding degree of repair or replacement needed.

Administrative Risks

Administrative risks relate to problems with either the warranty specifications themselves, or their administration by the agency. There are three recognized groups of administrative risks: specifications, project bonding, and other topics. Specifications risks refer to performance-based specifications, such as loose specifications, which could lead to low bid prices and low quality marking installations. Other specifications may be too stringent and set unrealistically high. Specifications should accommodate differences in climate, geography, and altitude.

Project bonding risks refer to issues that some contractors may have with obtaining project bonding for the entire duration of pavement warranties. This can lead to the situation where smaller firms are eliminated from the process because they cannot provide bonds. Other factors that contribute to administrative risks include calendar-based performance periods in areas with specific geography or climate, the agency's approach to administering a warranty contract, and prequalification of contractors.

Financial Risks

Two main types of financial risks are recognized: 1) having insufficient reserves to fund warranty repairs, and 2) having a situation where agency payments to contractors through the warranty period are not in step with the pace at which project costs are incurred.

Business Reputation Risks

Business-reputation risk concerns damage to a firm's reputation if a pavement marking project does not turn out well. Business reputation is important for maintaining good standing among current and future clients. Any of the sources of risk discussed earlier can have negative impacts on business reputation. The way to avoid harm to reputation is therefore to manage the various categories of risk.

Some of the recognized ways for risk mitigation includes the wider use of incentives for superior-performing pavement markings, with a balanced administrative approach that combined realistic incentives and penalties; considering warranties as one of a range of available options to achieve improved performance and cost-effectiveness; having materials manufacturers and contractors engaged to a greater degree in all aspects of project performance; improved communication and dispute resolution procedures; and greater use of quality control mechanisms such as approved product lists.

3.0 CONTRACTS REVIEW

Performance-Based Pavement Marking Warranty Contract

The performance-based pavement marking warranty contract, under the project name "State Route: I-15 from: 278.60 to: 380.00 for: 101.40, Pavement Marking on Interstate at Various Locations," was awarded in June 2012 to DOW Chemical/POLY-CARB Inc. This was a revised contract, since the previous request for bids failed due to much higher bidding prices than the funds allocated to this project.

The contract consists of the base bid, which covers the section of I-15 between 7200 S and 600 N (MP 297.3 to MP 309.0), in the length of 11.7 miles. Additive to the bid #1 covers the 2-mile section of I-15 between 9000 S and 7200 S (MP 295.3 to MP 297.3), while additive #2 covers the 2.1-mile section between 10600 S and 9000 S (MP 293.2 to MP 295.3). The base bid and additives 1 and 2 belong to UDOT Region 2. They include a default 4-year warranty on the performance of the installed pavement markings. Additives to the bid # 3 and 4 include pavement marking warranty for years 5 and 6, respectively. Additive to the bid #5 covers the section of I-215 in Region 1 in the length of 1.61 miles between Legacy Parkway and I-15 north interchange (MP 26.6 to MP 28.21). The total length for pavement markings covered in the base bid and additives 1, 2 and 5 is 17.41 miles. However, the contract specifies that the pavement marking warranty for years 5 and 6 (additives 3 and 4) covers only the base bid and additives 1 and 2, which are segments only along I-15. This means that the warranty for years 5 and 6 does not include the section of I-215.

The contractor was responsible for installing pavement markings along the mainline, as well as along the adjacent on and off ramps. The calculated quantity of all included pavement markings was as follows:

- A total of 800 symbols, including: 244 left turn arrows; 11 double arrows; 80 messages; 82 right turn arrows; 249 crosswalks; 134 stop bars
- 481,888 feet of 4-inch solid white lines
- 853,853 feet of 4-inch broken white lines
- 31,936 feet of 4-inch dotted white lines

- 265,245 feet of 4-inch solid yellow lines
- 1,299 feet of 4-inch skip yellow lines
- 6,790 feet of 4-inch solid yellow lines with skip
- 25,518 feet of 4-inch solid double yellow lines
- 321,284 feet of 8-inch solid white lines
- 64,193 feet of 8-inch dotted white lines

In practice, pavement striping is given in linear feet, while the symbols are represented in numbers or in square feet. For the purpose of determining the unit cost of the pavement marking installation, the researchers converted all pavement marking types to the equivalent number of linear feet. Based on the dimensions for different symbols provided in MUTCD and aerial images of the locations where the pavement markings were implemented, the following conversion to linear feet is estimated:

- 1 crosswalk = 540 linear feet
- 1 stop line = 180 linear feet
- 1 through arrow = 40 linear feet
- 1 left/right arrow = 50 linear feet
- 1 message = 90 linear feet

Adding all the striping lengths for different line types and using the given conversion factors, the following results are obtained:

- Length of all line types: 2,052,006 linear feet
- Symbols converted to linear feet: 180,500 linear feet
- **Total estimated length of all pavement markings: 2,232,506 linear feet (≈423 miles)**

The pavement marking warranty contract shows a total contracted amount of $3,951,349.00, which includes mobilization, traffic control, MOT and pavement marking warranty for the base bid and all additives to the bid. This gives a **unit cost of installation of $1.77 in 2012 USD per linear foot for a total of 6 years**, or approximately **$0.3 per linear foot per year**.
The contract also defines the implementation and pavement marking specifications for the contractor, which are provided under the warranty requirements, as follows:

- The contractor needs to select a durable pavement marking product for striping that is not a solvent or waterborne paint and that is intended to be applied with one initial application.
- The contractor needs to match the existing pavement marking width, type and alignment, including contrast striping.
- For the life of the contract, the contractor needs to maintain the striping to minimum retroreflectivity values of **200 millicandelas per square meter per lux (mcd/m^2/lux) for white** and **125 mcd/m^2/lux for yellow** as measured with a 30 meter geometry mobile retroreflectometer.
- The contractor needs to include all costs for the Manufacturer's Service Representative and other technical assistance in the contract unit price.

The payment schedule defined by the contract is 90% of the contracted amount after the initial acceptance, and 10% of the amount after the expiration of the warranty. In this case the warranty expires in 2017, after the 6 years period, since the additive bids 3 and 4 are included in the contract.

Table 3.1 shows a comparison of performance requirements related to retroreflectivity that different states have included in their warranty contracts. The table also shows the time for which the pavement markings need to retain the minimum level of retroreflectivity according to these contracts.

Table 3.1: Retroreflectivity Requirements and Performance Periods by State

State	**Utah**	Alaska	Arkansas	Delaware	Idaho	Maryland	Missouri
White markings (mcd/m^2/lux)	**200**	150[1] 40[2]	150	150	150	150	250
Yellow markings (mcd/m^2/lux)	**125**	150[1] 40[2]	150	150	125	125	175
Performance period	**6 yrs**	6 mos[1] 2 yrs[2]	4 yrs	1 yr	4 yrs	4 yrs	4 yrs

Previous Pavement Marking Contracts with Material Warranty

Previous UDOT pavement marking contracts included warranties for materials and workmanship, where the material supplier warranted the performance of the material over a certain period of time. One of those contracts was the I-15 Reconstruct from the year 2000. This contract was initially signed between UDOT and Wasatch Constructors, while Wasatch Constructors subcontracted Epoplex to provide and implement materials and to provide a warranty for the installed materials. However, the contract was reassigned, and Wasatch Constructors was no longer a side in the contract, and the subcontractor, Epoplex, was reassigned to be a prime contractor to UDOT.

This contract included the segment of I-15 between 10600 S and 600 N, in the total length of 15.8 miles, similar to the earlier described performance-based warranty contract. Epoplex fully warranted the performance of the installed epoxy pavement markings for a total duration of 8 years after July 2001, with a complete removal and reapplication in July of 2005 (after 4 years). The warranty included, but was not limited to, all cost such as material, labor, equipment, traffic control etc. The performance criteria were defined as follows:

- Minimum retroreflectivity of 125 mcd/m^2/lux per square meter for white, and 100 mcd/m^2/lux per square meter for yellow markings
- Color stability as defined by UDOT performance specifications
- Durability defined as 90 percent of the markings in 300 meters to maintain a minimum of 92 percent of the surface area

The total contracted amount in the reassigned contract, which included two applications and warranty, was **$3,613,705.00**. Using the available information on the quantities of installed pavement striping and symbols, the total estimated length of installed pavement markings was **2,192,314 linear feet**. This gives a **unit cost of installation of $1.65 per linear foot in 2000 USD for a total of 8 years**, or approximately **$0.21 per linear foot per year**. Using the inflation statistics from the Bureau of Labor Statistics between years 2000 and 2012, the **unit cost of installation in 2012 USD** would be approximately **$2.20 per linear foot for 8 years**, or **$0.28 per linear foot per year**. Therefore, the estimated unit costs of installation between the performance-based warranty and the I-15 Reconstruct are similar. However, the I-15 Reconstruct

has lower performance specifications, and did not include the additional costs to UDOT and the traveling public caused by the total reapplication in 2005.

Another contract that included a 4-year material and workmanship warranty was the I-80 polyurea contract from 2006. This contract included the installation of polyurea pavement marking on the section of I-80 from Wahsatch to Wyoming state line, in the total length of 5 miles. The estimated quantity of the installed materials was 125,225 linear feet for striping, and three messages. Using the previously given conversions for messages, the total pavement markings quantity was **125,495 linear feet**. The contract amount was $251,405.00 in 2006 USD, and it included a 4-year warranty. This gives the **unit cost of installation of $2.0 per linear foot for 4 years in 2006 USD, or $0.5 per linear foot per year**. Converted to **2012 USD**, the **unit cost of installation is $2.28 per linear foot for 4 years, or $0.57 per linear foot per year**.

Pavement Marking Life Cycle Estimation

The life cycle of the installed pavement markings depends on many conditions, such as the pavement marking material, pavement type, initial retroreflectivity, retroreflectivity requirement, AADT, weather conditions, snow plowing, etc. Different states report different results when it comes to measuring the life cycle. There are several theoretical models developed by researchers to estimate the pavement marking life cycle. The model used in this research was developed by Mull and Sitzabee in 2011 (*6*). It was selected among other models because, in addition to AADT, it incorporates snow plow events as a model input, which is an important factor in Utah. This model is represented as follows:

$$R_L = 65.5 + 0.72 \cdot R_{L,initial} - 2.55 \cdot t - 3.22 \cdot s - 0.0005 \cdot AADT, \text{ where:}$$

R_L – retroreflectivity level in mcd/m^2/lux
$R_{L,initial}$ – initial retroreflectivity
t – time in months
s – number of snow plow events
AADT – Annual Average Daily Traffic (per lane)

The retroreflectivity level required by the contract is 200 mcd/m^2/lux for white, and 125 mcd/m^2/lux for yellow markings. Since this is a freeway facility, the white markings are considered critical, so the calculations are performed for these markings. The model is redesigned to be solved for time *t*, where R_L is known. The number of major snow plow events is estimated to 10 per year, and the initial retroreflectivity for the white markings was assumed to be 354 mcd/m^2/lux for epoxy-based pavement markings based on Martin et al (*7*). The AADT values were obtained from UDOT's daily traffic maps (the last available data are for 2011), while the number of lanes were observed from aerial imagery. The calculated results for the sections along I-15 and I-215 are shown in Table 3.2.

Table 3.2: Estimated Life Cycle for Epoxy-based Durable Pavement Markings

	Segment	From MP	To MP	Length (mi)	AADT 2011	Total Lanes	AADT per lane	Estimated life cycle (months)
I-15	106th S to 90th S	293.63	295.64	2.01	160000	12	13333	32.0
	90th S to 72nd S	295.64	297.94	2.30	199640	12	16637	31.3
	72nd S to I-215	297.94	298.99	1.05	231905	12	19325	30.8
	I-215 to 54th S	298.99	300.33	1.34	173430	12	14453	31.7
	54th S to 45th S	300.33	301.67	1.34	200880	12	16740	31.3
	45th S to 33rd S	301.67	303.44	1.77	205320	12	17110	31.2
	33rd S to I-80	303.44	304.72	1.28	213040	12	17753	31.1
	I-80 to SR201	304.72	305.23	0.51	252165	12	21014	30.5
	SR201 to 13th S	305.23	306.35	1.12	230495	12	19208	30.8
	13th S to 6th S	306.35	307.49	1.14	204645	12	17054	31.2
	6th S to I-80	307.56	308.00	0.44	130290	12	10858	32.5
	I-80 to 6th N	308.00	309.33	1.33	127805	12	10650	32.5
I-215	Legacy to Redwood	26.7	27.42	0.72	33605	5	6721	33.3
	Redwood to I-15	27.42	28.93	1.51	24990	4	6248	33.4

The life cycle of the initial implementation is estimated to be between 30.5 and 33.4 months, which corresponds to the results published by UDOT for these types of markings, with the actual performance on Utah roads between 31 and 46 months (*8*). This means that the pavement markings will likely have to be repaired during the third year of the warranty period to satisfy the

retroreflectivity requirements. Any available retroreflectivity data from the site could potentially be used to recalibrate the Mull and Sitzabee model and re-estimate the performance life.

Benefit-Cost Analysis Methodology

The total cost of the pavement marking warranty project for the six-year warranty period is $3,951,349 (in 2012 USD), or $0.3 per linear foot per year. Potential benefits of the newly implemented pavement markings include increased safety, better visibility, a more precise vehicle operation, and a better subjective perception of the road by the drivers (*9*). The most significant benefit of higher pavement retroreflectivity is increased safety, as shown in numerous studies on visibility and retroreflectivity of pavement markings (*10-12*).

Some previous studies estimated the benefits of pavement markings can reach 60 times the cost (*13*). However, the research that relates benefits and different levels of pavement marking retroreflectivity is still in progress. The benefit-cost analysis should include two major costs related to traffic safety and traffic delays. The costs of traffic safety are much higher, and they need to relate the installation of the new pavement markings with higher minimum retroreflectivity values to crash rates for different crash types. For this purpose, the researchers propose a before-after safety analysis once at least two years of after installation crash data become available. The analysis could then show the potential benefits of the newly installed pavement markings, and allow for the benefit/cost analysis, since the cost of installation is known.

4.0 SURVEY ORGANIZATION

The experiences and lessons learned from the preconstruction, construction, and post-construction phases were collected through surveys of UDOT personnel from Region 2, Central Maintenance, Central Construction, and Central Preconstruction involved in some way with the pavement marking warranty contract. The surveys were performed on two occasions, the first one for the preconstruction and construction phases, and the second one for the post-construction phase.

Preconstruction and Construction Phase Survey

The researchers sent preconstruction and construction survey forms to thirteen individuals on December 20th, 2012. Four completed surveys were returned by January 4th, 2013. On January 8th, the nine remaining surveys were re-sent, and two of them were completed and returned. The researchers were also contacted by two respondents, stating that their familiarity on the subject was very limited and that they could not provide requested inputs. One returned survey reflected opinions of three people from Central Maintenance and Region 2. The researchers conducted two phone surveys with the remaining personnel. One person did not respond and was not interviewed by phone. In total, there were six completed surveys and two phone interviews that reflected opinions of ten people.

The survey on the preconstruction and construction phases of the pavement marking project with the performance specification included sixteen direct questions, and one additional, open-ended question for any notes, comments and suggestions. The questions were designed to obtain the following inputs from each respondent:

- Role and level of familiarity with the pavement marking warranty project
- Role and level of familiarity with other (“traditional”) pavement marking projects
- Familiarity with experiences from other agencies concerning pavement marking warranty contracts
- Whether the concept and objectives were clearly defined in this contract
- Whether the risks were clearly identified and managed in preconstruction phase

- Whether the appropriate UDOT staff were involved
- Familiarity, experience and special requirements for using IM funds for pavement markings
- Informed opinions on whether the markings will achieve the desired performance and last for the entire six-year warranty period
- Whether the contract or specifications were lacking anything
- Assessments of whether the MOT performed as expected
- Observed problems with the construction process
- Whether UDOT got what they requested, and if the contractor met specifications
- Advantages and disadvantages of the pavement marking warranty contract
- If this contracting process for pavement markings was perceived as being better than "traditional"
- Whether the PDBS system for monitoring progress and measuring success beneficial in this case

The responses from every surveyed person were scored on a scale 1 to 5 for each question by the research team, and then averaged. The scores used in this process were defined as follows:

1 – Strongly disagree / No / Not familiar

2 – Somewhat disagree / Probably no / Low familiarity

3 – Neutral / No opinion / No involvement

4 – Somewhat agree / Probably yes / Somewhat familiar

5 – Strongly agree / Yes / Very familiar

Post-Construction Phase Survey

The post-construction survey forms were sent to the same thirteen individuals on June 11, 2013. Three completed surveys were returned by June 18, where one survey was completed jointly by the personnel from Central Maintenance. Three persons replied that they had not been involved in the post-construction phase; however one respondent provided some clarification with the question related to the FHWA involvement in the process. The survey was resent on July 09, 2013, and resulted in two returned surveys, where one was complete, and the other only gave some clarification on the FHWA involvement in the process. The remaining four respondents

replied (by email and phone) that they had not had any involvement in the post-construction phase. In total, there were four complete surveys returned, which reflected opinions of five people involved in the process, and two partial surveys with additional clarification on the FHWA involvement.

The post-construction phase survey included twelve direct questions, and one additional, open-ended question for any notes, comments and suggestions. The questions were designed to obtain the following input from each respondent:

- Informed opinions on whether the markings will achieve the desired performance and last for the entire six-year warranty period
- Observed problems during the construction and post-construction processes
- The contractor's work organization and crew deployment
- Responsibilities related to the monitoring of paint performance and requesting repairs
- The schedule of measuring paint performance, including measurement verification by UDOT
- Whether there are differences related to monitoring, measuring and verifying the performance of pavement markings between the warranty project and traditional pavement marking projects
- Whether and how often the contractor was required to repair the markings
- The budget comparison for the warranty project and traditional pavement marking projects
- The role and involvement of the local FHWA office
- Whether it is cost-effective to implement pavement marking projects with performance-based warranties
- Estimation of the life-cycle and benefit-cost ratio for the warranty project
- Whether and how often UDOT should request funding from the Transportation Commission for additional performance-based pavement marking warranty contracts

Where applicable, the responses from every respondent were scored on a scale 1 to 5 for each question by the research team, and then averaged. The scores used in this process were defined as follows:

1 – Strongly disagree / No

2 – Somewhat disagree / Probably no

3 – Neutral / No opinion

4 – Somewhat agree / Probably yes

5 – Strongly agree / Yes

5.0 SURVEY RESULTS

Preconstruction and Construction Phases

All the responses from the preconstruction and construction phases were quantified using the given scale to allow for an easier representation of the results. Figure 5.1 shows the results of this process for the sixteen questions related to the preconstruction and construction phases.

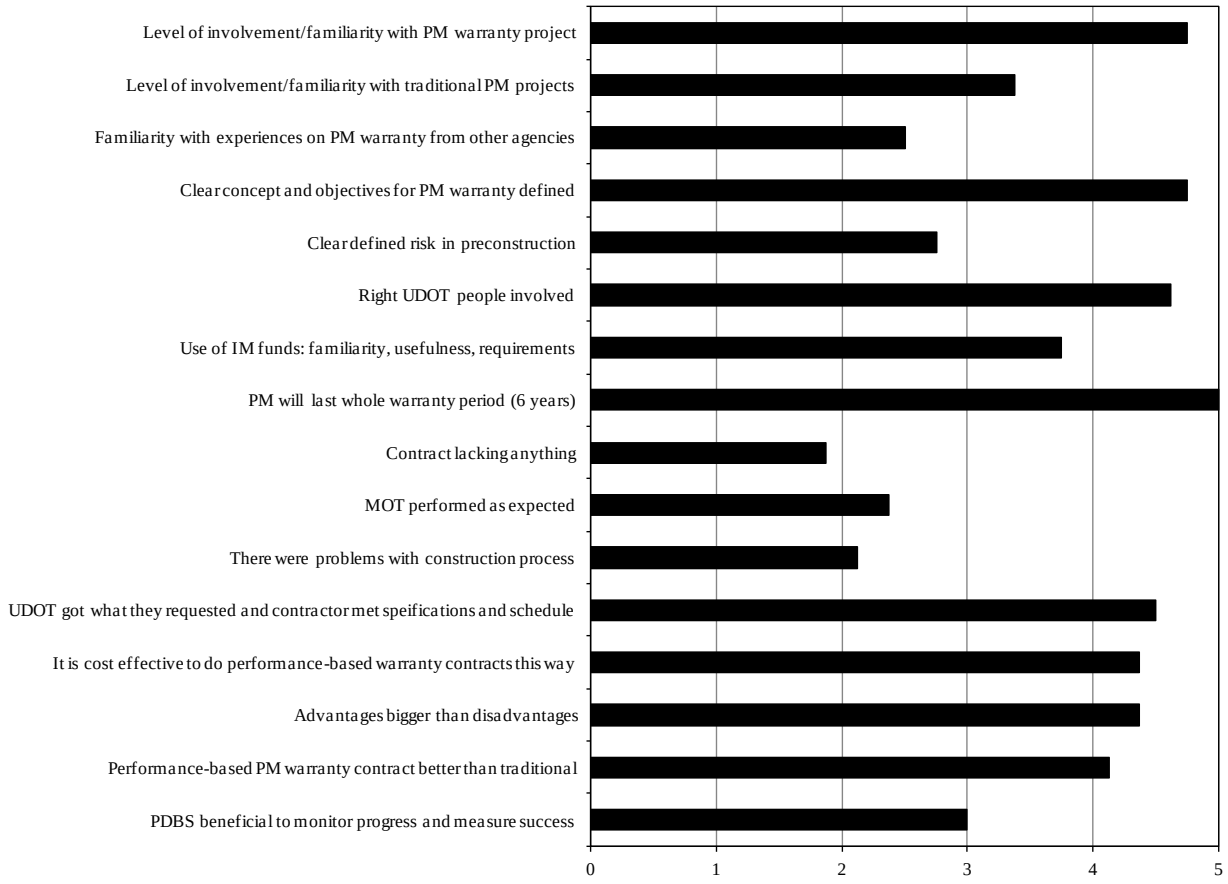

Figure 5.1: Average scores for questions from preconstruction and construction phases

All UDOT personnel that completed the survey had some role in the pavement marking warranty contract. However, some survey respondents did not have any experience/role with traditional pavement marking contracts. A majority of the surveyed respondents did not know about experiences from other agencies. Only persons from Central Maintenance and Region 2 had

knowledge about other similar contracts and conducted a review while working on contract specifications.

All surveyed personnel agree that UDOT defined a clear concept, set of objectives, and a desired outcome for this contract. All also agreed that the risks were not clearly defined at the beginning, resulting in a failure of the first bidding process. The risks were redefined a second time based on the lessons learned from the first bidding process, and the second bid was successful. All survey respondents agreed that the right UDOT personnel were involved in the process. The assembled team clearly communicated and worked effectively to bring the project to a completion.

The experience and familiarity with using IM funds was somewhat limited among the responders. However, most of them agree that the IM funds were very useful and that without them the project could not be executed in this way. A general conclusion was that the IM funds should potentially be used in future pavement marking warranty contracts.

All respondents strongly believe that the new markings will last the entire six-year warranty period. They base this conclusion on the specifications, materials, construction process and warranty that the contractor has provided.

Most of the respondents think that the contract was adequate and was not missing any essential information. Recommendations point towards a need to better define risks, develop a more detailed scope, and develop an explicitly defined timeline.

Those respondents with knowledge on the MOT plan used stated that there were minor problems. The contractor had a short period of time to complete the job, and the phasing was described as difficult. Single lane daytime closures during off-peak hours were needed to complete the job on time.

A majority of the survey respondents had no involvement in the construction process, so they were not familiar with it. One recognized problem was described that dealt with a different

contractor who was late in performing work on the same portion of I-15. Therefore, the striping contractor did not have full access to the project.

A high level of agreement exists among the respondents that UDOT received the work that was required of the contractor, and that the contractor met the specifications. They also agree that it is cost-effective to execute performance-based warranty contract for projects where performance can be clearly identified and measured; pavement marking projects with the desired performance well-defined is one such project type.

According to the survey responses, the advantages of executing a pavement marking warranty contract outweigh the disadvantages. The respondents agree that this is a better way of doing this type of contract. The most frequently recognized advantages identified in the survey responses were:

- Risk is reallocated to the contractor,
- Contractor is responsible to keep everything within defined specifications,
- Contractor is free to choose materials and processes as long as the final product meets given specifications,
- UDOT does not need to perform maintenance for the six-year warranty period,
- No additional pavement marking contracts during the warranty period will be needed at the project location, and
- Impacts to the traveling public (resulting from maintenance and/or replacement) are minimized.

The major disadvantages were identified as the higher initial cost of this type of contract, the bidding process and assessment of risk, and possible issues with future measurements and verifications for warranty items. Since it is contactor's responsibility to maintain the desired performance of the implemented pavement markings during the warranty period, the contractor must deal with all the risks and unexpected situations. This increases the initial costs. The contractor also had concerns related to the timing of the project, and with UDOT withholding money during the warranty period. The first bids came back higher than the allocated budget because of these concerns. The contract was then revised and requests for bids resent. This made the bidding process more complex and time consuming. The performance of the pavement

markings over the next few years is unknown, because it is challenging to predict the sources of a potential failure in performance (e.g., heavy traffic, snow removal, construction process, material that was used), as well as the resulting impacts and costs.

A majority of the respondents were not familiar with the Project Development Business System (PDBS) and its usefulness in monitoring progress and measuring success of this project. Those who were familiar agree that the PDBS is beneficial for any contract.

Post-Construction Phase

The averaged scores for the twelve post-construction survey questions are given in Figure 5.2.

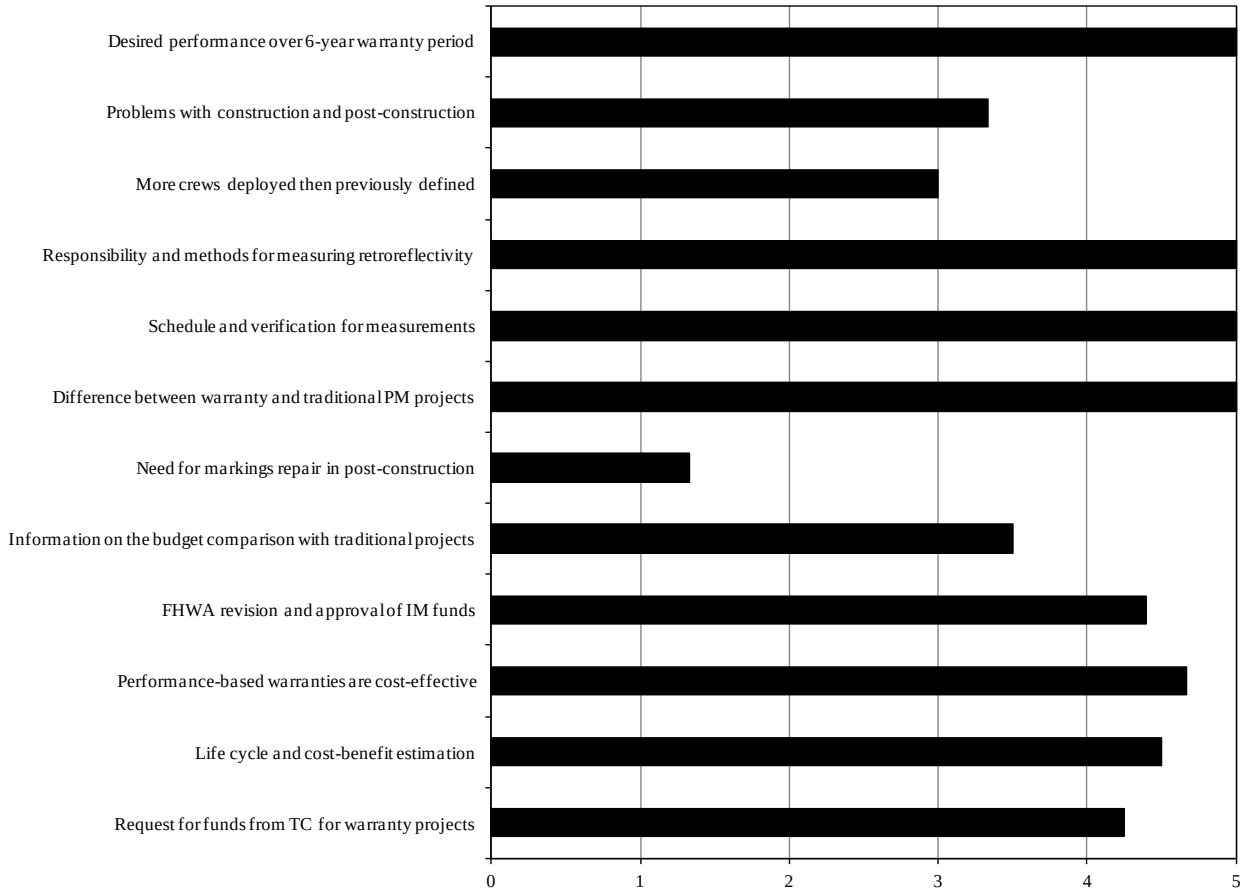

Figure 5.2: Average scores for questions from post-construction phase

All respondents agree that the pavement marking and bead specifications will achieve the desired performance over the six years warranty period. The answers are based on limited data, but are supported by the implementation procedures (all lines were recessed to try to minimize snow plow damage) and the fact that the contractor warranted the performance. Some paint touch-ups are expected over the warranty period.

Certain problems during the construction process were observed. The reason for this was mostly the short construction schedule, which created some difficulties in managing the contract and keeping track of all areas where the work was taking place. The contractor had to deviate from the original traffic control plan to complete the project on time.

The contractor had to deploy more crews than previously defined in order to meet the deadline. One recognized reason for this was the grooving process, which took a longer amount of time than anticipated. The larger number of crews also caused some problems described in the answers to the previous question, where it was more difficult for the contractor to keep track of all crews and areas where work was taking place.

The responses related to the responsibility for monitoring paint performance and requesting repairs were not straightforward. A majority of the respondents replied that this is a responsibility of a qualified and independent firm, while some named POLY-CARB as the responsible party. Section VI of the contract (Measurements and Payment), under the "Durable Pavement Stripping Warranty" bid item, defines the inspection and testing of the striping as the responsibility of the contractor to "Obligate a qualified and experienced independent firm to perform retroreflectivity and durability data collection and evaluation immediately after initial construction and once annually for 4 to 6 years, according to the additive bids accepted, for the duration of the Contract", and to "Notify the (UDOT) Engineer of the results of testing within three days of receiving the results." Based on the analysis of the responses for this question, it is recommended to review this section for future performance-based warranty contracts with a clearer definition of responsibilities for monitoring and reporting the paint performance to UDOT, as well as defining the future actions taken by UDOT in requesting repairs, if needed.

The performance of the pavement markings is measured once per year, as described by all respondents, but there is no information on how these measurements are verified by UDOT. Again, UDOT's verification of the reported paint performance should be defined more clearly in the future contracts. The respondents also noted that there is a difference between the traditional and performance-based warranty pavement marking projects when it comes to monitoring, measuring and verifying the performance of pavement markings. The traditional pavement marking projects have not been quantitatively monitored as part of a comprehensive statewide management program.

As of July 2013, according to the respondents, there has been no need for the contractor to perform any repairs to the implemented pavement markings. Also, as noted by one respondent, previous pavement markings along these same segments required almost yearly repairs, but the new markings perform much better since the lines were recessed into the pavement.

According to one respondent, the yearly Region Two budget for pavement markings is approximately $1.2 million. Based on the contracted price and the warranty period, the warranty contract is about 55 percent of the annual pavement marking budget for Region Two. However, the exact comparison between the traditional and warranty contracts cannot be obtained, since the warranty project also uses state IM funds in addition to the pavement marking funds.

FHWA was, according to the respondents, involved only in the preconstruction phase. FHWA's approval was needed to use the Federal IM funds for the pavement markings project. Also, FHWA provided review and approval for the Request for Qualifications (RFQ) short-listing and Advertised Bid Packet selection process. In order for the IM funds to be used, the project had to be on an Interstate roadway, and UDOT had to demonstrate that it was either a capital improvement, or an element of a preventive maintenance strategy. For UDOT, this was justified in both cases: it was a capital improvement since a durable product was used, and was warranted for six years; it was also a component of a preventive maintenance strategy, since the sections were selected based on the underlying pavement not needing to be ground or otherwise rehabilitated for at least as long as the warranty term. Based on those arguments, the FHWA Utah Division approved the use of IM funds for the project.

The respondents agree that it is cost-effective for the pavement marking projects of this size to be executed with performance-based warranties. The warranty projects, according to the respondents, would be appropriate for multi-lane highways with a lot of traffic, for which disturbances of traffic caused by re-striping would be significant, and/or which have significant traffic control costs and safety issues, as was the case for this particular project.

There are still not enough data to determine a more precise estimate of the life-cycle of the pavement markings or the benefit-cost ratio than that provided earlier in Chapter 3 of this report, but the respondents agree that the warranty contract in this case was the right direction to move, and that future durable pavement marking projects should include performance-based warranties. It is expected that the benefits in this case would outweigh the costs associated with the project.

According to the respondents, UDOT should define a set of projects which would be good candidates for performance-based warranties, including pavement markings, and approach the Transportation Commission with a request for more funding for these types of projects. They also agree that this should be the direction for large-scale pavement marking projects.

Respondents also concluded that it still may be too early to efficiently outsource pavement marking warranty projects, and assess the full performance and benefits of this warranty project, since this is still the initial phase. A similar study should be performed further down the life of the contract to provide more fact-based details and conclusions.

6.0 CONCLUSIONS

An increasing number of DOTs in the US have started to implement performance-based warranties for pavement marking projects. The duration of the warranties implemented by those agencies varies between 180 days and six years. Performance specifications are also different, and the highest levels of performance specifications were implemented by Missouri and Utah DOTs. Studies that looked into these warranty projects found that most of the agencies, about 70 percent, were satisfied with their warranty programs. Agencies viewed benefits in terms of improved pavement marking performance and quality, protection against premature failure, reduced lane occupancy for repairs or reapplication, and attendant savings in recurring and life-cycle costs. Potential disadvantages of pavement marking warranties recognized by the agencies were a perceived greater administrative burden, potentially higher bid prices, and possible increases in disputes or litigation with contractors.

The analysis of the pavement marking warranty contract implemented by UDOT shows a total estimated length of implemented markings of more than 2.23 million linear feet (approximately 423 miles), over the 17.4 miles of segments along I-15 and I-215. Based on the contract amount, the estimated cost per linear foot is $1.77 in 2012 USD for the entire 6-year warranty period, or approximately $0.3 per linear foot per year. This is close to or even a slightly a lower price per linear foot, when compared to previous material and workmanship warranty contracts implemented by UDOT for projects along I-15 and I-80, but the performance specifications are much higher than in previous contracts. Based on models for analyzing the life cycle of pavement markings, it is estimated that the pavement markings will probably need to be repaired during the third year of warranty to meet the performance specifications.

The survey results for the preconstruction, construction and post-construction phases of the I-15 pavement marking warranty contract show a high level of agreement that this type of pavement marking contract is a better option than traditional, non-warranty contracts. Although some disadvantages were recognized (higher initial cost, a more complex bidding process, difficulties in risk assessment), the identified advantages that this contract type outweighed them.

The most frequently recognized advantages identified in the survey responses were:

- Risk is reallocated to the contractor,
- Contractor is responsible to keep everything within defined specifications,
- Contractor is free to choose materials and processes as long as the final product meets given specifications,
- UDOT does not need to perform maintenance for the six-year warranty period,
- No additional pavement marking contracts during the warranty period will be needed at the project location, and
- Impacts to the traveling public (resulting from maintenance and/or replacement) are minimized.

The opinions of the survey respondents indicate that this contracting option is more cost effective that traditional marking contracts. The assessment of risk in the preconstruction process was cited as the most difficult task and of the reason that the first bidding process failed. After the UDOT team reassessed the risks and provided more favorable terms for the contractor, the second bidding process succeeded and the contract was awarded in June 2012. The use of the Interstate Maintenance (IM) funds was seen as very useful in this case. The IM funds helped to achieve the desired contract. Survey respondents expressed a general opinion that IM funds should be considered in the future for performance-based pavement marking warranty contracts.

Despite the issues at the beginning of the process, the performance-based warranty pavement marking contract was seen as a success. Performance-based warranty contracts should be used for projects where the desired performance can be clearly defined and measured; pavement marking projects belong to this group. Survey respondents believe that UDOT should pursue this type of contracting for major pavement marking projects. Risks in the preconstruction process should be carefully identified and assessed in the future projects to avoid any issues in the bidding process. Although the time that has elapsed since the completion of the construction was short, the survey respondents agree that the contract was executed and managed effectively, and expect to get the full six-year performance period from the new markings.

The implemented pavement markings are expected to meet the performance criteria over the entire life of the contract, although some touch-ups may be required over time. The initial results

show that these pavement markings perform much better than previous markings implemented along the same segments, mostly because of the high performance criteria, and the implementation process, where all lines were recessed into the pavement. As of July 2013, there has been no need for the contractor to perform any repairs to the implemented pavement markings. Although there are still not enough data to determine a more precise estimate of the life-cycle of the pavement markings or the benefit-cost ratio than that presented in Chapter 3 of this report, the warranty contract in this case was seen as the right direction to move, and future large-scale durable pavement marking projects should include performance-based warranty. It is expected that the benefits in this case would outweigh the costs associated with the project.

The post-construction surveys also identified some other potential places for improvement in future performance-based warranty projects. Construction scheduling should consider the size of the project and define the deadlines accordingly, so that the contractors can meet those deadlines within the defined specifics. Monitoring and verifying of the product performance should be more clearly defined in the contract, with clear roles and responsibilities of all parties involved, as well as whether a third-party contractor should be used for this purpose and who should hire them.

For the future, UDOT should define a set of projects which would be good candidates for performance-based warranties, including pavement markings, and approach the Transportation Commission with a request for more funding for this type of projects, as well as FHWA for the use of IM funds in cases where they are applicable. In any case, performance-based warranty is seen as the right choice for large-scale pavement marking projects.

Overall, the implemented performance-based pavement marking warranty project is seen as a success. Similar benefits, advantages, disadvantages and problems with this type of contracting are observed in this project as in similar projects implemented by other agencies. Some of the problems are recognized here, and they can be addressed in future implementations. Considering that this is still an innovative approach in pavement marking projects, it shows a lot of potential, and UDOT should choose this direction for large-scale pavement marking projects, as well as other construction projects where performances can be clearly defined and measured. These

types of interstate freeway projects are also good candidates for FHWA's support as well as additional funds obtained through the Transportation Commission, since they satisfy both capital improvement and preventive maintenance requirements.

The most significant expected benefit is increased safety, expressed through estimated reduction in the number of crashes after the implementation of the new pavement markings with stricter retroreflectivity requirements. However, the benefit-cost analysis cannot be performed at this point due to the lack of data. The researchers propose a safety evaluation of the new pavement markings once at least two years of crash data on these sections become available, since the costs of safety are the highest. Considering the change in crash frequency for different crash types and costs associated with those types, as well as the known costs for pavement marking implementation, the benefit-cost analysis can assess the rate of return of pavement marking implementation.

The pavement marking warranty project is in its initial phases, so there are still not enough data for a more detailed analysis and assessment. A similar study should be performed further down the life of the project, when more data on performance, pavement marking life, costs and benefits are available.

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APPENDIX A: PRECONSTRUCTION AND CONSTRUCTION SURVEY RESPONSES

Question 1: What is your role or level of familiarity with the pavement marking warranty project? (project number F-ST99(133), PIN 9266, "State Route I-15 from: 278.60 to: 380.00 for: 101.40, Pavement Marking on Interstate at Various Locations")

Respondent	Answer	Assigned Score
1	I was involved in the original conception of the project. Our plan was to use federal funds (IM) to let a project that would be performance based with a warranty provision. The federal funds available was $5,000,000, so our original idea was to advertize the project for that dollar amount, and let bidders propose how much work could be accomplished within that dollar limit. Because of controversy surrounding the I-15 CORE project at the time, which used a similar method of advertizing, UDOT leaders decided to use a more traditional contracting approach. In addition to being involved in the project concept, I participated in the RFQ process, which was a two-step bid. The first step was to short list prospective bidders, and the second was to award to the lowest bid from qualified bidders on the short list.	5
2	Resident Engineer UDOT Construction Crew	5
3	I attended meetings and gave input	4
4	I am the Project Manager from UDOT Region 2 for this project	5
5	I was the designer who assembled the package for advertising. I am very familiar with the project. I was assigned originally to assist in getting it advertised but that changed as the project went along.	5
6	I assisted Reg. 2 in putting the advertising package together. Reg. 2 had the main responsibility for design and construction.	5
7	Working on advertising the project, and involved in risk management. He was working in eliminating the risk for the contractor.	5
8	Was helping with putting up the contract	4
	AVERAGE SCORE	**4.75**

Question 2: What is your role or level of familiarity with more traditional (i.e., materials or methods specification) pavement marking projects?		
Respondent	**Answer**	**Assigned Score**
1	I have not participated in any other traditional pavement marking projects.	1
2	I have had a handful of paving projects that involved traditional traffic paint and tape.	5
3	I am fairly familiar with traditional methods.	4
4	Limited familiarity.	3
5	None. This was my first only pavement marking contract and the first warranty project.	1
6	I am familiar with them, but not on a regular basis. I have helped with specifications and have some field experience with contractors and our own forces.	3
7	Was involved in a lot of contracts before, but this was the biggest of this type.	5
8	Was involved in other traditional pavement marking contracts.	5
	AVERAGE SCORE	**3.375**

Question 3: Are there experiences from other agencies with pavement marking warranty contracts that you are aware of? Are there specific papers or reports that you have referenced?		
Respondent	**Answer**	**Assigned Score**
1	Missouri did one in 2009 or 2010. There were also several others from various states, the names of which I can't recall right now. We used some of the language from those in preparing our RFQ.	5
2	No.	1
3	No. Not to my knowledge.	1
4	No.	1
5	No.	1
6	There are several states that have experience with warranty contracts. I have several documents that I have reviewed. Contact me with specifics.	5
7	He heard that for example Nevada, Arizona, Wyoming have had similar contracts with their own specs, but is not certain how they approached the pavement marking warranty. Winter and snow removal is a major challenge in Utah.	3
8	Maybe Virginia and Florida have something similar, but does not know details.	3
	AVERAGE SCORE	**2.5**

Question 4: Did UDOT define a clear concept and objective for the pavement marking warranty project and a desired outcome?

Respondent	Answer	Assigned Score
1	I believe we did. The concept and objective were for the contractor to use an approved method to install the pavement markings, and warranty the work over a six year period, with an independent evaluation firm to assess initial quality of the installation and make retroreflectivity measurements on an annual basis afterward. The contractor would be responsible for "touch-ups" in areas where retroreflectivity levels fell below the minimum allowable.	5
2	Yes.	5
3	I'm not the best person to answer this. Ken Berg and Troy Peterson can answer this best. We believe after revisiting the original bid letting that there was a clear concept and objective with a desired outcome.	3
4	Yes, the objective of the project was to provide a pavement marking for the project with a minimum retroreflectivity and presence for a period of 6 years. The supplier is free to pick the durable marking that will achieve the desired results.	5
5	Yes.	5
6	We did our best.	5
7	Yes, a lot of right people were involved and there was a good and constructive communication and cooperation among them.	5
8	Yes, it seems good for now. One of the biggest issues was estimating the cost.	5
	AVERAGE SCORE	**4.75**

Question 5: In preconstruction, was risk associated with this project type clearly identified prior to initiating the bid process? If so, what were the perceived risks? How were those risks managed for UDOT and the contractor?

Respondent	Answer	Assigned Score
1	I don't know how clearly we identified risks prior to receiving bids. Perhaps that was a reason the initial bids came in as high as they did.	2
2	I don't know.	3
3	Again, either Troy Peterson or Ken Berg could answer this best. A lot of the risks identified were how contractors would deal with manufacturer warranties. There were also risks associated with interchanges. These two seemingly were the highest, but many others were also identified.	3
4	Yes, there were risks identified. Some of the risks were mitigated by involving multiple pay items that allowed UDOT to pay for services at the time of delivery and still retain a portion of the marking costs for the warranty.	4
5	We did talk about risk. But we thought most of the risk was on the contactor. The major risk we were talking about was the time the contractors would have to groove in the pavement markings. There also was another project on I-15 with the same limits we were concerned that they would overlap and cause a delay. To manage the risks we let the contractor decide if they wanted to groove in the markings. They also had choices as to what product they would use.	4
6	The first time the project was bid, more risk was put on the contractor and the bid prices reflected that. The project came in significantly over budget. The project documents were adjusted, the project rebid, and the bids came in within budget. The main factor that affected contractor risk, was requiring installation to be complete in the first year with an insufficient percentage of payment allotted to them to cover their costs.	4
7	Risk was the major issue for the contractor, and the bidding process failed the first time because risk was not clearly defined. The major concerns that the contractor had were timing of the project and holding of the money. With yearly payments, as first defined in the scope (the bidding that failed), the contractor would have to pay interest for the additional payments. Also, there was not enough traffic control at the beginning. The cost of traffic control had to be increased, but that on the other hand reduced the risk.	1
8	There were two biddings for this contract. In the first one, the risk was not defined good, and the bids came back too high. In the second bidding process, the risks were refined. Some of the ex-contractors helped with defining the risks, so the second bidding was successful.	1
	AVERAGE SCORE	**2.75**

Question 6: Were all the right people in UDOT central divisions and in the Regions involved during the preconstruction phase? If not, who else do you think needed to be involved?

Respondent	Answer	Assigned Score
1	I think the right people were involved. But everyone's involvement was not well coordinated. For example, in Central Maintenance we assumed we would have project management responsibility for the project. But because Central Maintenance doesn't have all the tools to effectively manage projects, that responsibility was moved to Region 2. At that point Central Maintenance kind of lost track of project progress, because we were no longer actively involved in preparing the bid package.	4
2	It would have been helpful had I been more involved in the preconstruction phase but was not.	3
3	I believe the right people were involved. Other supplemental information e.g. potential additional HOV lanes or current HOV lane management future I-15 plans, specific areas of I-15 made the decision making process more difficult.	5
4	Yes, I believe that the right people were involved during the preconstruction phase.	5
5	Yes.	5
6	Yes, we think all the right folks were involved.	5
7	Yes, a great team got together to come up with the best decisions.	5
8	Yes.	5
	AVERAGE SCORE	**4.625**

Question 7: This is the first time in the State that Interstate Maintenance (IM) funds have been approved by FHWA to be used solely for pavement markings. What was your familiarity and experience with using IM funds for this project? Are you aware of any special requirements associated with the use of IM funds on this project?

Respondent	Answer	Assigned Score
1	I prepared the justification document that was ultimately approved by the FHWA Utah Division. Our justification rested on two separate factors: 1) that the project constituted a capital improvement, because we were specifying that the new markings should be placed in grooves in the pavement to be prepared by the same contractor; and 2) that the project constituted preventive maintenance, due to the long term nature of the product and its warranty.	5
2	I am not aware of special requirements associated with IM funds.	3
3	I don't know. I didn't have great knowledge on the funding. I am not aware of special requirements on this project.	3
4	Not aware of any special requirements. We have many projects that are delivered that are IM funds.	4
5	No impact, no difference.	3
6	I had not had previous experience using IM funds for this type of project. The major requirement that affected our process was that because IM funds are federal, the project must go through the construction advertising process, rather than the procurement RFP process.	5
7	Has no experience and was not involved with the project funding.	3
8	This is the first time for Utah. He mentioned that maybe Virginia has some experiences with this, but is not sure.	4
	AVERAGE SCORE	**3.75**

Question 8: Do you expect that the pavement marking and bead specifications will work to achieve the desired performance? Do you have an opinion on whether UDOT will get the full six years out of the new markings?

Respondent	Answer	Assigned Score
1	I fully expect that the marking materials used will achieve the desired performance, and that UDOT will get the full six years out of the new markings, partly because I have confidence in the materials that the contractor installed, and partly because of the provision that requires the contractor to replace any markings that don't meet the performance requirements.	5
2	Yes.	5
3	More than whether it will work, we get comments from paint contractors regularly that our paint standards are more stringent than most other states. So, we likely will get the full six years, but that is part of how we expect to evaluate this.	5
4	I do expect the marking to achieve the desired performance and feel that the six years is obtainable.	5
5	The contractor says they will.	5
6	Yes I do think they will work because the contractor is warranting that it will work.	5
7	He surely hopes so. Based on the experience, maintenance and construction, the markings should last the entire period.	5
8	Yes. Maybe some tweaks will be needed, but in general it should last the whole period.	5
	AVERAGE SCORE	**5.00**

Question 9: Do you feel that the contract or specifications was lacking anything? If so, what should be added or modified?

Respondent	Answer	Assigned Score
1	I don't know of anything that would have been lacking.	1
2	There was ambiguity with the incentive payment for early completion in the specifications. The intent for contrast striping should have been specified better in the contract. The contractor's rule of thumb was to "match existing" but there were areas where there was not consistency. It would have been better to specify this in the contract.	4
3	To some extent, this is innovative contracting. We will evaluate the pros and cons to ascertain how differently (if at all) to address this in the future.	3
4	At this point I am not sure if there is anything that the specification was lacking. However, the contract for this work should be advertised in the winter months to take full advantage of the spring/summer temperatures so as not to be fighting the end of the construction season temperatures.	1
5	No.	1
6	We did our best but nothing is perfect. We will learn as the contract plays out. I especially am interested in the performance specification and how it might be improved.	2
7	No, the contract was handled well.	1
8	In general it was good, but maybe a little bit more detailed scope was needed. Maybe something was missed, and the time will tell.	2
	AVERAGE SCORE	**1.875**

Question 10: Based on your knowledge of the project, did the Maintenance of Traffic (MOT) plan perform as expected? If not, what were the issues?		
Respondent	**Answer**	**Assigned Score**
1	I wasn't involved enough in the project to make a comment regarding MOT.	3
2	There was too much work to be done in too little time. The contractor had crews jumping all over the place to get the work done. It was difficult to schedule and difficult to keep track of what all was going on. The expectation to keep a traffic lane open through the SPUI intersections while grinding and striping was unrealistic. Due to low temperatures and the fear of not finishing the contract this season, we allowed the contractor to do some single lane daytime closures during off-peak hours. This seemed to work okay.	2
3	I am not familiar with the outcome of the MOT.	3
4	I would say due to the time this contract was let and number of crews hired by the contractor to complete the work in one construction season, the MOT plan did not perform as expected due to resources needed and impact areas. However, the contractor did a great job coordinating his activities with the Resident Engineer to keep him apprised of nightly work.	1
5	No, the contractor had to close consecutive ramps to meet taper lengths.	1
6	I have no opinion on MOT. That was handled by the Region folks.	3
7	MOT is a standard defined by FHWA. He is not aware of any problems, everything was done according to the requirements. He mentions that phasing was a little bit of concern.	3
8	He is not sure about this, since he had no involvement.	3
	AVERAGE SCORE	**2.375**

Question 11: Were there problems with the construction process that you are aware of? If so, what were they?

Respondent	Answer	Assigned Score
1	I don't know, wasn't involved at that point.	3
2	Our biggest problem was another contractor working on I-15 who was not finished with his project and the striping contractor did not have full access to the project. This ended up changing the approach to the project for the striping contractor.	4
3	I am not familiar with issues associated with construction.	3
4	I am not aware of any problems with the construction process.	1
5	No.	1
6	I have no opinion as I was not involved. I would suggest asking those who were involved in construction.	3
7	He is not aware of any problems, everything was OK.	1
8	No. He mentioned that he heard some questions and complaints about grooved markings, but it was nothing major.	1
	AVERAGE SCORE	**2.125**

Question 12: Did UDOT get what they asked for in the contract up to this point in time? Based on your knowledge of the project, did the contractor meet the specifications and project schedule? If you answered "no" to either of these questions, please explain.

Respondent	Answer	Assigned Score
1	Again, I wasn't involved enough to make a comment.	3
2	Yes.	5
3	I am not sure at this point and won't know until we debrief with Construction.	3
4	Yes.	5
5	Yes, No the contractor had to close consecutive ramps to meet taper lengths.	5
6	As far as I know the contractor performed as directed. But I would strongly suggest asking the construction folks.	5
7	Yes.	5
8	One year is a short time to tell, but for now it seems good.	5
	AVERAGE SCORE	**4.50**

Question 13: Do you feel that it is cost effective to execute a performance-based warranty contract in this way? If you answered "yes," where/when should UDOT use this type of contract on other projects?		
Respondent	**Answer**	**Assigned Score**
1	Yes. I feel that this type of contracting was appropriate in this case because measuring the retroreflectivity is a good, objective way to measure performance under the contract. For other types of work, where the results and performance are not as easily measured, may not lend themselves to this type of contracting.	5
2	I don't know.	3
3	I wish I had a definitive answer to this. We have successfully implemented performance-based items into standards such as asphalt (02741) using sophisticated statistical analyses. I think that before we extrapolate to other projects, we need to regroup and evaluate our lessons learned; both on this contract and other performance-based items.	4
4	Yes. Anytime the desired performance can be identified with clear performance measures.	5
5	Yes on maintenance contracts.	5
6	Yes. We're still learning but anytime a durable marking is installed it should be under a warranty.	5
7	Yes. The good thing was that the contractor was prequalified for the job, which also helped reduce the risk. Having prequalified contractors for any job is always a good thing.	5
8	Still too early to tell. There are certainly a lot of advantages. For example, UDOT doesn't have such big crews to cover such a big project. Funding a big project like this can be an issue. IM funds certainly helped, since they added some money to the project.	3
	AVERAGE SCORE	**4.375**

Question 14: What are the advantages (benefits) and disadvantages of executing a pavement-marking contract in this way? How do you expect the benefit-cost ratio and life cycle cost compare with past non-warranty pavement marking contracts?

Respondent	Answer	Assigned Score
1	I don't know.	3
2	I don't know.	3
3	The benefits are that we give the risk management to the contractor. The disadvantages are that there may be issues with future interpretations for warranty items; MOT, degree of failure; marking manufacturer warranty vs. application, etc. With respect to comparisons, traditionally when we have implemented performance-based items, contractors have been able to use innovations that lead to better construction. That is my expectation with this endeavor.	4
4	Benefit to the Department is we have a product on the ground that we have a warranty for that we should not have to worry or pay to maintain for 6 years. I do not have the information to discuss life cycle costing.	5
5	I think the benefits are we do not need to do another contract and we have a long term way to maintain the striping on I-15.	5
6	It's an advantage to minimize impact to the travelling public. A nondurable product installed by UDOT forces or a contractor would need refreshing every year. A durable product, chosen and warranted by the supplier, will last 5 to 6 years with minimal impact to the public. A disadvantage is that it is a higher initial cost.	5
7	There are many advantages in doing contracts this way. He is not aware of any disadvantages.	5
8	Advantages: it is up to the contractor to keep everything in order and as specified. Disadvantages: the bidding process; it is hard to estimate the risks.	5
	AVERAGE SCORE	**4.375**

Question 15: Overall, is this performance-based warranty contract a better contract process than before (i.e., with "before" typically a materials or method specification)?		
Respondent	**Answer**	**Assigned Score**
1	I believe it is a better way to contract, because it places responsibility on the contractor for the performance of the product. It frees us from the responsibility of specifying exact materials components and properties that we think will perform. It gives the contractor (in this case, the supplier of the material) the opportunity to develop innovative means of producing a product that gives the intended results and to demonstrate the excellence of the material.	5
2	I don't know.	3
3	I don't think I have enough data to answer that definitively yet.	3
4	I believe it is a better contracting mechanism as it provides the suppliers an avenue to be innovative with enough assurances (warranty) that we are not just becoming a research testing contract.	5
5	The same, it had its struggles as to how it needed to be put together for advertisement.	3
6	They each have their place and each must be considered on a project by project basis. Factors such as AADT, remote location, agency work load, route functional classification, etc. should be considered.	4
7	Yes, warranty is needed for pavement markings.	5
8	Most of the time, yes.	5
	AVERAGE SCORE	**4.125**

Question 16: Do you feel that new ways to monitor progress and measure success (e.g., Project Development Business System, etc.) have been beneficial on this contract?

Respondent	Answer	Assigned Score
1	I don't know.	3
2	I don't know.	3
3	PDBS isn't new. Most of UDOT's advances in IT have been beneficial to all of our contracts including this one.	5
4	Probably a better question for the RE as I do not work with PDBS that often.	3
5	For me no.	1
6	I have no opinion. That is a question for the construction folks.	3
7	No comment on this question.	3
8	No comment on this question.	3
	AVERAGE SCORE	**3.00**

Question 17: Please provide any additional notes, comments, or suggestions that you may have.

Respondent	Answer	Assigned Score
1	I don't have any at this time.	N/A
2	We found that the ground-out markings were adequate to use as deliniation for up to 24 hours until new permanent markings could be installed.	N/A

APPENDIX B: POST-CONSTRUCTION SURVEY RESPONSES

Question 1: Based on the current data from the construction and post-construction phases, do you expect that the pavement marking and bead specifications will achieve the desired performance over the six years warranty period?

Respondent	Answer	Assigned Score
1	I haven't seen any data but I do expect performance will be achieved because the supplier warranted that it will be. I would contract Troy Peterson, tlpeterson@utah.gov, who could help you with construction and post-construction questions.	5
2	Yes with touch ups as all lines were recessed to try to minimize snow plow damage.	5
3	Yes.	5
4	I have only seen data from the construction phase of the project. Based on this data, I do expect that the pavement marking and bead specifications will achieve the desired performance.	5
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**5.00**

Question 2: Were there problems with the construction and post-construction processes that you are aware of? If so, what were they?

Respondent	Answer	Assigned Score
1	I would contract Troy Peterson, tlpeterson@utah.gov, who could help you with construction and post-construction questions.	N/A
2	Yes the project had to deviate from their original traffic control plan to try to get the project completed on time also grooved areas were left without paint in the grooves for extended periods of time.	5
3	No.	1
4	The very aggressive construction schedule made it difficult to manage the contract and keep track of all areas where work is taking place. I believe the contractor experienced some inefficiencies with so many crews being so spread out on the project.	4
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**3.33**

Question 3: During the construction phase, was there a need for the contractor to deploy more crews than previously defined to meet the deadline? If yes, what was the reason for this?

Respondent	Answer	Assigned Score
1	I would contract Troy Peterson, tlpeterson@utah.gov, who could help you with construction and post-construction questions.	N/A
2	Yes as the grooving process takes longer than anticipated but is a critical part of the warranty process.	5
3	Bryan Chamberlain, the RE can answer this question.	N/A
4	No. The contractor had a very aggressive schedule and numerous crews on the project from the beginning.	1
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**3.00**

Question 4: For the implemented pavement markings under the warranty contract, how are interim retro-reflectivity measures taken and who has responsibility for monitoring the paint performance and requesting repairs in the post-construction phase?

Respondent	Answer	Assigned Score
1	Interim retros are taken by a third party contractor. I would contract Troy Peterson, tlpeterson@utah.gov, who could help you with construction and post-construction questions.	5
2	In the contract an independent contractor readings of the retro-reflectivity is required every spring and the results are reviewed by the contractor and UDOT for any areas that are deficient.	5
3	POLY-CARB is required by contract to take retro-reflectivity reading yearly and provide results to UDOT.	5
4	Interim retro-reflectivity measures are taken by a qualified and independent firm. Based on these measurements, UDOT will request repairs in areas not meeting specification.	5
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**5.00**

Question 5: In the post-construction phase of this project, how often is the performance of pavement markings measured, and how are these measures verified by UDOT?

Respondent	Answer	Assigned Score
1	The awarded contract calls for measurements after installation and once per year thereafter for the life of the contract. I would contract Troy Peterson tlpeterson@utah.gov to see if that has changed.	5
2	Annually every spring.	5
3	See answer to question 4. Annual readings provided by POLY-CARB to UDOT.	5
4	Pavement marking performance is monitored once per year. The report from the independent firm is submitted to UDOT for verification.	5
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**5.00**

Question 6: When it comes to monitoring, measuring and verifying the performance of pavement markings, is there a difference between this warranty contract project, and "traditional" pavement marking projects?

Respondent	Answer	Assigned Score
1	Yes. Our traditional projects have not been quantitatively monitored as part of a comprehensive statewide management program.	5
2	Yes typically there are no retro-reflectivity readings taken unless there is a warranty associated with the project.	5
3	Yes. Minimum retro-reflectivity requirements.	5
4	This would be better answered by Dan Betts, UDOT Region 2 Paint Crew Manager.	N/A
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**5.00**

Question 7: In the post-construction phase, has there been a need for the contractor to come back to repair the markings? If yes, how often has this happened?

Respondent	Answer	Assigned Score
1	I would contract Troy Peterson, tlpeterson@utah.gov, who could help you with construction and post-construction questions.	N/A
2	Not in this project yet but almost yearly in the previous 8 year warranty project in the same area, as the lines were not recessed.	1
3	Yes. No repairs to date.	2
4	Not yet. The first of the annual pavement marking performance monitoring has not yet occurred.	1
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**1.33**

Question 8: Do you have information on how the budget for all phases of this warranty contract compares to the Region 2 payment budget for "traditional" pavement marking contracts?

Respondent	Answer	Assigned Score
1	No. I would contract Troy Peterson, tlpeterson@utah.gov.	3
2	The Region Two maintenance budget for pavement markings is approx. 1.2 million per year.	5
3	No. Our Maintenance Division should have those values.	3
4	No.	3
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**3.50**

Question 9: What was the local FHWA role during the preparation and execution of this contract, during all project phases (pre-construction, construction and post-construction)? How were they involved, and where were their acceptance and approval required?

Respondent	Answer	Assigned Score
1	I do know that FHWA gave their approval for the use of federal funds. I can't speak to any other involvement. I would contract Troy Peterson, tlpeterson@utah.gov.	N/A
2	They were involved but I can't answer as to what extent.	4
3	Approvals from the local FHWA office are consistent with our stewardship agreement.	5
4	This would be better answered by the UDOT Project Manager, Troy Peterson.	3
5	The only FHWA involvement that I was aware of was in the pre-construction phase. (Not to say that they didn't have a role during other phases, or even a larger role during preconstruction than I was aware of, because my own involvement ended pretty early on.) In the preconstruction phase, we needed to obtain approval from the FHWA to use federal IM funds for the project. So they needed to make a determination of eligibility for those funds. In order for IM funds to be used, the project had to be on an Interstate roadway, and we had to demonstrate that it was either a capital improvement or an element of a preventive maintenance strategy. We argued that the project qualified on both counts. It was a capital improvement in that we required a high end durable product to be placed, and required that it be warranted for a long term (five years). It was a component of a preventive maintenance strategy in that the sections were selected based on the underlying pavement not needing to be ground or otherwise rehabilitated for at least as long as the warranty term. Based on those arguments, the FHWA Utah Division approved the use of IM funds for the project. After that approval, I do not know what additional involvement FHWA had in the project.	5
6	FHWA was involved during the pre-construction phase (procurement phase). They provided review and approval for the Request for Qualifications (RFQ) short-listing and Advertised Bid Packet selection process. Because I was only involved during the pre-construction (specifically the procurement phase) I do not know if FHWA was involved beyond that stage.	5
	AVERAGE SCORE	**4.40**

Question 10: From your perspective and based on the current data from all project phases, do you think that it is cost-effective to do pavement marking contracts this way, with performance-based warranties?

Respondent	Answer	Assigned Score
1	Each potential project needs to be evaluated individually. This project made sense because of the amount of traffic.	4
2	Yes but only on large multi lane highway projects that are hard for maintenance crews to restripe or have significant traffic control costs and safety issues. There are also many other variables to be considered as to where this type of projects make sense.	5
3	I cannot answer this question as I do not have the information to determine the cost effectiveness of this project compared to traditional contracts.	N/A
4	Yes.	5
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**4.67**

Question 11: Do you have an estimation (or opinion) about the life-cycle of the pavement markings from this contract, and the benefit-cost ratio of the entire performance-based warranty project?

Respondent	Answer	Assigned Score
1	I think warranty contracts should be a tool in the tool belt and guidelines should be set to enable decision makers to evaluate the B/C ratio. In my opinion, projects that state forces can't efficiently do, for variable reasons, should be outsourced as warranty contracts. Also, any durable marking should be a warranty contract.	4
2	Not at this time.	N/A
3	Strictly an opinion, at this point the performance-based warranty for the pavement markings appears that the 6 years for this warranty is going to provide an excellent product for the money spent.	5
4	No.	N/A
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**4.50**

Question 12: If this is the direction in which UDOT should go, how soon should UDOT request more funding from the Transportation Commission for additional pavement marking projects that would involve performance-based warranty contracts?		
Respondent	**Answer**	**Assigned Score**
1	I think the need has to be established first and the Regions should be the ones to do that.	3
2	I think that there are other areas that might be considered for this type of a warranty project in the near future.	4
3	As early as they can if this is the direction UDOT decides to move with pavement marking projects.	5
4	Immediately.	5
5	No answer.	N/A
6	No answer.	N/A
	AVERAGE SCORE	**4.25**

Question 13: Please provide any additional notes, comments, or suggestions that you may have.		
Respondent	**Answer**	**Assigned Score**
1	We're learning about how to efficiently outsource pavement marking warranty projects in anticipation of a need for more in the future.	N/A
2	None.	N/A
3	None.	N/A
4	None.	N/A
5	None.	N/A
6	Because we are still in the initial stages of the life of the contract, many of your questions relating to durability, performance, and knowing if UDOT should go this route again may still be unknown. Hopefully this has been taken into account and a follow-up study will be done in the future, once the duration of the contract is further along.	N/A
	AVERAGE SCORE	**N/A**