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TRC1207

A Cost/Benefit Evaluation of Incentives Paid for Asphalt Concrete Hot Mix (ACHM) Properties

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FINAL REPORT

TRC 1207

A COST/BENEFIT EVALUATION OF INCENTIVES PAID FOR ASPHALT CONCRETE HOT MIX (ACHM) PROPERTIES

by

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TRC 1207: A Cost/Benefit Evaluation of Incentives Paid for Asphalt Concrete Hot Mix (ACHM) Properties

Abstract

The purpose of this study was establishing if projects receiving incentive payments for Asphalt Concrete Hot Mix (ACHM) properties were providing a better quality and longer pavement life cycle. Reviewing governmental agencies' and states' Department of Transportation (DOT) standards, through literary review, indicated other possible guidelines and recommendations.

Results were formulated by employing a specific methodology, allowing for data validation through an ordered series of groupings and project pairings. Arkansas Highway and Transportation Department (AHTD) databases furnished essential pavement data to accomplish this task. Derived from methodology, data analysis supported the comparison analysis of selected construction projects. Documented conclusions validated the theory of paid incentives for ACHM properties provide similar life cycles from projects which did not receive incentive payments.

This study presents material to constitute modifications to current AHTD specifications for incentive payments. Suggested recommendations were based on the findings through literature review and of the study's research data.

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List of Abbreviations & Acronyms

AASHTO – American Association of State Highway and Transportation Officials
ACHM – Asphalt Concrete Hot Mix
ADT – Average Daily Traffic
AHTD – Arkansas State Highway Transportation Department
ARAN – Automated Road Analyzer
BLM – Beginning Log Mile
Caltrans – California Department of Transportation
CBD – Construction Begin Date
CCD – Construction Completion Date
DOT – Department of Transportation
ELM – Ending Log Mile
ERS – End Result Specification
FHWA – Federal Highway Administration
GIS – Geospatial Information System
HMA – Hot Mix Asphalt
IN – Indiana
IP – Incentives Paid
IRI – International Roughness Index
ISO – International Organization for Standardization
M&C – Materials and Construction
MMHIS – Multimedia Highway Information System
NCHRP – National Cooperative Highway Research Program
NI – Nonincentive Paid
NDOR – Nebraska Department of Roads
OGC – Open Geospatial Consortium
PD – Percent Defective
PBD – Project Beginning Date
P.E. – Professional Engineer
PSR – Project Status Report
PWL – Percent Within Limits
QA – Quality Assurance
QC – Quality Control
SARS – Sitemanager Access Reports System
SCD – Substanially Completion Date
SCDOT – South Carolina Department of Transportation
SQA – Statistical Quality Assurance
VFA – Voids Filled with Asphalt binder
VMA – Voids in Mineral Aggregates
VMT – Vehicle Miles Traveled

CHAPTER 1 – INTRODUCTION

The Arkansas Highway and Transportation Department (AHTD) oversees Arkansas highway construction projects for coordinating public and private transportation activities and implementing a safe and efficient transportation system which includes interstates, state highways, state-aid county roads, bridges and signalized intersection work. Nationally, the Arkansas State Highway system ranks 12th in mileage and 43rd in total revenues per mile. As of January 1st, 2012, the Arkansas administered highway system totaled 16,414 miles (16.4%) of the 100,082 miles of public roads in Arkansas. During the 2012 State Fiscal Year, 243 projects totaling $566 million were awarded for Arkansas' state highways (AHTD, 2013a).

In order to ensure quality work, the AHTD established an incentive program to encourage highway contractors to improve the quality of delivered work beyond specified minimum standards. The AHTD is concerned with the lifecycle of roadway pavement, and thus, included in the AHTD standard specifications are guidelines for incentives paid for work of high quality. One of the incentives is monetarily rewarding the highway contractors for producing a top quality asphalt pavement with expected superior performance and durability. A determining factor in pavement performance are the Asphalt Concrete Hot Mix (ACHM) properties, including compaction, which is outlined in the AHTD 2003 Standard Specifications for Highway Construction. According to the AHTD 2003 Standard Specification for Highway Construction, an incentive payment will be accomplished by change order and will be shown on the final estimate as a separate item. An accumulated maximum 6.0% incentive payment is available as follows:

(a) An incentive payment of 3.0% will be added if:
1. The asphalt binder content is within ±0.2 percentage point of the mix design value, and
2. The total variation, low to high, in air voids is no more than 0.6%, with none outside of the compliance limits, and
3. All densities fall between 92.0%[1] and 96.0%, and
4. There are no areas of segregation outside of the compliance limits as verified by testing according to AHTD Standard Specification for Highway Construction (2003), Subsection 410.09(b)(3)

(b) An additional incentive payment of 2.0% will be added if the requirements of (a) above are met and if the Voids in Mineral Aggregates (VMA) are within the compliance limits.

(c) If the Contractor elects, an additional incentive payment of 1.0% of the total ACHM Surface Course quantities used on the project will be added if:
1. The pavement smoothness incentive criteria are met
2. There are no corrective patches[2]

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[1] When the minimum specification density is 90.0%, this value is changed to 90.0%.
[2] Any repaved section of 1000' (300 m) or greater in length for a full lane width will not be considered a patch.

3. The requirements of both (a) and (b) above are met.

Annually, the AHTD incentive program has currently paid incentives for approximately 85% of awarded contracts. In 2009, the AHTD paid $2.6 Million for ACHM Surface Course property incentives. Incentive payments indicate that the work has exceeded the minimal standard of the performance guidelines. It is the AHTD who sets both the required minimum standards and also the requirements to receive incentive payments.

Though studies for other state highway Department of Transportation (DOT) have been conducted, AHTD has not conducted a study to determine if paid incentives have led to projects with improved pavement quality. However, the AHTD has procured new technology to study pavement durability, effectively and accurately. The AHTD Pavement Management Section employs GeoMedia and the Multimedia Highway Information System (MMHIS) as their primary tools. These databases report and share information allowing, the user, to view road segments without leaving the office.

GeoMedia software (Figure 1) is Geographic Information System (GIS) management software, which permits the user to access any form of geospatial data. It is able to combine existing pavement data into a single map view for efficient processing, analysis, presentation and sharing. Utilized by organizations around the world, GeoMedia software provides flexibility, interoperability, open architecture, and adherence to industry standards such as Open Geospatial Consortium (OGC) and International Organization for Standardization (ISO) standards making it one of the most actively utilized technologies throughout the world (Hexagon Marketplace, 2013).

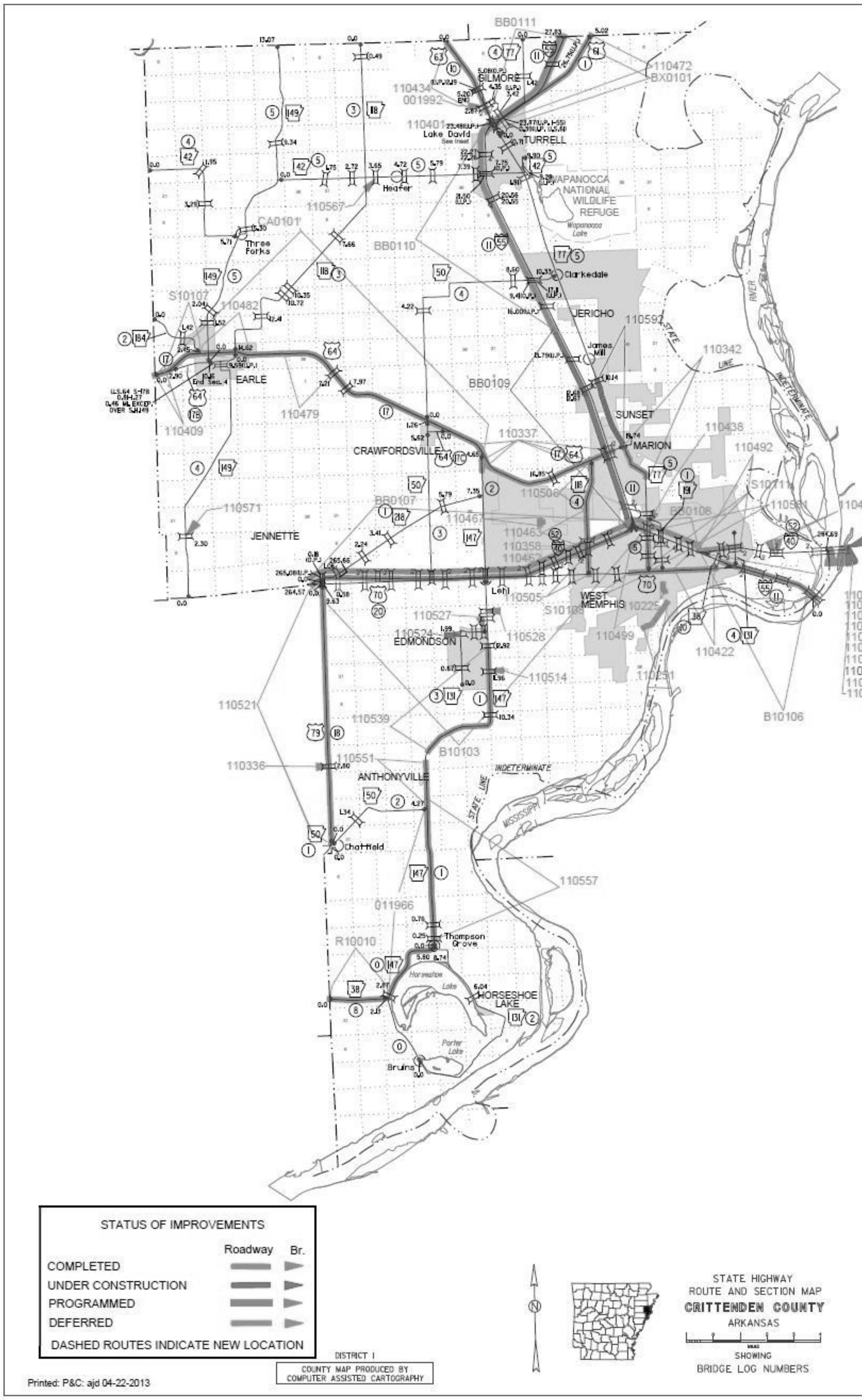

Figure 1: Image of Crittenden County utilizing GeoMedia

Multimedia Highway Information System (MMHIS) combines the images from the Automated Road Analyzer (ARAN) with the corresponding information from AHTD Section databases such as Bridge, Pavement Management System, Project History, Road Inventory and Safety. Figure 2 shows MMHIS ability to provide imagery of a selected road section from ARAN.

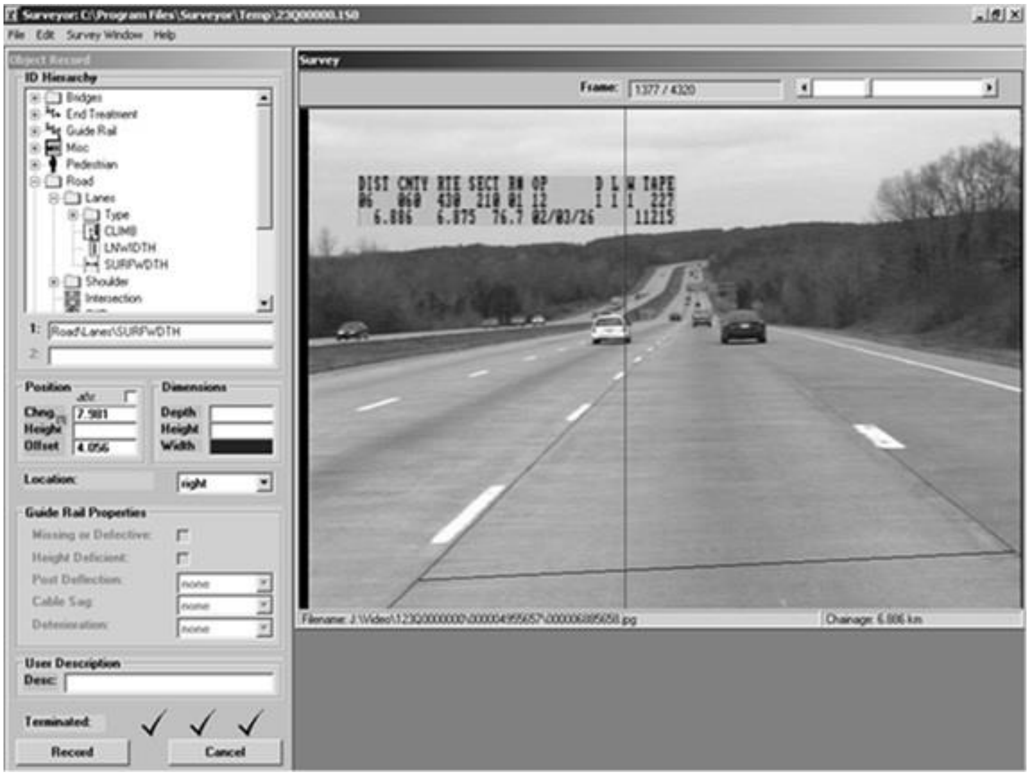

Figure 2: A Road Segment View thorugh MMHIS

Figure 3 shows the AHTD Pavement Management Section's primary tool, the ARAN, which collects pavement profile data and high-resolution images of the right-of-way and pavement. Its two part data collection platform provides International Roughness Index (IRI), rutting, faulting, cracking and geometrics.

Figure 3:Image of ARAN vehicle

Improvements to the AHTD Sitemanager Access Reports System (SARS) database and the 2010 ARAN pavement condition data collection, were influential in AHTD's decision to fund a research project on ACHM properties' incentives. With updated technology, the AHTD believes it is possible to determine if projects that received incentive payments provided a superior quality to those projects that did not receive incentives.

The main objective of this study is to determine whether or not the attained product quality and benefits justify the incentive amounts received by the highway contractors. To provide evidence and conclusions for this objective, historical data of highway projects was needed to evaluate projects where incentives were paid versus those projects that did not receive incentives. To obtain historical highway data, scheduled visits were coordinated with the Arkansas State Highway Transportation Department Construction Division, Subcontracts & Estimating Section, and Research & Development offices in Little Rock Arkansas to acquire access to network databases. Interviews were also conducted with several Professional Engineers (P.E.) at the AHTD to further understand project data.

Detailed research tasks included the following steps:

1. Sort historical highway project data according to size of the project, location, contractor, Average Daily Traffic (ADT) estimates, completion date, and incentives paid.
2. Identify and pair projects with close characteristics within the catagories of projects receiving paid incentives and projects that did not receive incentives.

3. Review pre-project and post-project pavement condition and detect problems associated with different projects, including pavement failure due to stripping, rutting, raveling, cracking and other unidentified causes.
4. Evaluate the improvement in highway conditions attained due to the paid incentives which were quantified through reduced maintenance and repair costs, absence of complaints and recorded lifecycle.
5. Determine if the expected benefits were attained, and if they justify the incentives paid to highway constructors.
6. Make recommendations of how to modify the incentive program to improve the AHTD expenditure outcome, if necessary.

This study comprises two phases: phase one: projects from the 10 Districts were retrieved through SARS and sorted by the project monetary amounts into three categories: Projects less than two million dollars, projects two to five million dollars and projects greater than five million dollars. For each project monetary catagory, ACHM Surface property projects were separated into two subcategories according to incentives paid and no incentives paid. To focus on the dependent variabiables, International Roughness Index (IRI) and Rutting, an incentive paid project was paired with a nonincentive paid project by using determination factors: project size, contractor (in some cases the subcontactor), district (route and location) and duration of service.

Phase two of this study was implemented upon the completion of phase one, where project characteristics were evaluated based on IRI and rutting. To determine if any measureable differences exist, project information was collected from AHTD's ARAN, SARS, MMHIS and GeoMedia databases. Shown in Figure 4 is the sequence of steps selected to narrow and pair highway projects for final evaluations.

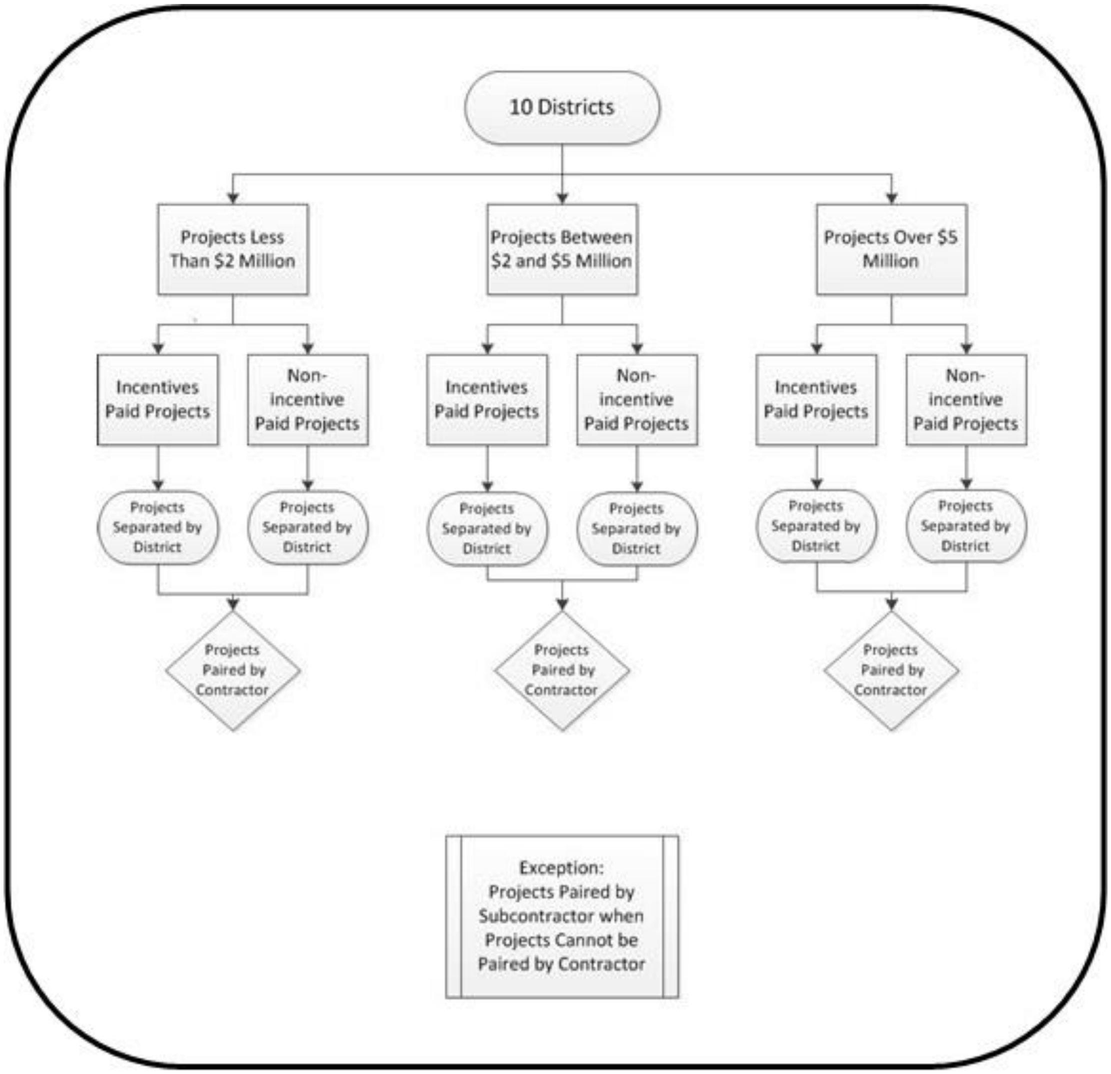

Figure 4: Organization of the Construction Project Information

Task three was accomplished by evaluating the selected projects related to this study by the dependent variables, IRI and Rutting, and catagorizing them by their respective rating scales. Task Four was achieved by evaluating the highway's dependent variables of paired projects according to those rating scales. Using the IRI and Rutting rating scales to assess paired projects, the goal was to determine if the incentive paid projects had actually provided a greater or superior quality pavement, an equal quality pavement or a less than quality pavement.

Task Five completed this study in the form a technical report presented to AHTD, providing conclusions, recommendations and possible future research. The data and information from this study could allow AHTD to make any necessary decisions whether to continue, modify or eliminate the incentive program for all roadway projects.

CHAPTER 2 – LITERATURE REVIEW

Due to the demand of superior quality pavement, the Federal Highway Administration and State Department of Transportation offices from all fifty states have implemented different incentive program for highway contractors. Other states' Department of Transportation have specifications for incentive payments according to Percent within Limits, Job Performance, Acclerated Schedules, Pavement Mix Designs and Pavement Smoothness. Performace measures can be aggregated from local to state to regional to national levels (Peruri, Jensen, Fischer, & Wentz, 2007). Some performance measurements may even allow an agency to be compared with other agencies, if a measure based on cost is used (Richter, 2004). The Nebraska Department of Roads (NDOR) as of May 2007 introduced a system of incentives to reimburse contractors for pavement quality upon completion of construction. This same system is also deficient of incentives encouraging highway contractors to use techniques which could significantly improve the long term quality of asphalt pavement (Peruri, Jensen, Fischer, & Wentz, 2007).

History of Road Construction Specification

The use of contractors to construct public roads, and specifications to control that construction, date from at least the 1850s. (Mahoney & Backus, 1999). The methods were described as early as the mid-19th century (Gillespie, 1849). Construction specifications have evolved from method specifications, which dictate contractor process, to final product specifications, which measure material properties that are thought to relate to performance. Table 1 shows the last 25 years of the evolution of construction specifications in the United States which are well documented in numerous National Cooperative Highway Research Program (NCHRP) Syntheses (Lundy, Wurl, & Remily, 2004).

Table 1: NCHRP Syntheses Related to Specifications (Lundy, Wurl, & Remily, 2004)

Synthesis Number	NCHRP Title
38	Statistically Oriented End-Result Specifications (Bowery & Hudson, 1976)
65	Quality Assurance (Halstead, 1979)
102	Material Certification and Material-Certification Effectiveness (Smith, 1983)
120	Professional Resource Management and Forecasting (Collins, 1985)
145	Staffing Considerations in Construction Engineering Management (Newman, 1989b)
146	Use of Consultants for Construction Engineering and Inspection (Newman, 1989a)
163	Innovative Strategies for Upgrading Personnel in State Transportation Departments (Poister, Nigro & Bush, 1990)
195	Use of Warranties in Road Construction (Hancher, 1994)
212	Performance Related Specifications for Highway Construction and Rehabilitation (Chamberlin, 1995a)
232	Variability in Highway Pavement Construction (Hughes, 1996)
263	State DOT Management Techniques for Materials and Construction Acceptance (Smith, 1998)

Developments in Road Construction Specifications

Noteworthy and critical events impacting the development of specifications have been abbreviated for this chapter from the most complete and thorough summary of William Chamberlain's NCHRP Synthesis 212: *Performance-Related Specifications for Highway Construction and Rehabilitation* of the development of highway construction specification. The very thorough documentation contained in that report will not be repeated, but here are some critical events impacting the development of specifications that are worth summarizing (Lundy, Wurl, & Remily, 2004).

Although it was not the first analysis of variability of highway materials and construction, the American Association of State Highway and Transportation Officials (AASHTO) Road Test (1956-1962) provided the most comprehensive and thoroughly documented measurement of Variability (Lundy, Wurl, & Remily, 2004). The Road Test specifications were intended to represent specifications typical of those used on a large highway construction program (Carey & Shook, 1996). Yet despite considerable effort, Carey and Shook were still unable to meet the many construction items specifications within a "country mile." Carey and Shook summarized in their report the importance for more well-trained inspectors which could economically be used in normal construction with high-speed testing techniques, a large-scale materials laboratory on site, the ability to control in detail the contractor's construction procedures, a highly competent and cooperative contractor who was well paid for everything he was required to do (Carey & Shook, 1996).

The magnitude of the measured variation at the Road Test surprised many highway engineers (Bowery & Hudson, 1976; Halstead, 1979). Carey and Shook summarized the sampling plans being used were inadequate for estimating the true characteristics of materials or specifications written for construction items. Thus, the sampling plans could not guarantee the specification limits would comply 100% (Carey & Shook, 1996).

In addition to the revelation that construction variations were higher than expected, several high profile highway failures occurred about the time of the AASHTO Road Test (Lundy, Wurl, & Remily, 2004). Stated in NCHRP Synthesis 38, the failures resulted in Congress forming a U.S. Congressional Committee and threatening to pass laws making it a federal offense to "knowingly incorporate" any non-complying materials in highway work (Bowery & Hudson, 1976). Changes in the traditional acceptance procedures and a higher level of accountability were required, giving the documented AASHTO Road Test construction variability and the U.S. Congress' intervention to become involved in construction specifications (Chamberlain, 1995b). The high-profile highway failures of the 1960s led to alternate measuring methods for material and construction (M&C) items. These alternate methods, Statistical Quality Assurance (SQA) or End Result Specification (ERS), recognized the inherent variability of M&C variables, acknowledging 100% compliance was impractical. (Lundy, Wurl, & Remily, 2004).

The development of new standards led to increased communication between the contractor and the agencies regarding the feasibility. Thus, contractors would assume more responsibility for quality control and highway agencies would judge acceptance on the end product or end result characteristics (Lundy, Wurl, & Remily, 2004). The standards ultimately distinguished between the responsibilities of the vendor (for quality control) and the purchaser (for specification and quality assurance). One consequence of this process was that more rapid testing methods were developed (Halstead & Dearasaugh, 1993).

Chamberlain (1968a) created a model to generally describe the elements of an ideal quality assurance system, shown in Figure 5. Although not specifically described in Chamberlain's model, both statistically based sampling and acceptance criteria are essential to a successful specification. These adjustments allowed the acceptance of materials deficient in terms of specification, but not without value, as an alternative to removal. Most of the early disincentives were related to the loss of pavement performance through the judgment of agency engineers. (Lundy, Wurl, & Remily, 2004).

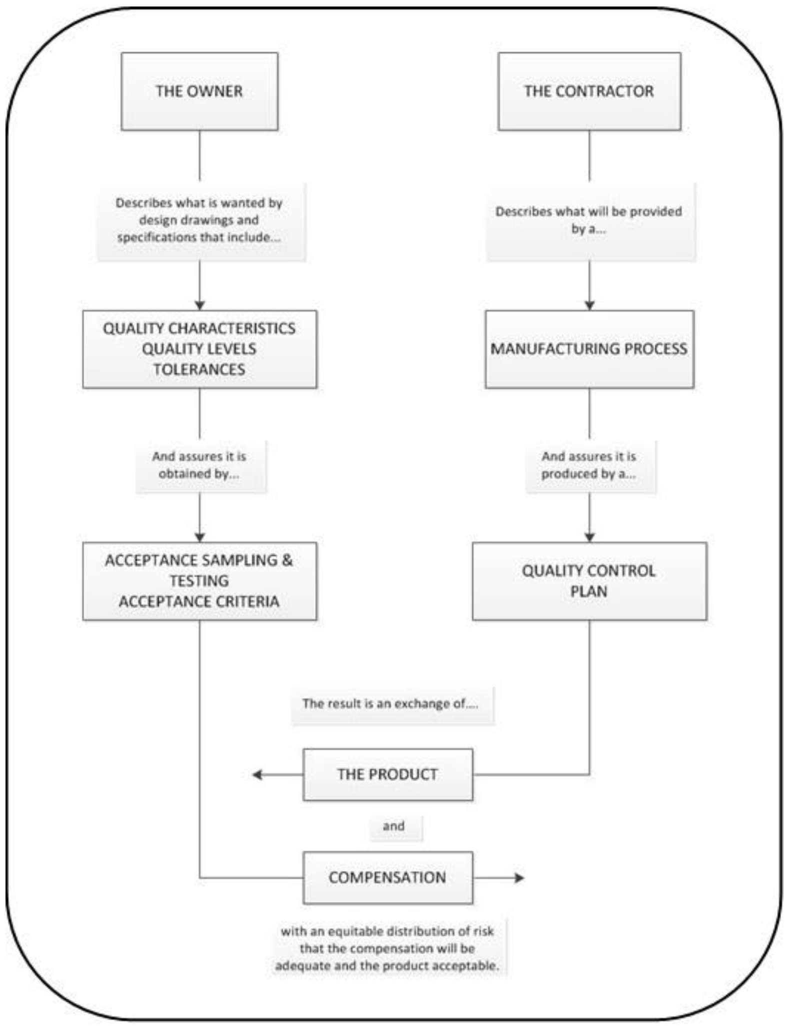

Figure 5: Elements of an ideal quality assurance system (Chamberlain 1968a)

Surveys for Incentives & Disincentive Pay Schedule

NCHRP Synthesis 232 (Hughes, 1996) reports that 42 of 48 respondents to a survey stated that they included incentives or disincentives in their pay schedule while four did not. Table 2 shows states' Department of Transportation (DOT) using incentives and disincentives on asphalt concrete material properties and construction field measurements. Thus, disincentives were used more frequently than incentives, except for ride quality (21 versus 25). During the time of Hughes 1996 survey, volumterics were not routinely used on pay factor calculations.

Table 2: DOT Use of Incentive and Disincentive Pay Schedules (Hughes 1996) [3]

Material Property or Construction Factor	Incentive	Disincentive
Aggregate Gradation	6	21
Asphalt Content	8	25
Volumetric Properties	3	10
Compaction	14	31
Thickness	5	26
Ride Quality	21	25

In NCHRP Synthesis 263 (Smith, 1998), 35 of the 41 survey respondents indicated an inclusion of some form of incentive/disincentives as part of their material and construction acceptance process. In September 1996, a survey was sent to Departments of Transportation inquiring about ACHM specification attributes with incentive or disincentives factors. Shown in Table 3, of the 35 agencies, 31 reported some form of incentive or nonincentives for HMA, 21 accounted the most common specification was smoothness with 14 reporting density specifications. (Lundy, Wurl, & Remily, 2004).

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[3] *Source:* SHA's use of Incentive and Disincentive Pay Schedules in 1996 of 46 Respondents

Table 3: Specification Attributes with Incentive/Disincentive Factors (Smith 1998)

State	HMA Density	HMA Mix	Asphalt Content	Aggregate Gradation	HMA Thickness	Smoothness
Alabama	**!Syntax Error,)**✓	✓	✓			✓
Alaska	✓			✓		
Arkansas		✓				✓
Arizona						✓
Connecticut	✓			✓		
California	✓		✓	✓		
Illinois						✓
Iowa					✓	✓
Maine	✓		✓	✓		
Maryland	✓		✓	✓		✓
Michigan	✓					✓
Minnesota						✓
Missouri						✓
Nebraska						✓
New Hampshire		✓				
New Jersey		✓				✓
New Mexico	✓	✓	✓	✓		
Nevada		✓				
North Carolina						✓
North Dakota						✓
Ohio						✓
Oklahoma	✓		✓	✓		✓
Pennsylvania	✓		✓		✓	✓
South Carolina	✓				✓ (Base)	✓
Tennessee			✓	✓		✓
Texas		✓				✓
Utah	✓		✓	✓		
Vermont		✓				
Washington	✓		✓	✓		
Wisconsin						✓
Wyoming	✓			✓		✓
TOTAL	14	9	10	11	3	21

HMA: Hot Mix Asphalt

In an April 1999 survey, 12 out of 50 states provided additional information on Statistical Quality Assurance (SQA) specifications in use and under development (Mahoney & Backus, 1999). Most agencies reported requiring contractor Quality Control (QC) measures on the mix process (binder content, gradation), Volumetrics (VMT, VMA), construction elements (density) that are amendable to rapid testing/reporting. Six of the 12 responsive states were requiring or developing a Quality Assurance (QA) measure for smoothness requirement (Lundy, Wurl, & Remily, 2004). Table 4 outlines the April 1999 survey results.

Table 4: 1999 Specification Information (after Mahoney 1999)

State	Contractor QC Requirements				Agency QA Requirements				
	AG	BC	IPD	VOL	AG	BC	IPD	SM	VOL
AR	✓	✓	✓	VMT, VMA	✓	✓	✓	✓	VMT, VMA
FL	✓	✓	✓	VMT	✓	✓	✓	✓	VMT
IN	✓	✓	✓	VMT, VMA	✓	✓	✓	✓	
KY	✓	✓	✓	VMT, VMA		✓	✓		VMT, VMA
OH	✓	✓	✓[1]		✓	✓	✓		VMT, VMA
OR	✓	✓	✓	VMT, VMA, VFA[2]	✓	✓	✓		VMT, VMA, VFA
RI					✓	✓	✓	✓	
SC	✓					✓	✓		VMT, VMA
WA	✓				✓	✓	✓	✓	
WI	✓			VMT	✓	✓	✓	✓	VMT
WY				[3]	✓	✓	✓	[4]	

AG: Aggregate Gradation; BC: Binder Content; IPD: In Place Density; SM: Smoothness; VOL: Volumetrics; VMA: Voids in Mineral Aggregates; VMT: Vehicle Miles Traveled

Notes: [1]Contractor option; [2]Also smoothness, moisture in mixture; [3]Mix verification during startup, then once per 20,000 tons; [4]Under development

The 1999 survey by Mahoney and Backus also included several other questions on QC/QA requirements. The following statements summarize the responses of the states reporting QC/QA programs (Lundy, Wurl, & Remily, 2004):

- Agencies reported QC program increased the quality of work performed by the contractor.
- The “typical” QA specification has been in service for about 12 years. Most states revise their QA program annually or biannually.
- Only one state, Indiana (IN), reported the statistical risk to the seller (α) or buyer (β).
- One-third of the states (4) reported that no incentives were allowed; the remainder reported maximum incentives ranged for 105% to 112%. Of these states, the average incentive was 103%.
- States allowing incentives reported that the percentage of jobs receiving bonuses ranged from 60 to 100 % (average 85%). One state, Arkansas, reported that only 20% received bonuses.
- QA lot sizes ranged from 750 tons to 5,000 tons. Some states varied lot size with the attribute tested or use of the material (base or surface course)
- Eight out of 10 states responding to the question reported virtually no HMA were rejected (removal and Replacement) during a typical year while two states reported HMA rejection between 10 and 50 percent.

Additional current information about states' existing specifications was requested by Mahoney and Backus through their 1999 survey, allowing them to directly analyze and compare elements of states' QC/QA specifications. In addition to collecting information on the general use and nature of QC/QA specifications, the Mahoney and Backus survey also requested copies of current specifications allowing direct comparisons of some elements. Table 5 shows Binder Content Tolerances, Density Limits and other information taken from these states' specifications. The report notes that states have developed a wide array of quality requirements and specifications despite the fact that in each case the end product serves essentially the same function (Mahoney & Backus, 1999). In 2004, Lundy, Wurl, & Remily reported most state DOTs were using the quality level approach to determine the Percent Defective (PD) or Percent within Limits (PWL).

Table 5: Binder Content and Density Reqirements (Lundy, Wurl, & Remily, 2004)

State	Binder Content Tolerance				Percent Density Requirements				
AR	✓	✓	✓	VMT, VMA	✓	✓	✓	✓	VMT, VMA
FL	✓	✓	✓	VMT	✓	✓	✓	✓	VMT
IN	✓	✓	✓	VMT, VMA	✓	✓	✓	✓	
KY	✓	✓	✓	VMT, VMA		✓	✓		VMT, VMA
OH	✓	✓	✓[1]		✓	✓	✓		VMT, VMA
OR	✓	✓	✓	VMT, VMA, VFA[2]	✓	✓	✓		VMT, VMA, VFA
RI					✓	✓	✓	✓	
SC	✓					✓	✓		VMT, VMA
WA	✓				✓	✓	✓	✓	
WI	✓			VMT	✓	✓	✓	✓	VMT
WY				[3]	✓	✓	✓	[4]	

Notes: [1]Percent of Maximum Specific Gravity unless otherwise noted; [2]Percent of valid Control Strip Density; [3]Dependss on number of samples taken; VFA: Voids Filled with Asphalt Binder; VMA: Voids in Mineral Aggregates; VMT: Vehicle Miles Traveled

Arkansas Highway & Transportation Department Incentive Specifications

According to AHTD 2003 Standard Specifications, for a general contractor to receive incentives for ACHM Binder Course and/or ACHM Surface course, it is necessary to produce a pavement that is durable and consistently exceeds the minimum test values set forth in the specification manual. When the entire quantity of either the ACHM Binder Course or ACHM Surface Course (including any sublots used for leveling) meets the following criteria, an incentive of the percentage designated will be applied to the dollar amount for all the components of the designated mix (AHTD, 2003). Only the average test results for each lot will be given consideration for incentive purposes. A Change Order for incentive payments will be listed as a separate item increase on the final estimate. As indicated in the AHTD Standard Specifications (2003), an accumulated maximum 6.0% incentive payment is available as follows:

(a) An incentive payment of 3.0% will be added if:
1. The asphalt binder content is within ±0.2 percentage point of the mix design value, and
2. The total variation, low to high, in air voids is no more than 0.6%, with none outside of the compliance limits
3. All densities fall between 92.0%[4] and 96.0%, and
4. There are no areas of segregation outside of the compliance limits as verified by testing according to AHTD Standard Specification for Highway Construction (2003), Subsection 410.09(b)(3)

(b) An additional incentive payment of 2.0% will be added if the requirements of (a) above are met and if the VMA are within the compliance limits.

(c) If the Contractor elects, an additional incentive payment of 1.0% of the total ACHM Surface Course quantities used on the project will be added if:
1. The pavement smoothness incentive criteria are met
2. There are no corrective patches[5]
3. The requirements of both (a) and (b) above are met.

AHTD Standard Specifications (2003) states that in order for contractors to receive smoothness incentive payment, Contractors must furnish and operate a California-style profilograph complying with ASTM E1274-03 specifications (ASTM, 2012a). The Contractor may choose to utilize an automated lightweight profilometer, but must be calibrated to the California-style profilograph scale complying with ASTM E 950, Class I. The AHTD Standard Specifications (AHTD, 2003) also specifies that:

1. The finished surface shall have a maximum profile index of 3 inches per mile (± 0.1 inch blanking band) per 0.1 mile section (50 mm/km [± 2.5 mm blanking band] per 200 m section), or portion thereof, for the entire project (California Deapartment of Transportation, 2002). Individual sections will not be considered for the incentive.

   In addition to the above requirements for profile indices, on the final surface course, no areas representing high or low points having a deviation greater than 0.3 inches in 25 feet (7.5 mm in 7.5 m) as determined by the profilograph shall be present.

2. The Contractor shall take all profiles required by this subsection under the observation of the Engineer. All data obtained from the profiling operations will be furnished to the Engineer to be considered for any incentive payment.

[4] When the minimum specification density is 90.0%, this value is changed to 90.0%.
[5] Any repaved section of 1000 feet (300 m) or greater in length for a full lane width will not be considered a patch.

The road's profile will be taken near the center of each main traffic lane using a California-style profilograph or lightweight profilometer. To assure its proper operation, the Engineer will verify the profilograph equipment's calibration as frequently as needed. Also scheduling and testing will be coordinated with the Engineer and the Contractor will be responsible for providing all traffic control associated with the surface testing operations.

For daily operations, the profile shall begin 10 feet (3.25 m) back onto the previous day's route and continuously proceed within 10 feet (3.25 m) of existing structures/pavement or from the end of the pavement. The profile may also be determined upon project completion by a trace running continuously within 10 feet (3.25 m) of existing structures/pavement or from the end of the pavement. For either case, the incentive payment will be determined once the project is complete and all profile traces have been submitted to the Engineer for the project files.

CHAPTER 3 – METHODOLGY

Research conducted by the American Association of State Highway and Transportation Officials (AASHTO) revealed sustaining deteriorating roads costs significantly more over time than regularly maintaining a road in good condition. Illustrating the reconstruction costs per lane mile can be more than three times the preservation treatment costs over a 25 year period (Becker & Moretti, 2009). The objective of Pavement Management is to assess the planning, constructing and repairing of its network of state highways and road systems. This helps to ensure that pavement networks are upheld to optimal conditions. Pavement management includes numerous phases and responsibilities. These requirements aid in sustaining pavement and assuring overall status of the highway and road systems to continue at desired levels. The incorporation of life cycle costs for any pavement management plan is an organized method for major and minor pavement maintenance, rehabilitation projects and new construction. Before any construction projects commence, budget estimates, right-of-way constraints, environmental issues and roadway requirements should first be considered.

AHTD Pavement Management System

Contributing factors such as age, weather, traffic volume and delayed maintenance can cause road deterioration. Moisture, freezing, thawing and poor drainage also contribute to cracks, ruts, potholes and foundation deterioration (Becker & Moretti, 2009). The mission statement of the AHTD Pavement Management Section is to offer essential tools and methods that decision makers need to institute cost effective strategies to provide the public quality and serviceable pavement (AHTD, 2013b). It is the responsibility of the AHTD Pavement Management Section to collect, process, analyze and report pavement performance data for over 16,400 miles of centerline roads. Reporting the state highway system’s pavement performance data is a federally mandated requirement for each route every two years. Any exceptions to this mandate require that reports to the National Highway System and the Interstate Highway System must be provided every year.

The Pavement Management Section employs the Multimedia Highway Information System (MMHIS) as their primary tool for reporting and sharing data with AHTD. The main feature of the MMHIS is its ability to provide viewing of road segments without leaving the office. Utilizing images generated from Automatic Road Analyzer (ARAN), the MMHIS will combine roadway images with the corresponding information from section databases such as Bridge, Pavement Management System, Project History, Road Inventory and Safety. The MMHIS has function buttons allowing the user to view recorded road segments, which employs as many as six different camera perspectives. The ARAN vehicle has five right-of-way and one pavement camera, which can be attached to corresponding data into a separate window of MMHIS.

Besides pavement and bridges, the Pavement Management department oversees the roadway right-of-way assets to include signs, sign structures, culverts, guard rails, barrier walls, and median cross-over avoidance systems. Managing these assets is of great importance to AHTD since these items add an immense capital cost to roadways. To locate and inventory these assets, the Pavement Management Section uses imaging software in conjunction with camera images provided by the ARAN. Through this technology, each asset can be located by log mile and geographic coordinates and store condition assessments for use in an asset management database system (AHTD, 2013b).

Automatic Road Analyzer (ARAN)

The most important data tool utilized in the Pavement Management section is Automatic Road Analyzer (ARAN) which collects pavement profile data and high-resolution right-of-way and pavement imagery for nearly 9,500 centerline miles of roadways per year (AHTD, 2013b). The ARAN is a two part data collection platform having the capability for collecting the majority of data and imagery required in determining pavement condition. Its advanced platform provides current pavement conditions and essential data for analysis, while the modular platform allows the data to be acquired at "highway speeds." Some of the elements provided by the ARAN are:

- International Roughness Index (IRI)
- Rutting (Figure 6) / Faulting (Figure 7) / Cracking (Figure 8)
- Macro Texture (Figure 9)
- Geometrics (Curve, Grade, Crossfall, Super-elevation)
- Geographic Location
- Roadway Features
- Roadway Assets

Figure 6: Example of Rutting

Figure 7: Example of Faulting

Figure 8: Example of Cracking

Figure 9: Example of Macro Texture

ARAN Data Processing & Analysis

Once the pavement data has been downloaded from the ARAN to the AHTD computer servers, the data is available for departmental use. It can be processed with numerous software packages providing data in a ready-to-use format with the department's analysis software.

Several steps must be completed before any analysis can take place. The Geographic Location data is generated within the Pavement Management department's Geographic Information System (GIS) allowing accuracy when referencing all other data items. All sensor measured data items are verified for accuracy through vendor provided software. With the completion of these two steps, the analysis process will begin with importing the data so each route can be broken into segments of similar characteristics. The comparison of pavement classes provides historical performance allowing a determination for the class of pavements' overall performance, which can be gauged to provide a tool to establish the best cost effective method of maintaining the system.

The majority of asphalt pavement surface cracking is measured by vendor software made, which measures each crack's extent, type and average width. The automated system collects any major distresses, for example transverse, reflective, fatigue and longitudinal cracking, which is tracked both inside and outside the wheels' path. These results are statistically similar to other manual measurement and analysis methods. The automated crack detection system is not suitable for chip seal asphalt and most concrete pavement, which require a semi-automated computer based crack detection system (AHTD, 2013b).

The computer images being employed by both the automated and the manual detection systems can detect cracks, locate extents, estimate average widths and establish the type of crack. The software also quantifies types of asphalt pavement distresses such as edge and joint distress as well as surface raveling, bleeding and patches, which can be reported in a database format. The distresses can be collected into manageable pieces and into the Pavement Management database that can be retrieved by log mile or geographic location.

International Roughness Index & Rutting Background

Since its introduction in 1986, IRI has become the road roughness index most commonly used worldwide for measuring and evaluating longitudinal road profiles and managing road systems (Sayers, Gillespie, & Paterson, 1986). IRI measurement data is required to be provided to the United States Federal Highway Administration (FHWA). The standards governing the IRI are ASTM E1926 – 08, Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements (ASTM, 2008) and ASTM E1364 – 95, Standard Test Method for Measuring Road Roughness by Static Level Method (ASTM, 2012b). IRI calculated using a quarter-car vehicle math model, whose response is accumulated to yield a roughness index with units of slope expressed in inches per miles (in/mi) or meters per kilometer (m/km) (Sayers & Karamihas, 1998). IRI is also used to evaluate new pavement construction and to determine penalties or bonus payments based on smoothness.

States use the IRI to rate road conditions for which the FHWA will compile the data to create an assessment of pavement conditions and rate the condition of the road as good, fair, mediocre and poor. The FHWA findings are based partly on a study which measured driver reactions to various road conditions to determine what level of road roughness was unacceptable to most drivers (Shafizadeh, Mannering, & Pierce, 2002).

Roads which are rated as poor will have noticeable rougher surfaces, cracks and broken pavement, which places more stress on a driver's vehicle. These are significant indicators of pavement distress and deterioration. The effect is an unacceptable ride quality on roads rated poor that are in need of pavement resurfacing and/or reconstruct the underlying surface to correct any problems. Roads rated as being in either mediocre or fair condition may also show signs of deterioration and may be noticeably inferior to those of new pavements. These roads can still be improved to good condition with cost-effective resurfacing or other surface treatments, which will extend the roads' service life (Becker & Moretti, 2009). The FHWA found road conditions with an IRI rating (U.S. Department of Transportation, 2002) in Figure 10 shows the typical ranges of IRI.

- Below 95 provides a good ride quality and is in good condition
- 95 to 119 provides an acceptable ride quality and is in fair condition
- 120 to 170 provides an acceptable ride quality and is in mediocre condition
- above 170 provides an unacceptable ride quality and is in poor condition

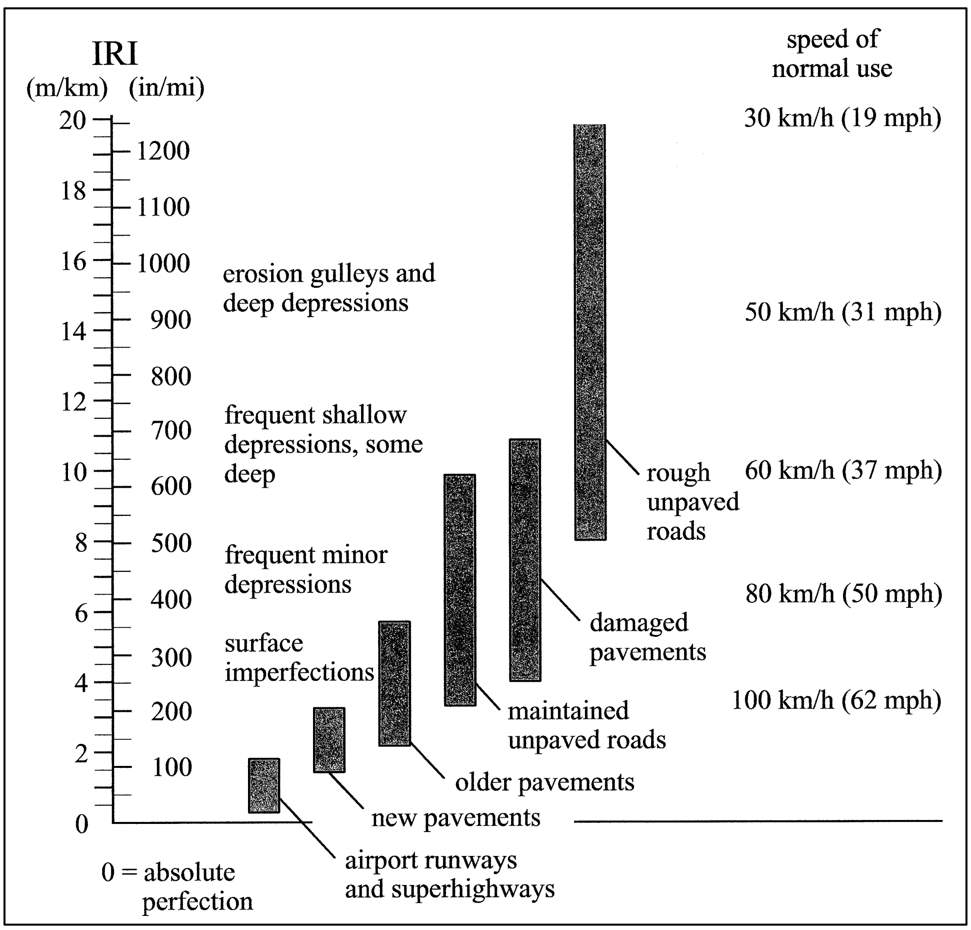


Figure 10: Typical Ranges of IRI

Rutting can be defined as the accumulation of small amounts of unrecoverable strains as a result of applied loading to a pavement (Kandhal & Cooley, 2003). Rutting arises when the upper portion of pavement from traffic loading combines with the shear failure of lateral movement of the Asphalt Concrete Hot Mix (ACHM). This occurrence reduces pavement life and if the rutting depth is significant may lead to vehicle hydroplaning ,where water has accumulated in rutted areas. ATHD utilizes a three catergory system to evaluate pavement rutting measured in inches per mile:

- 0.000 – 0.349 provides a good ride quality and is in good condition
- 0.350 – 0.499 provides an acceptable ride quality and is in fair condition
- Above 0.500 provides an unacceptable ride quality and is in poor condition

ACHM consists of aggregate, binder and air formulate, which any of the three can have an influence on rutting for an ACHM pavement. A dense-graded ACHM is composed of approximately 90 percent of aggregate, whose shape and texture can influence mixture performance. In most cases, aggregate provides better performance with a rough texture than smooth, because the rougher texture allows aggregate to interlock better and reduce the potential for rutting.

The binder is also an important factor in rutting, since the asphalt binder becomes less viscous at higher temperatures. Lowering the viscosity creates a less rigid pavement which can be prone to lateral movement from traffic loads. To produce a more durable and superior pavement, compaction during construction is essential. The final element to ACHM is air and if the mixture's air content is high, the pavement can be susceptible to rutting caused by more compaction under traffic loading. Should the air content be too low could be an indicator of an excess of binder in the mixture, causing the binder to be less rigid and increasing the hazard of rutting (Maupin & Mokarem, 2006).

Truck speed, contact pressure, layer thickness and truck wheel wandering are other factors than can induce rutting in ACHM pavements. As truck speeds decrease, stress increases due to longer contact time on pavements, which increases the probability of rutting. The contact pressure also influences pavement performance since higher tire pressure can create higher stresses on pavement. Typically, a thicker ACHM pavement layer has a better ability to resist rutting since the layer is usually more firm. The final influence on rutting can be truck wheel wandering which increases the amount and distance of lateral movement in the pavement. Excessive wheel wandering has the potential to create wider and deeper ruts in an ACHM pavement.

International Roughness Index & Rutting Data Investigation

Phase One of this study began with the separation of the ten districts in Arkansas. This would allow for consistent comparison of raw materials, asphalt batch plants, Average Daily Traffic (ADT), weather and topography which are unique to each district. To begin this phase, projects were collected through AHTD SiteManager Access Reports System (SARS) (Figures 11 and 12).

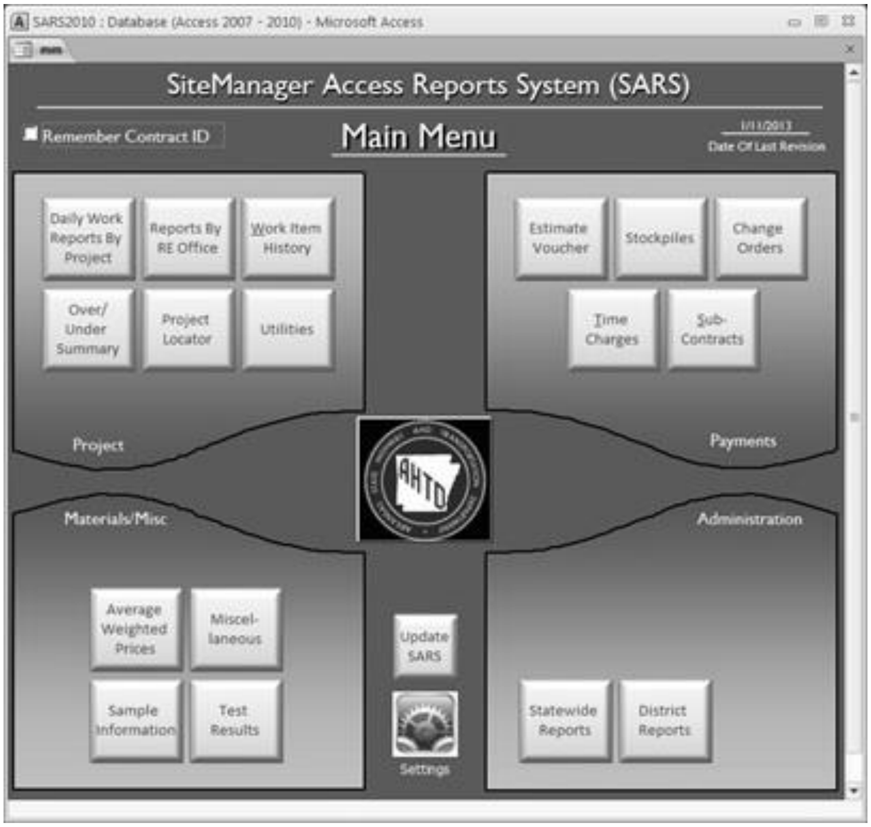


Figure 11: SARS Main Menu Selection Page

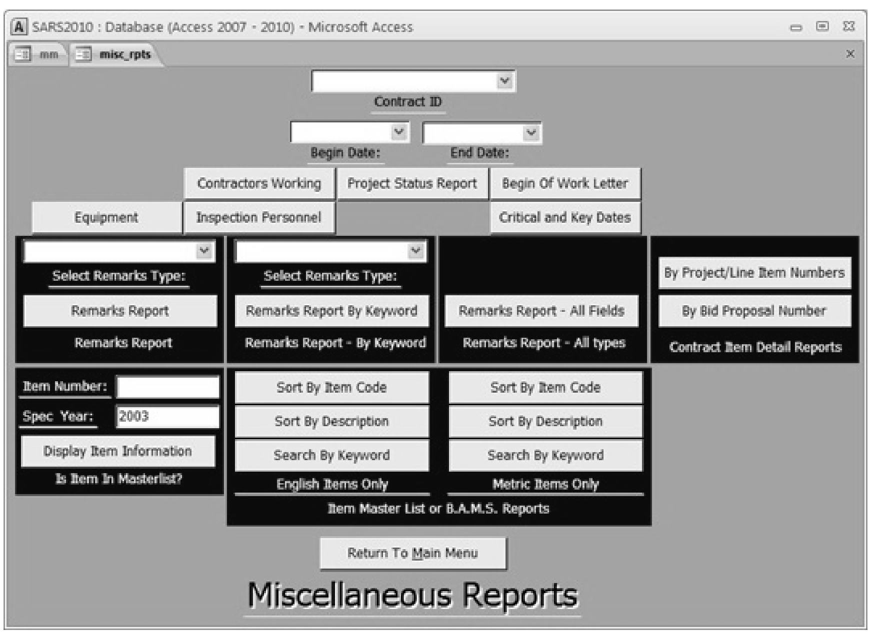


Figure 12: SARS Miscellaneous Reports Search Page

There were 867 completed ACHM construction projects, from 2005 to 2011. These were initially reviewed as potential candidates for this study. Projects were separated into two groups, projects that received ACHM incentive pay and projects that did not. These two groups were further divided into three monetary categories: projects less than two million dollars, projects between two and five million dollars and projects over five million dollars. Table 6 outlines the number of projects for each monetary group for both incentive and non-incentive projects.

Table 6: AHTD Completed Projects, 2005 to 2011

Projects Receiving Incentive Payment		Projects Not Receiving Incentive Payment	
Less Than $2 Million	532	Less Than $2 Million	181
Between $2 to $5 Million	40	Between $2 to $5 Million	30
Over $5 Million	40	Over $5 Million	44

The three monetary groups were established by the type of construction performed. Projects less than two million dollars usually consisted of ACHM pavement overlays. Projects between two million and five million dollars were typically notch & widening or lane addition jobs. Projects over five million dollars were usually new construction or complete rehabilitation jobs. Projects within each monetary group were separated by AHTD District, which insured the criteria of raw materials, asphalt batch plants, ADT, weather and topography were similar. These groupings were made to ensure validity of project comparisons.

From the intial pool of 867 construction projects, 231 construction projects were selected for the initial pavement data retrieval from the Pavement Management section. The initial retrieval produced 159 projects with available annual pavement data reports. Thirty-six (36) projects (Table 7) were selected for the final project pairing comparison of IRI and rutting data according to AHTD districts, monetary amounts and contractor. The second and final pavement data retrieval provided data results supporting the comparison analysis of the 18 construction projects pairings.

Table 7: Final Project Pairing Selection for Data Analysis

Projects Receiving Incentive Payment		Projects Not Receiving Incentive Payment	
Less Than $2 Million	6	Less Than $2 Million	6
Between $2 to $5 Million	5	Between $2 to $5 Million	5
Over $5 Million	7	Over $5 Million	7

Project comparison criteria were restricted to help eliminate the variables inherent within the gross amount of project data available. Because construction methods, experience and workmanship greatly varies between contractors, the project pairing had to be sorted by the contractor performing the ACHM placement. This standard meant the contractor would have completed the ACHM for incentive paid and non-incentive paid projects for that pairing, regardless of whether they were the prime contractor or not. Since acceptance testing is performed by the ACHM contractor, this also guaranteed the testing methods were the same for the pairings. Tables 8, 9 and 10 shows Excel spreadsheet examples of monetary groups for AHTD construction projects.

Table 8: AHTD Projects Receiving & Not Receiving Incentives Paid - Less Than Two Million Dollars

AHTD Projects Receiving Incentives Paid – Less Than $2 Million									
Job #	**Bid Amount**	**Contractor**	**Dist.**	**Rte.**	**BLM**	**PL**	**ELM**	**PBD**	**CCD**
110539	$1,385,321	APAC-TENNESSEE, INC.	01	147	7.4	5.50	12.90	8/18/09	9/4/09
S10106	$581,062	DRUMMOND ASPHALT CONST., INC. (Section 12)	01	64	2.29	0.95	3.24	5/15/08	6/17/08
S10106	$581,062	DRUMMOND ASPHALT CONST., INC. (Section 13)	01	64	1.10	0.00	1.10	5/15/08	6/17/08
040537	$551,922	APAC-CENTRAL, INC.	04	412	6.59	1.78	8.37	5/26/09	7/8/09
040567	$516,279	BLACKSTONE CONSTRUCTION, LLC	04	022	20.49	1.89	22.38	6/29/10	9/16/10
080393	$866,520	BLACKSTONE CONSTRUCTION, LLC (Section 7)	08	9	2.25	2.85	5.10	8/24/10	10/14/10
080393	$866,520	BLACKSTONE CONSTRUCTION, LLC (Section 8)	08	9	7.1	1.90	9.00	8/24/10	10/14/10
100718	$1,421,906	ATLAS ASPHALT, INC.	10	63	3.57	5.00	8.57	6/1/10	7/20/10
AHTD Projects Not Receiving Incentives Paid – Less Than $2 Million									
Job #	**Bid Amount**	**Contractor**	**Dist.**	**Rte.**	**BLM**	**PL**	**ELM**	**PBD**	**CCD**
110551	$627,641	APAC-TENNESSEE, INC.	01	147	5.34	1.60	6.94	6/17/11	7/6/11
110475	$554,664	DRUMMOND ASPHALT CONST., INC.	01	64	11.60	2.21	13.81	4/21/05	6/16/05
S10402	$730,972	APAC-CENTRAL, INC.	04	412	8.39	2.47	10.86	9/13/07	10/12/07
040592	$616,081	APAC-CENTRAL, INC.	04	71	1.44	1.15	2.59	7/20/11	8/13/11
040592	$616,081	APAC-CENTRAL, INC.	04	71	3.25	0.58	3.83	7/20/11	8/13/11
S10401	$562,772	BLACKSTONE CONSTRUCTION, LLC	04	22	0.00	2.40	2.40	6/18/07	7/25/07
080374	$826,949	BLACKSTONE CONSTRUCTION, LLC	08	9	11.90	4.01	15.91	8/10/10	11/4/10
S11007	$1,667,984	ATLAS ASPHALT, INC.	10	63	0.00	8.29	8.29	8/13/07	11/19/08

BLM – Beginning Log Mile; PL – Project Length; ELM – Ending Log Mile; PBD – Project Begin Date; CCD – Construction Completed Date

Table 9: AHTD Projects Receiving & Not Receiving Incentives Paid - Two Million to Five Million Dollars

AHTD Projects Receiving Incentives Paid - $2 Million to $5 Million									
Job #	**Bid Amount**	**Contractor**	**Dist.**	**Rte.**	**BLM**	**PL**	**ELM**	**PBD**	**CCD**
110521	$2,143,171	APAC-TENNESSEE INC.	01	79	0.00	9.63	9.63	4/22/09	7/15/09
110469	$2,219,288	ROBERTSON CONTRACTORS, INC.	01	79	0.00	0.00	0.00	2/23/09	9/14/10
020322	$3,774,322	IDEAL CONSTRUCTION CO.	02	133	0.00	1.24	1.24	3/6/07	4/22/09
020044	$3,459,557	JOHNSONVILLE CO., LLC	02	1	0.00	0.00	0.00	6/30/05	6/21/07
020286	$2,072,571	R. THOMPSON, INC.	02	35	10.37	0.87	11.24	12/4/06	12/27/07
020418	$2,767,168	TOTAL SITE DEVELOPMENT, LLC	02	278	5.54	0.62	6.16	7/16/09	11/29/10
030329	$2,598,356	APAC-TEXAS, INC.	03	71	7.96	0.60	8.56	5/5/05	8/22/05
030285	$2,391,443	BEST-YET BUILDERS, LLC	03	26	12.39	0.78	13.17	10/4/07	11/3/08
AHTD Projects Not Receiving Incentives Paid - $2 Million to $5 Million									
Job #	**Bid Amount**	**Contractor**	**Dist.**	**Rte.**	**BLM**	**PL**	**ELM**	**PBD**	**CCD**
110342	$ 4,386,264	MOBLEY CONTRACTORS, INC.	01	77	12.85	1.52	14.37	4/17/06	3/13/08
110463	$ 4,481,120	APAC-TENNESSEE, INC.	01	118	3.12	1.17	4.29	10/12/05	8/7/07
110505	$3,196,773	APAC-TENNESSEE, INC.	01	118	3.30	0.84	4.14	4/19/10	6/29/11
S10105	$2,765,856	APAC-TENNESSEE, INC.	01	1	1.84	0.95	2.79	5/15/08	11/6/08
020339	$3,627,049	R. THOMPSON, INC.	02	133	5.42	3.54	8.96	3/30/05	3/27/06
020415	$3,473,848	R.M. COURSON, INC.	02	425	3.70	3.64	7.34	9/8/06	9/11/07
020417	$2,272,148	MANHATTAN ROAD & BRIDGE CO.	02	33	5.59	0.51	6.10	8/25/09	3/8/11
030078	$4,162,443	R.K. HALL CONSTRUCTION, LTD. (Section 5)	03	278	24.12	0.18	24.30	9/6/07	10/1/10
030078	$4,162,443	R.K. HALL CONSTRUCTION, LTD. (Section 5B)	03	278B	0.00	1.17	1.17	9/6/07	10/1/10
R30026	$2,108,640	EARNEST INVESTMENTS, LLC	03	24	0.10	0.71	0.81	6/13/08	9/29/09

BLM – Beginning Log Mile; PL – Project Length; ELM – Ending Log Mile; PBD – Project Begin Date; CCD – Construction Completed Date

Table 10: AHTD Projects Receiving & Not Receiving Incentives Paid - Over Five Million Dollars

AHTD Projects Receiving Incentives Paid - Over $5 Million									
Job #	**Bid Amount**	**Contractor**	**Dist.**	**Rte.**	**BLM**	**PL**	**ELM**	**PBD**	**CCD**
110517	$5,849,734	APAC-TENNESSEE, INC.	01	40	277.22	2.19	279.41	6/16/10	8/12/11
090116	$21,579,430	KIEWIT SOUTHERN CO.	04	412	0.00	5.52	5.52	9/28/06	10/27/08
040439	$7,588,661	FORSGREN, INC.	04	22	8.90	2.10	11.00	7/6/09	11/17/10
061185	$13,677,341	KIEWIT SOUTHERN CO.	06	67	6.46	1.62	8.08	7/10/09	4/13/10
090154	$14,060,426	APAC-CENTRAL, INC.	09	59	20.75	3.03	23.78	6/12/06	1/23/09
100716	$22,210,773	DELTA ASPHALT OF ARK., INC.	10	55	62.41	5.21	67.62	1/24/11	7/6/12
100566	$11,731,844	ROBERTSON, INC., BRIDGE & GRADING DIV.	10	412	2.62	4.18	6.80	8/3/05	4/1/10
AHTD Projects Not Receiving Incentives Paid - Over $5 Million									
Job #	**Bid Amount**	**Contractor**	**Dist.**	**Rte.**	**BLM**	**PL**	**ELM**	**PBD**	**CCD**
110492	$26,693,323	APAC-TENNESSEE, INC.	01	40	279.32	1.32	280.64	1/7/09	9/15/10
004818	$6,072,038	GILBERT CENTRAL CORP.	04	309	18.72	4.38	23.10	11/8/05	8/6/07
061239	$18,813,387	KIEWIT SOUTHERN CO.	06	430	6.30	0.07	6.37	7/20/09	1/19/11
090148	$7,247,908	APAC-CENTRAL, INC.	09	59	22.51	2.81	25.32	5/25/07	6/11/09
100304	$11,579,770	DELTA ASPHALT OF ARK., INC.	10	18	6.20	4.43	10.63	4/16/07	11/14/08
100307	$8,626,637	DELTA ASPHALT OF ARK., INC.	10	18	0.00	6.20	6.20	8/25/10	12/10/12
100478	$7,373,154	ROBERTSON, INC., BRIDGE & GRADING DIV.	10	412	6.82	1.18	8.00	8/25/03	11/21/06

BLM – Beginning Log Mile; PL – Project Length; ELM – Ending Log Mile; PBD – Project Begin Date; CCD – Construction Completed Date

The information needed to properly pair each project was retrieved through Project Status Reports (PSR) (Figure 13), which were obtained through SARS database to build these two subcategories.

Project Status Report

Page 1 of 1
Current As Of: 2/28/2013 12:59:47 PM

Contract ID: **050011**
Contract Name: **Knob Creek Strs. & Apprs. (S)**
F.A.P. Number: **BRN-0033(18)**
County: **Izard**
Route: **9** **Section:** **13**

Prime Contractor: Cameron Const. Co., Inc.
Assigned To RE Office: 53

Contract Bid Amount:	$2,724,628.18	
Net Changes by Change Order:	$174,748.09	
Current Contract Amount	$2,899,376.27	
Total Amount Paid:	$2,804,804.05	
Amount Remaining:	$94,572.22	(Based on Current Contract Amount)
Percent Complete:	96.7%	(Calculated from the Current Contract Amount)

Total Days Charged As Of Last Estimate:	153	
Total Contract Time:	150	
Percent Time Used:	102.0%	This is a working day contract.
Liquidated Damages Amount Per Day:	$1,380.00	

Work Order Date: 10/7/09
Ending Date Of Last Estimate: 2/27/12

Substantially Complete Date: 11/22/10
Acceptance Date: 9/6/11
Release Date: 4/19/12

Total Days Assessed: 153
Percent of Total Days Assessed: 102.0%

Note: The Total Days Assessed includes time charges which have been included in an estimate and time charges which have not been included in an estimate.

Insurance Company: The Cashion Company
Surety Company: Liberty Mutual Insurance Group
Surety Agent: Judy Schoggen

Description of Project:

The Purpose Of This Project Is To Replace Three Bridges On Hwy. 9 In Izard County. This Project Consists Of Aggregate Base Course, Achm Base, Binder And Surface Courses, One Quadruple R.C. Box Culvert (Total Span Length 50.39'), One Quintuple R.C. Box Culvert (Total Span Length 68.16'), One Triple R.C. Box Culvert (Total Span Length 45.41'), Erosion Control Items And Misc. Items.

Figure 13: Project Status Report example

By using the PSR Job number, each state highway project was then reviewed to verify and document the Job Number, Project Begin Date, Substanially Completion Date, Beginning Log Mile, Ending Log Mile, Route and Section Number. The video sources gathered from the Multimedia Highway Inspection System (MMHIS) database verified the data acquired through SARS. Before AHTD Planning & Reseach Division could perform the first round data search of the pavement profiles for each project, an Excel spreadsheet (Tables 11, 12 and 13) had to be created.

Table 11: Final Project Data for submission Construction Projects: Less Than $2 Million

AHTD Projects Not Receiving Incentives Paid – Less Than $2 Million					
Job Number	**PBD**	**CCD**	**BLM**	**ELM**	**Route & Section**
110551	6/17/2011	7/6/2011	5.34	6.94	147010
110475	4/21/2005	6/16/2005	11.60	13.81	064160
S10402	9/13/2007	10/12/2007	8.39	10.86	412020
040592	7/20/2011	8/13/2011	1.44	2.59	07116B
040592	7/20/2011	8/13/2011	3.25	3.83	07116B
040513	1/6/2009	3/23/2009	0.00	5.80	059050
S10401	6/18/2007	7/25/2007	0.00	2.40	022040
080374	8/10/2010	11/4/2010	11.90	15.91	009060
S11007	8/13/2007	11/19/2008	0.00	8.29	063030
AHTD Projects Receiving Incentives Paid – Less Than $2 Million					
Job Number	**PBD**	**CCD**	**BLM**	**ELM**	**Route & Section**
110539	8/18/2009	9/4/2009	7.4	12.90	147010
S10106	5/15/2008	6/17/2008	2.29	3.24	064120
S10106	5/15/2008	6/17/2008	1.10	1.10	064130
040537	5/26/2009	7/8/2009	6.59	8.37	412020
040567	6/29/2010	9/16/2010	20.49	22.38	022030
080393	8/24/2010	10/14/2010	2.25	5.10	009070
080393	8/24/2010	10/14/2010	7.1	9.00	009080
100718	6/1/2010	7/20/2010	3.57	8.57	063070

BLM – Beginning Log Mile; ELM – Ending Log Mile; PBD – Project Begin Date; CCD – Construction Completed Date

Table 12: Final Project Data for submission for Construction Projects: $2 Million to $5 Million

AHTD Projects Receiving Incentives Paid – $2 Million to $5 Million					
Job Number	**PBD**	**CCD**	**BLM**	**ELM**	**Route & Section**
110342	4/17/2006	3/13/2008	12.85	14.37	077050
040397	8/18/2005	10/19/2006	8.90	9.76	062010
040472	10/15/2009	10/20/2010	4.43	6.63	022030
040184	9/23/1999	5/11/2001	1.24	2.22	253020
040399	6/13/2006	7/26/2007	0.91	1.52	112000
040111	3/10/2006	4/30/2007	4.25	4.71	252010
040398	9/9/2004	10/9/2006	0.00	6.86	270010
090147	9/15/2005	7/3/2007	0.00	2.48	043000
090223	1/7/2010	12/7/2012	4.90	7.20	177010
AHTD Projects Not Receiving Incentives Paid – $2 Million to $5 Million					
Job Number	**PBD**	**CCD**	**BLM**	**ELM**	**Route & Section**
110521	4/22/2009	7/15/2009	0.00	9.63	079180
110469	2/23/2009	9/14/2010	9.40	9.64	079140
040423	11/13/2006	6/27/2008	10.30	12.04	016020
040514	9/16/2009	6/2/2010	21.35	21.62	023070
090266	6/22/2009	8/24/2009	4.82	10.00	412010
090202	10/7/2009	8/2/2011	18.83	20.65	412050
090153	4/3/2006	7/25/2007	3.56	4.00	072030
090073	1/29/2008	6/15/2009	2.80	3.99	023100

BLM – Beginning Log Mile; ELM – Ending Log Mile; PBD – Project Begin Date; CCD – Construction Completed Date

Table 13: Final Project Data for submission for Construction Projects: Over $5 Million

AHTD Projects Not Receiving Incentives Paid – Over $5 Million					
Job Number	**PBD**	**CCD**	**BLM**	**ELM**	**Route & Section**
110492	1/7/2009	9/15/2010	279.32	280.64	040520
040480	4/4/2007	8/26/2009	16.80	21.39	062010
004818	11/8/2005	8/6/2007	18.72	23.10	309020
040344	3/2/2006	8/15/2008	15.80	17.00	045010
090148	5/25/2007	6/11/2009	22.51	25.32	059010
090179	9/22/2008	8/23/2011	1.79	4.14	102030
100295	12/2/2003	7/16/2007	2.08	8.89	063040
100304	4/16/2007	11/14/2008	6.20	10.63	018060
100478	8/25/2003	11/21/2006	6.82	8.00	412090
AHTD Projects Not Receiving Incentives Paid – Over $5 Million					
Job Number	**PBD**	**CCD**	**BLM**	**ELM**	**Route & Section**
040583	6/5/2012	10/1/2012	62.00	63.80	540040
040151	1/4/2005	3/15/2007	20.68	24.60	412020
004938	10/24/2008	2/23/2011	4.36	5.77	071160
040439	7/6/2009	11/17/2010	8.90	11.00	022010
090229	1/16/2009	11/10/2011	10.50	12.18	062050
090226	11/6/2006	9/30/2009	3.06	7.78	062110
100716	1/24/2011	7/6/2012	62.41	67.62	055120
100566	8/3/2005	4/1/2010	2.62	6.80	412090

BLM – Beginning Log Mile; ELM – Ending Log Mile; PBD – Project Begin Date; CCD – Construction Completed Date

The first round data search compiled every project annual profile report from AHTD GeoMedia database ever gathered by the ARAN. For the second round of data retrival, only significant years were selected. To show a consistant comparison, a minimum of three data reports were required: One year preconstruction, construction year and one year postconstruction. Due to the AHTD's ARAN schedule, it was not always possible to have data representing one year before construction started and/or one year after construction completion. However, it was possible to match the data annually so that incentive paid projects and nonincentive paid projects could be precisely measured. After receiving the second round of the annual highway analysis data, Excel spreadsheets were separated into the three contract monetory amounts. Further investigation to obtain the project length was necessary to complete the averages for International Roughness Index (IRI) and rutting. Tables 14, 15 and 16 show the project comparison for a nonincentive paid and an incentive paid projects for each montary contruction category.

Table 14: IRI & Rutting Comparison for Projects Less Than $2 Million

	Job Number	Bid Amount	Contractor	IRI	Rutting	Dist.	PBD	CCD	Route & Section
NI1	110551	$627,641	APAC-TENNESSEE, INC.			01	6/17/11	7/6/11	147010
			JUL 2012	78.14	0.088				
			JUN 2010	165.86	0.332				
			JUN 2007	149.75	0.336				
	Job Number	Bid Amount	Contractor	IRI	Rutting	Dist.	PBD	CCD	Route & Section
PI1	110539	$1,385,321	APAC-TENNESSEE, INC.			01	8/18/09	9/4/09	147010
			JUL 2012	63.17	0.107				
			JUN 2010	162.93	0.309				
			JUN 2007	138.97	0.328				
NI – No Incentives; PI – Paid Incentives; Poject Begin Date; CCD – Construction Completed Date									

Table 15: IRI & Rutting Comparison for Projects $2 Million to $5 Million

	Job Number	Bid Amount	Contractor	IRI	Rutting	Dist.	PBD	CCD	Route & Section
PI	050188	$3,581,158	DELTA ASPHALT OF ARK., INC.			05	4/28/10	8/28/11	016130
			NOV 2012	99.61	0.096				
			JUL 2011	97.40	0.087				
			SEPT 2010	110.43	0.090				
			DEC 2009	99.42	0.125				
	Job Number	Bid Amount	Contractor	IRI	Rutting	Dist.	PBD	CCD	Route & Section
NI	050039	$3,047,510	DELTA ASPHALT OF ARK., INC.			05	2/15/07	10/6/08	025020
			OCT 2012	81.62	0.119				
			AUG 2011	79.40	0.123				
			SEPT 2010	76.42	0.126				
			JUL 2008	87.05	0.444				
			MAY 2002	149.64	0.263				
NI – No Incentives; PI – Paid Incentives; Poject Begin Date; CCD – Construction Completed Date									

Table 16: IRI & Rutting Comparison for Projects Over $5 Million

	Job Number	Bid Amount	Contractor	IRI	Rutting	Dist.	PBD	CCD	Route & Section
NI	100478	$7,373,154	ROBERTSON, INC., BRIDGE & GRADING DIV.			10	8/25/03	11/21/06	412090
			JAN 2002	178.27	0.217				
			MAR 2008	73.63	0.293				
			JUN 2009	69.83	0.179				
			APR 2012	71.91	0.093				
	Job Number	**Bid Amount**	**Contractor**	**IRI**	**Rutting**	**Dist.**	**PBD**	**CCD**	**Route & Section**
PI	100566	$11,731,844	ROBERTSON, INC., BRIDGE & GRADING DIV.			10	8/3/05	4/1/10	412090
			JAN 2002	154.46	0.217				
			JAN 2008	74.40	0.293				
			JUN 2009	72.78	0.179				
			APR 2012	58.04	0.093				

NI – No Incentives; PI – Paid Incentives; Poject Begin Date; CCD – Construction Completed Date

Once the projects were properly documented with their measureable data, Phase Two of this study was implemented by evaluating the projects’ characteristics based on IRI, rutting and maintenance records. This data was used to determine if any measureable differences exist by gathering information from the AHTD GeoMedia database. From these project characteristics, the incentive paid projects were evaluated with its paired nonincentive paid projects to determine if the incentive paid projects had actually provided a greater or superior quality pavement, an equal quality pavement or a less than quality pavement.

CHAPTER 4 – DATA ANALYSIS & RESULTS

AHTD provided the guidelines of the evaluation of incentives paid for ACHM. The most important preliminary analysis was related to controlling the dependent variables while removing the independent variables. This preliminary analysis is outlined on page 9, Chapter One, Figure 4.

The process of organizing and analyzing data was the key to understanding what the data contains. Raw data can take a variety of forms, including measurements, spreadsheets and charts. In its raw form, information can be incredibly useful, but also overwhelming. Over the course of the data analysis process, the raw data from the ARAN was arranged in a way to be valuable for AHTD in future specification reviews.

Analysis of Data

The data analysis for this study included annual pavement measurements and readings which were translated numerically into Excel spreadsheets. Table 17 is an example of the raw data for Job Number 110551, Route 147 Section 1. The July 2012 data is comprised of over 2300 lines of mileage ranging from 0.000 to 12.902 miles with a reading approximately every 0.003 miles.

Table 17: Example of Numerical Data collected by ARAN

Job Number 110551 Tue Jul 17 11:34:58 2012					
Route: 147 Section: 1					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
5.341	5.344	1.19	2.29	1	2
5.344	5.347	1.39	2.02	1	1
5.347	5.350	2.45	2.98	1	2
5.350	5.353	2.47	3.24	1	2
5.353	5.356	2.05	2.71	1	2
5.356	5.360	1.61	1.66	1	3
5.360	5.363	0.99	1.95	1	1
5.363	5.366	1.35	1.69	1	4
5.366	5.369	0.94	1.9	2	2
5.369	5.372	1.06	1.78	2	2
5.372	5.375	1.06	2.5	1	2
5.375	5.378	0.99	1.36	1	3
5.378	5.381	0.64	0.89	1	1
5.381	5.384	0.98	1.05	1	2
5.384	5.387	1.19	2.46	2	3
5.387	5.391	2.07	2.8	2	2
5.391	5.394	1.3	1.85	2	2
5.394	5.397	1.51	1.77	1	2
5.397	5.400	0.73	1.03	1	2
5.400	5.403	1.13	1.51	1	1
5.403	5.406	1.36	2	2	2

Construction project length for Job Number 110551 was 1.60 miles which began at mile marker 5.34 miles and was completed at 6.94 miles. Table 18 shows the IRI and Rutting for Left and Right Side of the route.

Table 18: Project Length Data for Job Number 110551

Job Number 110551 Tue Jul 17 11:34:58 2012					
Route: 147 Section: 010					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
5.341	5.344	1.19	2.29	1	2
6.938	6.941	0.77	0.78	3	3

Method of measurement for conducting and calibrating road roughness measurements, IRI, was set forth by the World Bank in the 1980s (Sayers, Gillespie, & Paterson, 1986). Readings for IRI and Rutting were computed to the tenths and thousandths, respectively. Using Excel formulas, the mean average for the left and right sides of routes for IRI and Rutting could be calculated using the data values for each column. A final average was taken to provide an overall mean average reading for IRI and Rutting. Values were then converted from m/km to in/mi using the SI[6] Conversion Chart (U.S. Department of Transportation, 2013) to make them applicable for AHTD. For the conversions, IRI was multiplied by 63.36 inches and Rutting was multiplied by 0.03937 inches.

Data Results

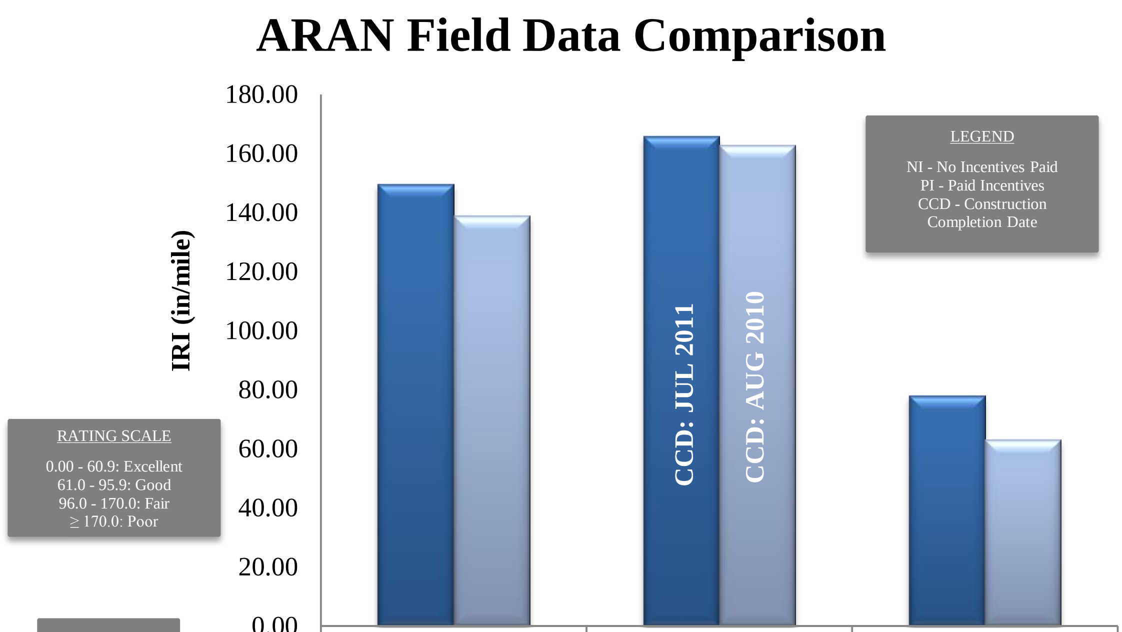
The first data comparison (Table 19) selected the July 2012 final mean averages from Job Number 110551 (Non-incentive Paid Project) and Job Number 110539 (Incentive Paid Project) from the category of Projects Less Than Two Million Dollars. The final mean average values reported for Job Number 110551 was an IRI of 78.20 in/mi and Rutting of 0.088 in/mi. The final mean average values for Job Number 110539 was an IRI of 63.17in/mi and Rutting of 0.107 in/mi.

Table 19: Final Mean Average Values for Job Number 110551 and 110539

Job Number 110551 Tue Jul 17 11:34:58 2012					
Route: 147 Section: 010					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
5.341	5.344	1.19	2.29	1	2
6.938	6.941	0.77	0.78	3	3
	Average	76.49	79.92	0.101	0.076
			78.20		**0.088**
Job Number 110539 Tue Jul 17 11:34:58 2012					
Route: 147 Section: 010					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
7.400	7.403	0.51	0.6	1	1
12.899	12.902	0.61	0.42	3	4
	Average	63.23	63.12	0.117	0.097
			63.17		**0.107**

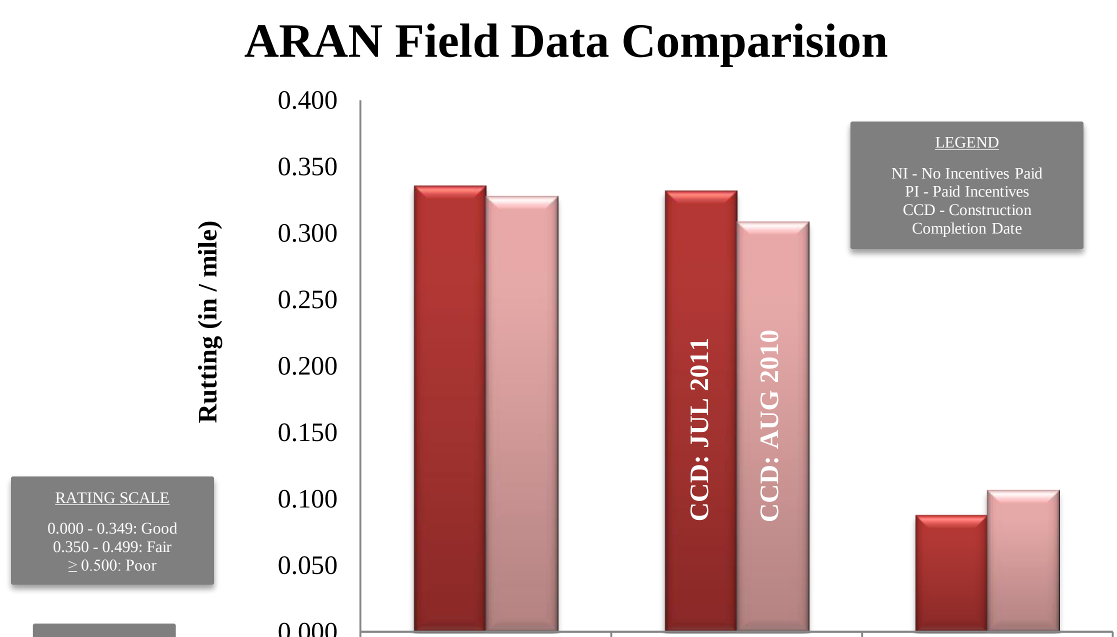
Once the data analysis was completed for Job Number 110551 and 110539, charts were generated through Excel to illustrate the ARAN field data for IRI and Rutting as shown in Figure 14 and 15.

[6] SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380 (ASTM, ASTM F1332 199 Standard Practice for Use of SI (Metric) Units in Maritime Applications, 1999).



Data Year	JUNE 2007	JULY 2010	JUNE 2012
Job # 110551: IRI (NI)	149.75	165.86	78.14
Job # 110539: IRI (PI)	138.97	162.93	63.17

Figure 14: ARAN Field Data Comparison of IRI for Job Number 110551 and 110539



Data Year	JUNE 2007	JULY 2010	JUNE 2012
Job # 110551: Rutting (NI)	0.336	0.332	0.088
Job # 110539: Rutting (PI)	0.328	0.309	0.107

Figure 15: ARAN Field Data Comparison of Rutting for Job Number 110551 and 110539

In Figures 14 and 15, the June 2012 data shows Job Number 110551 had an IRI of 78.14 and Rutting of 0.088 while Job Number 110539 had an IRI of 63.17 and Rutting of 0.107. After the Construction Completion Date (CCD), Job Number 110551, a non-incentive (NI) paid project, and 110539, an incentive paid (IP) project, received lower scores, taking both projects from Fair to Good category and showing no significant point range between the two projects. Job Number 110539 and 110551 scored in the Good category for rutting also showing no significant point range between the two projects.

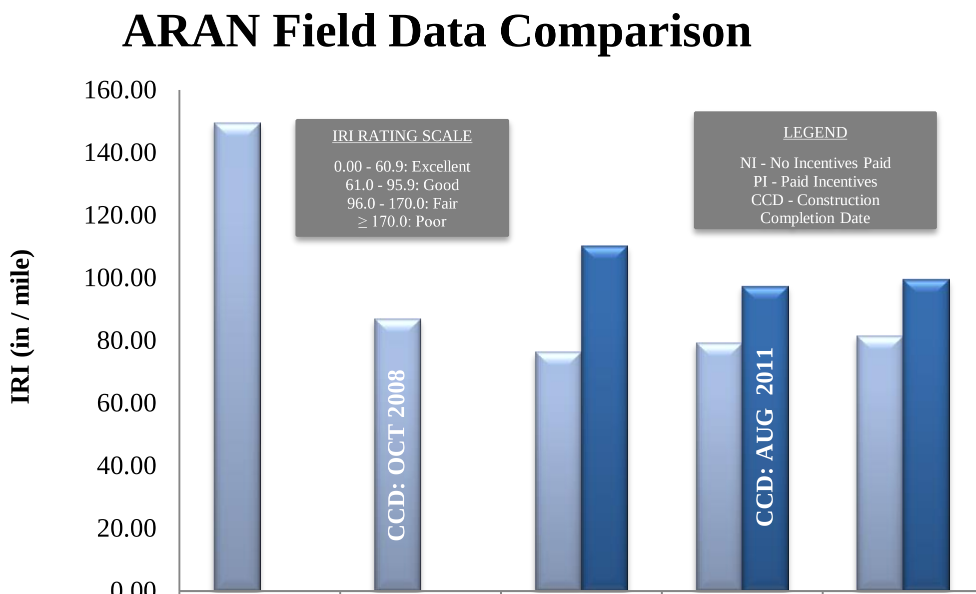
The second data comparison (Table 20) selected final mean averages from October 2012, Job Number 050039 (Non-incentive Paid Project), and November 2012, Job Number 050118 (Incentive Paid Project), from the category of Projects between Two and Five Million Dollars. The final mean average reported for Job Number 050039 was an IRI of 81.56 in/mi and Rutting of 0.119 in/mi. The final mean average for Job Number 050118 was an IRI of 99.91 in/mi and Rutting of 0.097 in/mi.

Table 20: Final Mean Average Values for Job Number 050039 and 050118

Job Number 050039 Thu Oct 25 11:20:35 2012					
Route: 025 Section: 020					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
8.801	8.804	0.7	1.46	3	4
11.168	11.171	1.31	1.54	3	4
	Average	77.851	85.273	0.114	0.124
			81.62		**0.119**

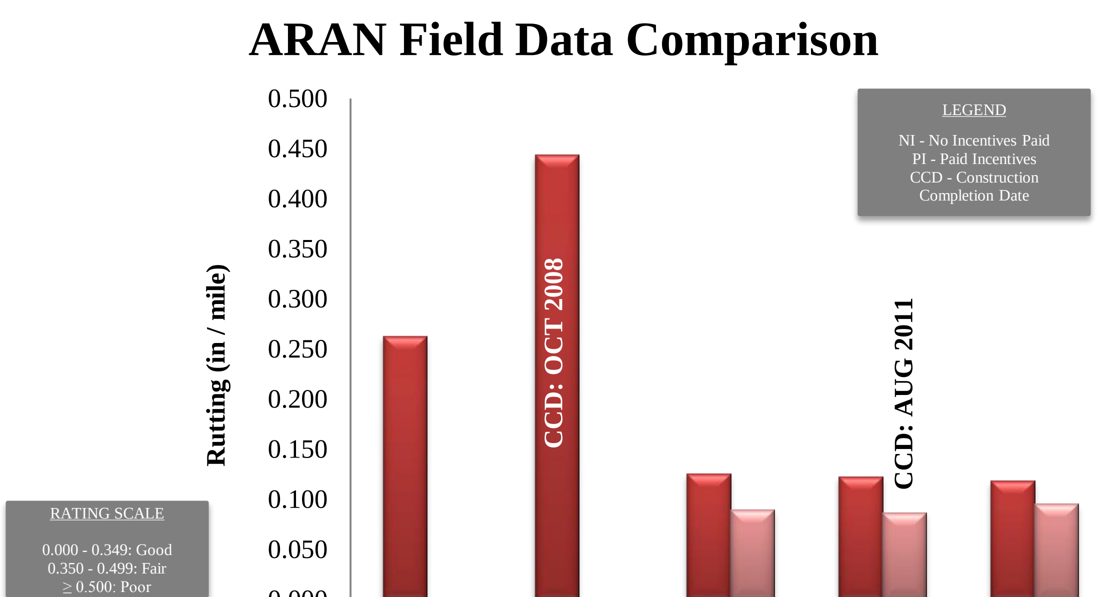
Job Number 050118 Wed Nov 07 14:05:43 2012					
Route: 016 Section: 130					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
3.255	3.258	2.54	4.4	1	0
5.569	5.572	1.09	2.21	5	2
	Average	85.340	114.474	0.105	0.090
			99.91		**0.097**

Once the data analysis was completed for Job Number 050039 and 050188, charts were generated through Excel to illustrate the ARAN field data for IRI and Rutting as shown in Figure 16 and 17.



Data Year	MAY 2002	JUL 2008	SEPT 2010	JUL / AUG 2011	OCT / NOV 2012
Job # 050039 IRI (NI)	149.64	87.05	76.42	79.40	81.62
Job # 050188 IRI (PI)			110.43	97.40	99.61

Figure 16: ARAN Field Data Comparison of IRI for Job Number 050039 and 050188



Data Year	MAY 2002	JUL 2008	SEPT 2010	JUL / AUG 2011	OCT / NOV 2012
Job # 050039 Rutting (NI)	0.263	0.444	0.126	0.123	0.119
Job # 050188 Rutting (PI)			0.090	0.087	0.096

Figure 17: ARAN Field Data Comparison of Rutting for Job Number 050039 and 050188

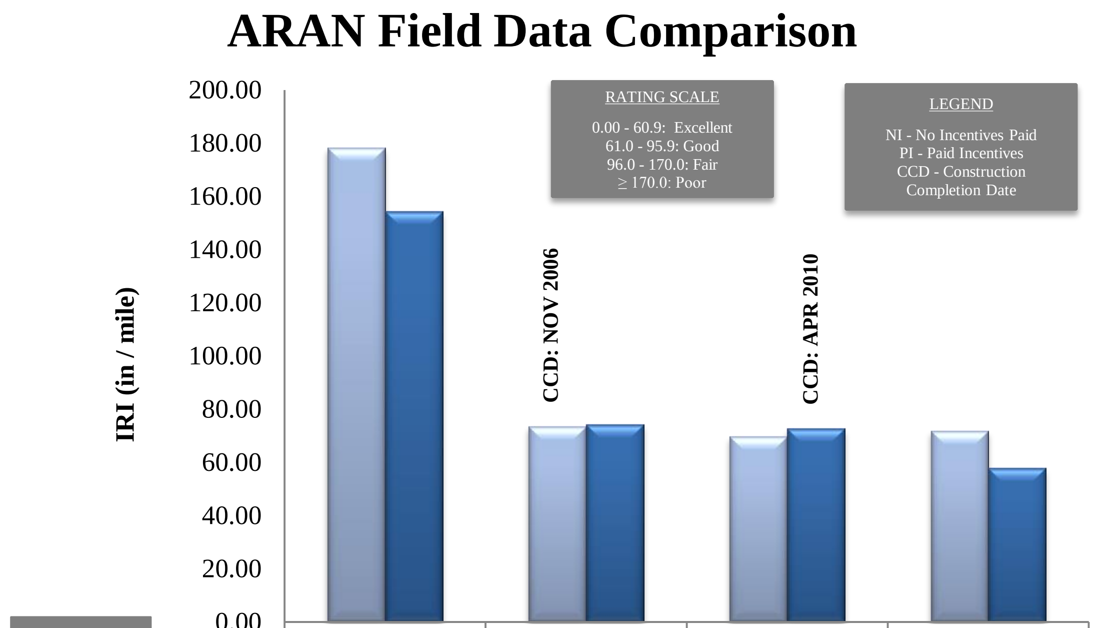
In Figures 16 and 17, the 2012 data shows in, Job Number 050039 had an IRI of 81.62 and Rutting of 0.119 while Job Number 050188 had an IRI of 99.61 and Rutting of 0.096. Over the course of ten years, Job Number 050039 remained in the Good category for IRI after the Construction Completion Date (CCD) October 2008. As for Job Number 050039, it remained in the Fair category for IRI even after the CCD August 2011. This comparison shows Job Number 050039, a non-incentive (NI) paid project, maintained better scores than Job Number 050188, an incentive paid (IP) project. Both Job Number 050039 and 050188 scored in the Good category for Rutting with Job Number 050188 having slightly lower averages than Job Number 050039.

The third data comparison (Table 21) selected final mean averages from April 2012, Job Number 100478 (Non-incentive Paid Project), and Job Number 100566 (Incentive Paid Project), from the category of Projects over Five Million Dollars. The final mean average reported for Job Number 100478 was an IRI of 71.99 in/mi and Rutting of 0.087 in/mi. The final mean average for Job Number 100566 was an IRI of 58.04 in/mi and Rutting of 0.093 in/mi.

Table 21: Final Mean Average Values for Job Number 100478 and 100566

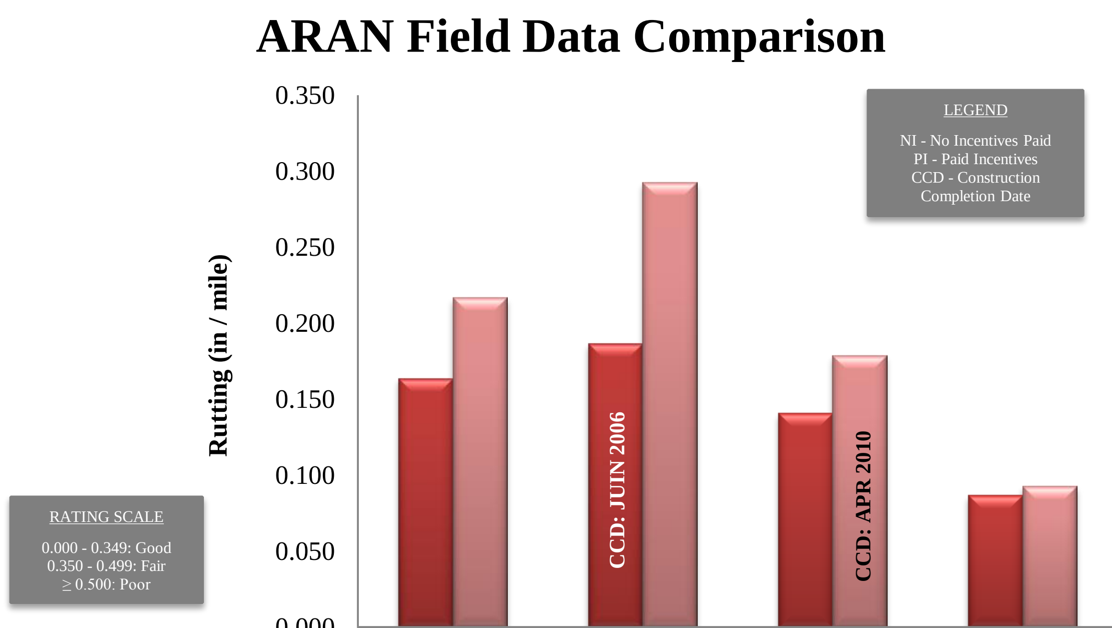
Job Number 100478 Thu Apr 12 09:21:23 2012					
Route: 412 Section: 090					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
6.822	6.825	0.85	1.84	1	1
7.998	8.001	1.18	1.82	1	2
	Average	66.584	77.393	0.095	0.078
			71.99		**0.087**
Job Number 100566 Thu Apr 12 09:21:23 2012					
Route: 412 Section: 090					
BEGIN	END	IRI_L	IRI_R	RUT_L	RUT_R
2.622	2.625	0.56	0.99	3	4
6.798	6.801	0.8	1.03	3	2
	Average	52.011	64.069	0.101	0.085
			58.04		**0.093**

Once the data analysis was completed for Job Number 100478 and 100566, charts were generated through Excel to illustrate the ARAN field data for IRI and Rutting as shown in Figures 18 and 19.



Data Year	JAN 2002	MAR 2008	JUN 2009	APR 2012
Job # 100478 IRI (NI)	178.27	73.63	69.83	71.91
Job # 100566 IRI (PI)	154.46	74.40	72.78	58.04

Figure 18: ARAN Field Data Comparison of IRI for Job Number 100478 and 100566



Data Year	JAN 2002	MAR 2008	JUN 2009	APR 2012
Job # 100478 Rutting (NI)	0.164	0.187	0.141	0.087
Job # 100566 Rutting (PI)	0.217	0.293	0.179	0.093

Figure 19: ARAN Field Data Comparison of Rutting for Job Number 100478 and 100566

In Figures 18 and 19, the 2012 data shows Job Number 100478 had an IRI of 71.91 and Rutting of 0.087 while Job Number 100566 had an IRI of 58.04 and Rutting of 0.093. Over the course of ten years, Job Number 100478 went from the Poor to Good Category for IRI after the Construction Completion Date (CCD) June 2006. Job Number 100566 remained in the Good category for IRI after the CCD April 2010. This comparison shows Job Number 100478, a non-incentive (NI) paid project and Job Number 100566, an incentive paid (IP) project, and both remained in the Good Category after CCD. Both Job Number 100478 and 100566 scored in the Good category for Rutting with Job Number 100478 having slightly lower averages than Job Number 10056.

Using the IRI and rutting annual data from each construction project, a Percent Improvement Factor was calculated to illustrate a pavement's quality and durability. The Percent Improvement Factor was calculated using a Percent Change formula:

$$\text{Percent Improvement Factor } (\%\,\Delta) = \left[\,\frac{(PC_a - PC_b)}{|PC_b|}\,\right] \times 100\%$$

Where:

PC_a = Pavement Condition after substantial completion of construction

PC_b = Pavement Condition before substantial completion of construction

$|PC_b|$ = Absolute Value of Pavement Condition before substantial completion of construction

This formula was applied into an Excel spreadsheet for each construction project of the three monetary groups. In Table 22, a comparison was calculated using the latest preconstruction IRI and rutting before substantial completion and the most current postconstruction IRI and rutting data. This assigned a Percent Change each time ARAN data was collected, excluding the initial year. In Table 22, the Percent Improvement Factor was calculated using JUN 2010 and JUL 2012 for Job Number 110551 and 110539.

Table 22: Calculating Percent Change for IRI and Rutting

AHTD Construction Projects Less Than $2 Million							
	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting
NI1	110551	$627,641	APAC-TENNESSEE, INC.				
			NEW ARAN ARRIVED AUG 2008				
			JUN 2010	165.86		0.332	
			SC - JUL 2011				
			JUL 2012	78.20	53%	0.088	73%
			PERCENT IMPROVEMENT		**53%**		**73%**
PI1	110539	$1,385,321	APAC-TENNESSEE, INC.				
			NEW ARAN ARRIVED AUG 2008				
			JUN 2010	162.93		0.309	
			SC - AUG 2010				
			JUL 2012	63.17	61%	0.107	65%
			PERCENT IMPROVEMENT		**61%**		**65%**

(NI) Non-Incentive; (PI) Paid Incentive

Illustrated in Table 23, the overall Pavement Condition for each of the three monetary groups was calculated by averaging the IRI and rutting data available prior to substantial completion for both non-incentive and paid incentive projects. This step was repeated using the most current data collected after substantial completion. Using the Overall Averages (λ) in the Percent Improvement Factor equation, overall averages for non-incentive and paid incentive projects was derived for both IRI and rutting. Overall comparisons between non-incentive and paid incentive projects for each of the three monetary groups, shows paid incentive projects obtained higher percentages in four of the six comparisons. In the $2 Million to $5 Million group, the IRI was a draw between non-incentive and incentive paid projects. In the Over $5 Million group, rutting produced a slightly higher percentage for the non-incentive paid projects.

Table 23: Overall Performance Results for the Three Monetary Groups

AHTD Construction Projects Less Than $2 Million						
	Total Bid Amounts	Overall Average (λ)	λ / IRI (in/mi)	% Δ / IRI	λ / Rutting (in/mi)	% Δ / Rutting
NI	$6,203,149	Before Construction	135.00		0.363	
		After Construction	113.94		0.150	
		Percent Improvement		15.6%		58.6%
	Total Bid Amounts	Overall Average (λ)	λ / IRI (in/mi)	% Δ / IRI	λ / Rutting (in/mi)	% Δ / Rutting
PI	$6,770,597	Before Construction	125.93		0.228	
		After Construction	69.78		0.084	
		Percent Improvement		44.6%		63.0%
AHTD Construction Projects Between $2 Million and $5 Million						
	Total Bid Amounts	Overall Average (λ)	λ / IRI (in/mi)	% Δ / IRI	λ / Rutting (in/mi)	% Δ / Rutting
NI	$35,421,271	Before Construction	126.13		0.253	
		After Construction	99.78		0.119	
		Percent Improvement		20.9%		52.9%
	Total Bid Amounts	Overall Average (λ)	λ / IRI (in/mi)	% Δ / IRI	λ / Rutting (in/mi)	% Δ / Rutting
PI	$26,605,537	Before Construction	114.45		0.213	
		After Construction	90.54		0.095	
		Percent Improvement		20.9%		55.5%
AHTD Construction Projects Over $5 Million						
	Total Bid Amounts	Overall Average (λ)	λ / IRI (in/mi)	% Δ / IRI	λ / Rutting (in/mi)	% Δ / Rutting
NI	$72,356,098	Before Construction	134.91		0.285	
		After Construction	84.78		0.115	
		Percent Improvement		37.2%		59.8%
	Total Bid Amounts	Overall Average (λ)	λ / IRI (in/mi)	% Δ / IRI	λ / Rutting (in/mi)	% Δ / Rutting
PI	95,088,873	Before Construction	95.00		0.208	
		After Construction	58.00		0.090	
		Percent Improvement		38.9%		56.6%

(NI) Non-Incentive; (PI) Paid Incentive

For the project comparisons completed for this study, the purpose was to determine if projects which received incentive payments for ACHM properties provide a superior, more durable pavement over construction projects which did not receive incentive payments. To assure the validity of this study, it was necessary to control the variables of the raw materials, asphalt batch plants, AHTD districts, project size, contractor, weather and topography. With these guidelines, a comparison analysis of IRI and rutting data was achieved using the IRI and Rutting Rating Measurements scales (ASTM, 2008) & (ASTM, 2005). From the methodology and data results, it was concluded the life cycle of pavement projects receiving incentive payments for ACHM properties demonstrated higher quality pavement conditions by using the Percent Improvement Factor. It was also concluded that projects receiving incentive payments deteriorated at the same rate as pavement projects not receiving incentive payments.

All data for the construction projects selected for this study in located in Appendices A, B and C.

CHAPTER 5 – CONCLUSIONS & RECOMMENDATIONS

Summary

The purpose of this study was to evaluate historical highway construction projects to determine if projects receiving incentive payments for ACHM properties provide a better quality, longer lasting pavement compared to projects that do not receive incentives. To verify this hypothesis, a comparison analysis was accomplished through project pairing according to AHTD district, monetary amount, incentives received/not received and contractor. A literature review was also conducted to investigate governmental agencies' studies and states' Department of Transportation incentive payment programs. The literature review posed sequential and existing methods indicating other possible guidelines and recommendations to AHTD for incentive payments for ACHM properties. Suggested recommendations for possible modifications to current AHTD specifications of incentive payments for ACHM properties were based on the findings of the study's research and literature review.

Results were formulated by employing a specific methodology, allowing grouping and project pairing data to be validated through IRI and rutting comparison between projects receiving incentive payments for ACHM properties and those that did not receive incentives. Pavement data was obtained through the AHTD Pavement Management section and was furnished by the Pavement Management ARAN, MMHIS and SARS databases. After selecting and grouping projects based on AHTD districts and monetary amount, an incentive paid and a non-incentive paid project were then paired according to an identical contractor.

The initial pool of AHTD construction projects totaled 867. Two hundred thirty-one (231) construction projects were selected for the initial pavement data retrieval from the Pavement Management section. The initial retrieval produced 159 projects with available annual pavement data reports. Forty-two (42) projects were selected for the final project pairing comparison of IRI and rutting data according to AHTD districts, monetary amounts and contractor. The second and final pavement data retrieval involved assessing the available annual pavement data for each project. Annual pavement data was selected by the first pavement data report before the construction begins date and all sequential annual data reports during and after the construction completion date.

Derived from methodology, data results supported the comparison analysis of the 21 construction projects pairings. Documented conclusions validated the hypothesis that projects receiving incentive payment for ACHM properties provide similar pavement life cycles to construction projects which did not receive incentive payments. Although non-incentive and incentive paid projects have similar life cycles, the majority of overall averages for incentive paid project groupings exhibited better-quality pavement in regards to IRI and rutting.

Conclusion

The purpose of this study was to examine existing surface conditions of highway construction projects receiving paid incentives to non-incentive paid construction projects. The post-construction field data was used to determine if incentive paid construction projects produced a pavement of higher quality, more durable and consistently exceeded the minimum requirements established in the 2003 AHTD Standard Specifications for Highway Construction (AHTD, 2003). Data results were formulated by employing a specific methodology. This allowed for data validation through an ordered series of groupings and project pairings for incentive paid and non-incentive paid projects using the IRI and rutting rating measurements (ASTM, 2008) & (ASTM, 2005).

The difference between incentive paid and non-incentive paid projects was evident by pavement condition comparison through data compilation and ASTM rating scales for IRI and rutting for IRI and rutting. For the majority of incentive paid projects, when compared to its counterparts, exhibited better performance using the Percent Improvement Factor formula. Although the overall performance of paid incentive projects generated better conditions than non-incentive projects using Percent Improvemnet Factor, both incentive and non-incentive construction projects demonstrated deterioration at a common rate.

It was also discovered during research the testing method for ACHM incentives is the average test results for each standard lot. Currently, the specification states the testing method is a 4:1 ratio, meaning during the course of a construction project, an evaluation of five random tests per lot are taken; four tests by the contractor and one test by AHTD. This is to guarantee the ACHM are within the standards of the AHTD specification 410.10 (AHTD, 2003). However, AHTD specifications do not assign which of the five tests AHTD is to obtain as all tests are by random number generation.

Recommendations

Establishing favorable findings for incentive paid projects, it is still recommended an evaluation of the AHTD Subsection 410.10 Incentives be completed (AHTD, 2003). Consideration should be taken into account how sample testing is accomplished. A possible modification could specify AHTD to govern sample testing and to assign AHTD a majority of the sample testing (3:2). To state this modification in detail, AHTD would procure the first, third and fifth samples with the Contractor procuring the second and fourth samples for each standard lot. Another possible comparison measurement is to evaluate IRI and/or rutting data between documented field testing/measurements (manual) and the ARAN (computer-generated).

Future research for the AHTD incentive program could be to evaluate other Department of Transportation's incentive programs. Currently, many state DOT's utilize Percent Within Limits (PWL) for ACHM payments. This system establishes payment based on adherence to a standard deviation complied for each mix design. PWL allows for incentives and disincentives, depending on the Contractor's adherence to the standard deviation established. It is worth noting the California Department of Transportation

(Caltrans) has completed similar research on Performance-Based Pay Factors including PWL. As an example, Caltrans rutting model emphasizes the importance of asphalt content, degree of compaction, and aggregate gradation as defined by the P200 fraction while the fatigue model emphasizes degree of compaction, pavement thickness, and asphalt content. While the contractor might consider increasing the binder content somewhat for improved degree of compaction for fatigue, increase of the asphalt content above the design target precludes this because of rutting considerations (Popescu & Monismith, 2006).

South Carolina DOT (SCDOT) has supplemented a technical specification for Hot Mix Asphalt (HMA) Quality Assurance into their specification standards guideline. This specification details the acceptance and pavement structure are characteristics that most affect performance. SCDOT cited one of the advantages of the performance-base approach, which emphasizes acceptance of HMA mixtures, mainline paving and low tonnage paving. This technical specification also describes requirements, frequency, sampling and testing methods, accpetance and verification, and the party repsonsbile for each item. acceptance (SCDOT, 2010).

In most cases, the performance-based approach emphasizes the importance of consistency in both materials production and placement with reasonable controls placed on inherent variability. Moreover, it emphasizes the importance of adhering to design target values while attempting to consider only the materials and construction variance by eliminating the influence of test variance (Popescu & Monismith, 2006).

A final recommendation would to document pavement maintenance work. During this research, it was discovered AHTD Maintenance and Pavement Management sections did not have measures to record maintenance work performed on state highways. Road maintenance is achieved on a case-by-case basis and not documented within AHTD database. An added measure to this recommendation may be to digitally log and track public concerns/complaints as they relate to the maintenance work order generated by public complaints.

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APPENDIX A – AHTD Construction Selected Projects:

Less Than Two Million Dollars ($2,000,000.00)

AHTD Construction Projects Less Than $2 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
NI1	110551	$627,641.49	APAC-TENNESSEE, INC.					01	147, 1	5.34	1.60	6.94
			NEW ARAN ARRIVED AUG 2008									
			JUN 2010	165.86		0.332						
			SC - JUL 2011									
			JUL 2012	78.20	53%	0.088	73%					
			PERCENT IMPROVEMENT		**53%**		**73%**					
PI1	110539	$1,385,321.90	APAC-TENNESSEE, INC.					01	147, 1	7.4	5.50	12.90
			NEW ARAN ARRIVED AUG 2008									
			JUN 2010	162.93		0.309						
			SC - AUG 2010									
			JUL 2012	63.17	61%	0.107	65%					
			PERCENT IMPROVEMENT		**61%**		**65%**					
NI2	110475	$554,664.74	DRUMMOND ASPHALT CONST., INC.					01	64, 16	11.60	2.21	13.81
			SC - JUN 2005									
			SEPT 2005	82.00		0.161						
			JUL 2007	83.87	-2%	0.235	-46%					
			NEW ARAN ARRIVED AUG 2008									
			AUG 2009	81.09	3%	0.206	12%					
			MAY 2012	83.50	-3%	0.170	17%					
			PERCENT IMPROVEMENT		**-2%**		**-6%**					
PI2	S10106	$581,062.85	DRUMMOND ASPHALT CONST., INC.					01	64, 12	2.29	0.95	3.24
			JUL 2007	171.65		0.296						
			SC - JUN 2008									
			NEW ARAN ARRIVED AUG 2008									
			MAY 2012	80.88	53%	0.097	67%					
			PERCENT IMPROVEMENT		**53%**		**67%**					

AHTD Construction Projects Less Than $2 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
PI2	S10106	$581,062.85	DRUMMOND ASPHALT CONST., INC.					01	64, 13	1.10	0.00	1.10
			JUL 2007	158.40		0.339						
			SC - JUN 2008									
			NEW ARAN ARRIVED AUG 2008									
			MAY 2012	164.74	-4%	0.082	76%					
			PERCENT IMPROVEMENT		**-4%**		**76%**					
NI3	S10402	$730,972.04	APAC-CENTRAL, INC.					04	412, 2	8.39	2.47	10.86
			JUN 2004	175.04		0.561						
			SC - JUN 2005									
			APR 2009	86.03	51%	0.148	74%					
			NEW ARAN ARRIVED AUG 2008									
			JUN 2009	92.89	-8%	0.148	0%					
			NOV 2009	99.09	-7%	0.180	-22%					
			AUG 2010	99.85	-1%	0.096	47%					
			MAR 2011	105.06	-5%	0.109	-14%					
			APR 2012	104.48	1%	0.095	13%					
			PERCENT IMPROVEMENT		**40%**		**83%**					
NI3	040592	$616,081.70	APAC-CENTRAL, INC. (Section 16B Part 1)					04	71B, 16B	1.44	1.15	2.59
			MAY 2004	121.19		0.488						
			SC - JUN 2008									
			NEW ARAN ARRIVED AUG 2008									
			MAY 2010	176.97	-46%	0.246	50%					
			MAR 2011	178.61	-1%	0.244	1%					
			PERCENT IMPROVEMENT		**-47%**		**50%**					
NI3	040592	$616,081.70	APAC-CENTRAL, INC. (Section 16B Part 2)					04	71B, 16B	3.25	0.58	3.83
			MAY 2004	123.58		0.506						
			SC - JUN 2008									
			NEW ARAN ARRIVED AUG 2008									
			MAY 2010	198.98	-61%	0.252	50%					
			MAR 2011	193.89	3%	0.242	4%					
			PERCENT IMPROVEMENT		**-57%**		**52%**					

AHTD Construction Projects Less Than $2 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
PI3	040537	$551,922.15	APAC-CENTRAL, INC.					04	412, 2	6.59	1.78	8.37
			JUN 2004	103.54		0.368						
			APR 2009	107.69	-4%	0.291	21%					
			JUN 2009	107.08	1%	0.274	6%					
			NEW ARAN ARRIVED AUG 2008									
			SC - JUL 2009									
			NOV 2009	74.32	31%	0.093	66%					
			AUG 2010	73.57	1%	0.068	27%					
			MAR 2011	75.14	-2%	0.068	0%					
			APR 2012	72.77	3%	0.083	-22%					
			PERCENT IMPROVEMENT		**30%**		**77%**					
NI4	S10401	$562,772.62	BLACKSTONE CONSTRUCTION, LLC					04	22, 4	0.00	2.40	2.40
			JUN 2004	147.77		0.405						
			SC - OCT 2007									
			NEW ARAN ARRIVED AUG 2008									
			JUN 2011	108.04	27%	0.175	57%					
			PERCENT IMPROVEMENT		**27%**		**57%**					
PI4	040567	$516,279.64	BLACKSTONE CONSTRUCTION, LLC					04	22, 3	20.49	1.89	22.38
			NEW ARAN ARRIVED AUG 2008									
			APR 2009	131.80		0.243						
			SC - APR 2011									
			JUN 2011	69.68	47%	0.053	78%					
			PERCENT IMPROVEMENT		**47%**		**78%**					

AHTD Construction Projects Less Than $2 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
NI5	080374	$826,949.94	BLACKSTONE CONSTRUCTION, LLC					08	9, 6	11.90	4.01	15.91
			APR 2002	118.88		0.158						
			NEW ARAN ARRIVED AUG 2008									
			APR 2010	138.41	-16%	0.135	15%					
			SC - JUN 2011									
			NOV 2012	86.51	37%	0.078	42%					
			PERCENT IMPROVEMENT		**27%**		**51%**					
PI5	080393	$866,520.64	BLACKSTONE CONSTRUCTION, LLC (Section 7)					08	9, 7	2.25	2.85	5.10
			APR 2002	103.64		0.156						
			NEW ARAN ARRIVED AUG 2008									
			MAR 2010	119.02	-15%	0.150	4%					
			SC - JUN 2011									
			OCT 2012	77.62	35%	0.073	51%					
			PERCENT IMPROVEMENT		**25%**		**53%**					
PI5	080393	$866,520.64	BLACKSTONE CONSTRUCTION, LLC (Section 8)					08	9, 8	7.1	1.90	9.00
			JUL 2008	114.69		0.281						
			NEW ARAN ARRIVED AUG 2008									
			FEB 2010	111.91	2%	0.332	-18%					
			OCT 2010	62.28	44%	0.062	81%					
			MAY 2011	67.69	-9%	0.067	-8%					
			SC - JUN 2011									
			SEPT 2011	68.65	-1%	0.081	-21%					
			APR 2012	69.08	-1%	0.088	-9%					
			OCT 2012	72.44	-5%	0.091	-3%					
			PERCENT IMPROVEMENT		**37%**		**68%**					

AHTD Construction Projects Less Than $2 Million													
	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
NI6	S11007	$1,667,984.85	ATLAS ASPHALT, INC.					10	63, 3	0.00	8.29	8.29
			AUG 2001	62.64		0.537						
			NOV 2001	96.61	-54%	0.149	72%					
			MAY 2008	105.99	-10%	0.232	-56%					
			NEW ARAN ARRIVED AUG 2008									
			MAY 2009	64.78	39%	0.094	59%					
			SC - OCT 2010									
			APR 2012	78.25	-21%	0.111	-18%					
			PERCENT IMPROVEMENT		**-25%**		**79%**					
PI6	100718	$1,421,906.95	ATLAS ASPHALT, INC.					10	63, 7	3.57	5.00	8.57
			NEW ARAN ARRIVED AUG 2008									
			MAY 2009	88.86		0.142						
			SC - MAY 2011									
			APR 2012	51.90	42%	0.086	39%					
			PERCENT IMPROVEMENT		**42%**		**39%**					

APPENDIX B – AHTD Construction Selected Projects:

Between Two and Five Million Dollars ($2,000,000.00 - $5,000,000.00)

AHTD Construction Projects $2 Million to $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	PL	Ending LM
NI1	110463	$4,481,120.13	APAC-TENNESSEE, INC.					01	118, 4	3.12	1.17	4.29
			JUL 2001	136.87		0.336						
			DEC 2005	96.36	30%	0.233	31%					
			JUN 2007	125.91	-31%	0.310	-33%					
			SC - AUG 2007									
			NEW ARAN ARRIVED AUG 2008									
			JUL 2012	107.26	15%	0.092	70%					
			PERCENT IMPROVEMENT		**22%**		**73%**					
NI1	110505	$3,196,773.48	APAC-TENNESSEE, INC.					01	118, 4	3.30	0.84	4.14
			JUN2007	116.76		0.292						
			NEW ARAN ARRIVED AUG 2008									
			SC- JUN 2011									
			JUL 2012	99.44	15%	0.084	71%					
			PERCENT IMPROVEMENT		**15%**		**71%**					
PI1	110521	$2,143,171.90	APAC-TENNESSEE INC.					01	79, 18	0.00	9.63	9.63
			JUN 2007	103.57		0.350						
			NEW ARAN ARRIVED AUG 2008									
			APR 2009	98.57	5%	0.439	-25%					
			SC - JUL 2009									
			JUL 2012	63.38	36%	0.086	80%					
			PERCENT IMPROVEMENT		39%		75%					
NI2	020339	$3,627,048.86	R. THOMPSON, INC.					02	133, 1	5.42	3.54	8.96
			SC- MAR 2006									
			JUN 2006	98.35		0.208						
			JUN 2007	82.36	16%	0.191	8%					
			NEW ARAN ARRIVED AUG 2008									
			JUN 2012	86.76	-5%	0.159	17%					
			PERCENT IMPROVEMENT		12%		24%					

AHTD Construction Projects $2 Million to $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	PL	Ending LM
NI2	020415	$3,473,847.51	R.M. COURSON, INC.+					02	425, 1	3.70	3.64	7.34
			JUN 2005	128.53		0.213						
			JUN 2007	136.51	-6%	0.236	-11%					
			SC - SEPT 2007									
			NEW ARAN ARRIVED AUG 2008									
			JUL 2009	139.91	-2%	0.335	-42%					
			AUG 2010	141.25	-1%	0.223	33%					
			MAR 2012	145.97	-3%	0.235	-5%					
			PERCENT IMPROVEMENT		**-14%**		**-10%**					
PI2	020286	$2,072,571.60	R. THOMPSON, INC.					02	35, 7	10.37	0.87	11.24
			OCT 2004	118.80		0.209						
			MAY 2007	127.79	-8%	0.223	-7%					
			SC - DEC 2007									
			NEW ARAN ARRIVED AUG 2008									
			JUN 2012	110.32	14%	0.045	80%					
			PERCENT IMPROVEMENT		**7%**		**78%**					
NI3	050039	$3,047,510.92	DELTA ASPHALT OF ARK., INC.					05	25, 2	8.80	2.37	11.17
			MAY 2002	149.64		0.263						
			JUL 2008	87.05	42%	0.444	-69%					
			NEW ARAN ARRIVED AUG 2008									
			SC - OCT 2008									
			JAN 2010	77.34	11%	0.213	52%					
			SEPT 2010	76.42	1%	0.126	41%					
			MAY 2011	78.80	-3%	0.117	7%					
			AUG 2011	79.40	-1%	0.123	-5%					
			OCT 2012	81.62	-3%	0.119	3%					
			PERCENT IMPROVEMENT		**45%**		**55%**					

AHTD Construction Projects $2 Million to $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	PL	Ending LM
PI3	050188	$3,581,158.63	DELTA ASPHALT OF ARK., INC.					05	16, 13	3.26	2.31	5.57
			NEW ARAN ARRIVED AUG 2008									
			DEC 2009	99.42		0.125						
			SEPT 2010	110.43	-11%	0.090	28%					
			JUL 2011	97.40	12%	0.087	3%					
			SC - AUG 2011									
			NOV 2012	99.61	-2%	0.096	-10%					
			PERCENT IMPROVEMENT		**-0.2%**		**23%**					
NI4	050098	$4,701,566.74	WHITE RIVER MATERIALS, INC.					05	62, 13	3.90	4.99	8.89
			JAN 2001	229.67		0.116						
			OCT 2005	100.81	-11%	0.142	-22%					
			SC - JUL 2006									
			NEW ARAN ARRIVED AUG 2008									
			AUG 2009	80.49	20%	0.144	-1%					
			APR 2012	84.17	-5%	0.095	34%					
			DEC 2012	86.39	-3%	0.086	9%					
			PERCENT IMPROVEMENT		**62%**		**26%**					
PI4	050187	$4,469,053.47	WHITE RIVER MATERIALS, INC.					05	167, 19	22.19	1.17	23.36
			NEW ARAN ARRIVED AUG 2008									
			JUL 2009	97.44		0.153						
			APR 2012	96.03	-11%	0.189	-24%					
			SC - NOV 2012									
			DEC 2012	67.98	29%	0.111	41%					
			PERCENT IMPROVEMENT		**30%**		**27%**					

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	PL	Ending LM
NI5	061171	$2,965,936.23	TOM LINDSEY CONTRACTOR, INC.*					06	107, 1	9.07	0.85	9.92
			FEB 2008	157.88		0.280						
			NEW ARAN ARRIVED AUG 2008									
			NOV 2009	163.96	-4%	0.306	-9%					
			MAY 2010	166.72	-2%	0.220	28%					
			SC - AUG 2011									
			PERCENT IMPROVEMENT		**-6%**		**21%**					
PI5	060529	$3,829,891.80	GRAVES AND ASSOCIATES, INC.*					06	13, 10	0.00	0.97	0.97
			MAY 2008	213.99		0.151						
			NEW ARAN ARRIVED AUG 2008									
			MAY 2010	198.83	7%	0.127	16%					
			SC - JUL 2010									
			SEPT 2012	134.03	33%	0.109	14%					
			PERCENT IMPROVEMENT		**37%**		**28%**					
NI6	FS8007	$2,109,383.03	ROGERS GROUP, INC.*					08	105, 1	0.00	13.57	13.57
			NEW ARAN ARRIVED AUG 2008									
			MAR 2010	142.25		0.142						
			AUG 2011	150.48	-6%	0.144	-1%					
			SC - MAR 2012									
			SEPT 2012	88.76	38%	0.059	59%					
			PERCENT IMPROVEMENT		**38%**		**58%**					

Table: AHTD Construction Projects $2 Million to $5 Million

AHTD Construction Projects $2 Million to $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	PL	Ending LM
PI6	080302	$3,495,257.60	TOM LINDSEY CONTRACTOR, INC.*					08	64, 8	3.57	0.97	4.54
			JAN 2004	106.53		0.291						
			NEW ARAN ARRIVED AUG 2008									
			SC - NOV 2008									
			NOV 2009	108.39	-2%	0.172	41%					
			OCT 2012	110.76	-2%	0.126	57%					
			PERCENT IMPROVEMENT		**-4%**		**57%**					
NI7	090147	$4,666,947.78	APAC-CENTRAL, INC.					09	43, 0	0.00	2.48	2.48
			MAY 2004	145.87		0.370						
			SC - JUL 2007									
			NEW ARAN ARRIVED AUG 2008									
			NOV 2011	102.05	30%	0.121	67%					
			PERCENT IMPROVEMENT		**30%**		**67%**					
PI7	090266	$2,205,512.10	APAC-CENTRAL, INC.					09	412, 1	4.82	5.18	10.00
			JUN 2004	82.96		0.320						
			JUN 2006	85.60	-3%	0.189	41%					
			NEW ARAN ARRIVED AUG 2008									
			APR 2009	89.63	-5%	0.195	-3%					
			SC - AUG 2009									
			NOV 2010	66.55	26%	0.106	46%					
			APR 2012	67.19	-1%	0.103	3%					
			PERCENT IMPROVEMENT		**19%**		**68%**					

AHTD Construction Projects $2 Million to $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	PL	Ending LM
NI8	090223	$3,151,136.60	TWIN LAKES QUARRYS, INC.					09	177, 1	4.90	2.30	7.20
			FEB 2006	121.86		0.257						
			NEW ARAN ARRIVED AUG 2008									
			FEB 2011	105.08	14%	0.121	53%					
			SC - DEC 2012									
			PERCENT IMPROVEMENT		**14%**		**53%**					
PI8	090239	$4,808,920.60	TWIN LAKES QUARRY, INC.					09	62, 9	4.57	3.16	7.73
			OCT 2001	100.81		0.149						
			SC - MAY 2008									
			NEW ARAN ARRIVED AUG 2008									
			AUG 2009	67.71	33%	0.089	40%					
			JUN 2010	69.41	-3%	0.068	24%					
			APR 2012	71.02	-2%	0.080	-18%					
			PERCENT IMPROVEMENT		**30%**		**46%**					

APPENDIX C – AHTD Construction Selected Projects:

Greater Than Five Million Dollars ($5,000,000.00)

AHTD Construction Projects Greater Than $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
NI1	110492	$26,693,323.94	APAC-TENNESSEE, INC.					01	40, 52	279.32	1.32	280.64
			NEW ARAN ARRIVED AUG 2008									
			SEPT 2008	181.27		0.231						
			APR 2010	145.41	20%	0.127	45%					
			SC - SEPT 2010									
			APR 2011	115.36	21%	0.102	20%					
			FEB 2012	115.60	-0.2%	0.110	-8%					
			PERCENT IMPROVEMENT		**36%**		**52%**					
PI1	110337	$16,879,760.99	APAC-TENNESSEE, INC.					01	64, 17	13.62	5.30	18.92
			JUL 2001	118.00		0.259						
			DEC 2005	108.00	8%	0.142	45%					
			SC - JUN 2007									
			JUN 2007	70.00	35%	0.213	-50%					
			NEW ARAN ARRIVED AUG 2008									
			JUL 2012	69.00	1%	0.139	35%					
			PERCENT IMPROVEMENT		**42%**		**46%**					
NI2	004818	$6,072,038.10	GILBERT CENTRAL CORP.					04	309, 2	18.72	4.38	23.10
			JUN 2003	218.00		0.398						
			JUL 2006	187.86	14%	0.284	29%					
			SC - AUG 2007									
			NEW ARAN ARRIVED AUG 2008									
			JUN 2011	110.51	41%	0.078	73%					
			PERCENT IMPROVEMENT		**49%**		**80%**					
PI2	090116	$21,579,430.81	KIEWIT SOUTHERN CO.					04	412, 3	0.00	5.52	5.52
			OCT 2005	92.08		0.241						
			NEW ARAN ARRIVED AUG 2008									
			SC - OCT 2008									
			JUN 2009	41.23	55%	0.112	54%					
			MAY 2010	42.37	-3%	0.067	40%					
			APR 2012	42.59	-1%	0.066	1%					
			PERCENT IMPROVEMENT		**54%**		**73%**					

AHTD Construction Projects Greater Than $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
NI3	090148	$7,247,908.82	APAC-CENTRAL, INC.					09	59, 1	22.51	2.81	25.32
			MAY 2004	87.83		0.222						
			NEW ARAN ARRIVED AUG 2008									
			SC- JUN 2009									
			NOV 2010	69.83	20%	0.074	67%					
			PERCENT IMPROVEMENT		**20%**		**67%**					
PI3	090154	$14,060,426.25	APAC-CENTRAL, INC.					09	59, 1	20.75	3.03	23.78
			MAY 2004	99.89		0.229						
			NEW ARAN ARRIVED AUG 2008									
			SC - JAN 2009									
			NOV 2010	62.37	38%	0.063	72%					
			PERCENT IMPROVEMENT		**38%**		**72%**					
NI4	100304	$11,579,770.92	DELTA ASPHALT OF ARK., INC.					10	18, 6	6.20	4.43	10.63
			MAY 2003	119.30		0.372						
			DEC 2007	117.26	2%	0.342	8%					
			NEW ARAN ARRIVED AUG 2008									
			SC - NOV 2008									
			MAR 2013	72.00	39%	0.187	45%					
			PERCENT IMPROVEMENT		**40%**		**50%**					
PI4	100307	$8,626,637.25	DELTA ASPHALT OF ARK., INC.					10	18, 6	0.00	6.20	6.20
			MAY 2003	125.73		0.369						
			DEC 2007	134.07	-7%	0.359	3%					
			NEW ARAN ARRIVED AUG 2008									
			SC - DEC 2012									
			PERCENT IMPROVEMENT		**-7%**		**3%**					

AHTD Construction Projects Greater Than $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
NI5	100478	$7,373,154.56	ROBERTSON, INC., BRIDGE & GRADING DIV.					10	412, 9	6.82	1.18	8.00
			JAN 2002	178.27		0.217						
			SC - NOV 2006									
			MAR 2008	73.63	59%	0.293	-35%					
			NEW ARAN ARRIVED AUG 2008									
			JUN 2009	69.83	5%	0.179	39%					
			APR 2012	71.91	-3%	0.093	48%					
			PERCENT IMPROVEMENT		**60%**		**-35%**					
PI5	100566	$11,731,844.34	ROBERTSON, INC., BRIDGE & GRADING DIV.					10	412, 9	2.62	4.18	6.80
			JAN 2002	154.46		0.217						
			JAN 2008	74.40	52%	0.293	-35%					
			NEW ARAN ARRIVED AUG 2008									
			JUN 2009	72.78	2%	0.179	39%					
			SC - APR 2010									
			APR 2012	58.04	20%	0.093	48%					
			PERCENT IMPROVEMENT		**62%**		**57%**					

AHTD Construction Projects Greater Than $5 Million

	Job #	Bid Amount	Contractor	IRI (in/mi)	% Δ / IRI	Rutting (in/mi)	% Δ / Rutting	Dist.	Route & Section	Beginning LM	Project Length	Ending LM
NI6	100295	$13,389,902.47	ATLAS ASPHALT, INC. (Section 4)					10	63, 4	2.08	6.81	8.89
			AUG 2001	92.81		0.520						
			SC - JUL 2007									
			APR 2008	68.32	26%	0.193	63%					
			NEW ARAN ARRIVED AUG 2008									
			MAY 2009	65.68	4%	0.179	7%					
			APR 2012	68.85	-5%	0.147	18%					
			PERCENT IMPROVEMENT		**26%**		**72%**					
PI6	100716	$22,210,773.65	DELTA ASPHALT OF ARK., INC.					10	55, 12	62.41	5.21	67.62
			NEW ARAN ARRIVED AUG 2008									
			APR 2010	144.09		0.115						
			APR 2011	158.66	-10%	0.120	-4%					
			FEB 2012	63.15	60%	0.097	19%					
			SC - JUL 2012									
			PERCENT IMPROVEMENT		**56%**		**16%**					

APPENDIX D – AHTD Construction Selected Projects:

Overall Average Comparison for Monetary Groups Using IRI and rutting

AHTD Construction Projects Less Than $2 Million							
Construction Project Information		Averages (λ) for IRI (in/mi)			Averages (λ) for Rutting (in/mi)		
Project Type	Total Bid Amount	BC	AC	PI	BC	AC	PI
NI	$6,203,149.08	135.00	113.94	15.6%	0.363	0.150	58.6%
PI	$6,770,597.62	125.93	69.78	44.6%	0.228	0.084	63.0%

AHTD Construction Projects Between $2 Million and $5 Million							
Construction Project Information		Averages (λ) for IRI (in/mi)			Averages (λ) for Rutting (in/mi)		
Project Type	Total Bid Amount	BC	AC	PI	BC	AC	PI
NI	$35,421,271.28	126.13	99.78	20.9%	0.253	0.119	52.9%
PI	$26,605,537.70	114.45	90.54	20.9%	0.213	0.095	55.5%

AHTD Construction Projects Over $5 Million							
Construction Project Information		Averages (λ) for IRI (in/mi)			Averages (λ) for Rutting (in/mi)		
Project Type	Total Bid Amount	BC	AC	PI	BC	AC	PI
NI	$72,356,098.81	134.91	84.78	37.2%	0.285	0.115	59.8%
PI	$95,088,873.29	95.00	58.00	38.9%	0.208	0.090	56.6%

(BC) Before Construction; (AC) After Construction; (PI) Percent Improvement