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Evaluation of HeadLight: An E-Construction Inspection Technology

by

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13. Abstract

Traditionally, DOTD has relied on a primarily paper-based process for field data collection. Mobile technology (defined as hardware and software that can be used in concert to allow integrated data collection, access to project-related information, and real-time communication capabilities) continues to improve and become more affordable. This research project explored the feasibility of replacing the traditional, paper-based inspection process with a cloud-based, mobile project inspection technology named HeadLight, piloting this technology on over 50 projects across four districts in Louisiana. A materials module was also developed.

Inspectors using HeadLight experienced a 28 percent increase in productivity when creating and submitting daily work reports (DWRs). The increase in productivity for Department-wide adoption is estimated to exceed 117,000 hours per year.

Inspectors collected and shared 1.9 times more observations while increasing the number of photo and other media observations which contributes to a more complete record of the project and provides immeasurable value to DOTD.

Project inspectors using HeadLight provide more complete and consistent data tagged with time and location metadata. DWRs are automatically generated from daily observations eliminating omission and transcription errors with submission rate improvements up to 66 percent completed within 24 hours and up to 82 percent completed within 72 hours. By increasing the timeliness of submitted DWRs, data is more readily available across DOTD.

Data stored in HeadLight provides a wealth of material for future training of new employees and even training of existing employees for particularly unique construction scenarios.

It was observed that none of the projects using HeadLight had a lost claim that occurred during this pilot study. While more research is warranted, this suggests that HeadLight provided both DOTD and contractors an improved communication platform to resolve issues before they escalated to a dispute and/or claim. It is anticipated that the benefits listed will be more considerable when the technology is further leveraged using big data analytics.

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Each research project will have an advisory committee appointed by the LTRC Director. The Project Review Committee is responsible for assisting the LTRC Administrator or Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, oversight of approved research projects, and implementation of findings.

LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

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Implementation Statement

The research team recommends the Department adopt the use of HeadLight department-wide. Annually, 117,000 hours of increased employee productivity is estimated to be realized. Additionally, the impact of e-construction to other job functions should be considered including: managing force account work, contract management functions, emergency management, construction audit, and asset management. Further investigation to determine the impact of HeadLight on the quantity and size of change orders and claims also should be carried out.

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Introduction

Project inspection and delivery are challenging, resource-intensive tasks. Project inspectors working for the Louisiana Department of Transportation and Development (DOTD) are responsible for collecting vast amounts of data and information in the field. Acquiring timely and accurate inspection information assists in tracking project control elements such as: cost, schedule, and materials aiding in project delivery. External factors (e.g., declining public spending on transportation infrastructure projects) have generally led DOTs throughout the country to reduce their workforce levels, making it difficult for a reduced inspection workforce to collect a growing amount of information each year [1, 2, 3, 4].

Traditionally DOTD has relied on a primarily paper-based process for field data collection. Mobile technology (defined as hardware and software that can be used in concert to allow integrated data collection, access to project-related information, and real-time communication capabilities) continues to improve and has become affordable. This has allowed many DOTs the opportunity to use these technologies to improve the paper-based, time consuming, and disconnected nature of collecting and disseminating project inspection information [5].

This research project explored the feasibility of replacing the traditional, paper-based inspection process with a cloud-based, mobile project inspection technology named HeadLight. Based on previous research conducted by three DOTs outside of Louisiana, HeadLight has been reported to increase inspector productivity and improve the quality of the inspection data collected in the field. This report assesses the productivity and inspection data quality impacts of using HeadLight on DOTD project inspection in the field.

Literature Review

Research on using mobile technology to reduce administrative efforts associated with construction field documentation has been conducted since the 1990s [6, 7, 8, 9, 10, 11, 12, 13, 14]. Past studies have generally presented details on the development, functionality, and the application of the mobile system. Few authors have examined the benefits and process changes resulting from the adoption of these technologies, and a small portion of these studies have collected empirical performance data over a short period of time with a small group of participants.

Time Savings and Productivity Improvements

Information on the time savings and productivity improvements of using mobile technology in construction applications has typically been collected through survey responses and similar qualitative data. McCullouch and Gunn developed and field tested a time-keeping application for DFM Travelite pen-based handheld computers on two industrial construction projects. The authors concluded that end-user perception of data collection time was similar to that of the paper-based method, but they saved time from not having to duplicate their timekeeping data in their electronic data management system [6].

Liu developed and tested an electronic tunnel inspection form identical to the paper form on a handheld personal computer (PC), which automatically uploaded the information to a web server. Comments from 10 participants that used the system for one day concluded the users saved time in filling out inspection reports, but the mobile hardware was not rugged enough to endure the rough construction site environment [7].

Saidi et al. estimated the time consumption differences between the paper-based method and the handheld computer method for six construction field activities and showed activities can be performed more efficiently by using handheld computers onsite [8].

Bowden et al. assembled case studies and previous research related to mobile technology use in construction and found these technologies can potentially help reduce construction time and cost, defects, accidents, waste, and operation and maintenance costs while improving productivity. This study identified major barriers to innovative IT technology adoption in the industry, which included the lack of empirical performance and benefit data as well as the mismatch between information technologies developed by researchers compared to the actual needs of the end users in the construction industry [9].

Kimoto et al. conducted interviews with construction managers working on building projects to identify key user requirements that were used to develop a building inspection application. The mobile data collection system developed by the researchers allowed text-based field data to be collected on a mobile personal digital assistant (PDA) device and saved to a memory card for further PC analysis at the office. This approach eliminated the duplication of data collected from the field to the PC and reduced the time taken for such administrative work [10].

Rojas et al. examined the use of paper forms, laptop computers, digital pens, and handheld computers in capturing existing facility as-built information and found handheld computers to be the most time and cost-efficient method. Direct measurements of task completion times revealed that handheld computer users were able to collect as-built data approximately three times faster than the paper-based method [15].

Mobile Technology in State DOTs

Research on mobile technology, specific to use in DOTs, has focused on similar impacts, typically discussing process time savings and improved access to project reference documentation. These metrics are often used to assess the impacts of new technology in transportation construction as an American Association of State Highway Transportation Officials (AASHTO) report prepared by Crossett and Hines indicated that an average of 2 to 4 percent in cost overruns are generally caused by:

- Poor communication and coordination between agency personnel;
- Delays in the decision-making process; and
- Improper planning and lack of project control.

The use of mobile technology and other modern technologies is believed to reduce the above three factors that generally cause project cost overruns [16].

Asbahan and DiGirolamo provided tablet computers loaded with project reference documents to 10 inspectors working on Pennsylvania DOT projects for one month. Participant surveys revealed that inspectors perceived the use of tablet computers helped save approximately 20 minutes per day on tasks related to finding content in the project reference documents. The resulting time savings allowed employees to spend more time on general field inspection activities. The participants perceived no time savings from filling out paperwork and daily reports [17].

Valdes and Perdomo documented the development of a prototype application for tablet computers that creates inspection daily reports for the inspectors working for the Puerto Rico Highway and Transportation Authority. The prototype was field tested to an unspecified number of inspectors for a few weeks, but the study did not collect any data that measured performance impacts [13].

More recently, Yamaura and Muench conducted a study on the productivity and data quality impacts associated from the use of the HeadLight inspection system by three state departments of transportation (DOTs): Washington, Minnesota, and Texas. This research program, funded by the State Pavement Technology Consortium (SPTC), piloted the HeadLight technology to these three DOTs. Each DOT piloted HeadLight for one month and collected data to support changes observed in inspector productivity and changes to the quality of inspection observations. On average, the findings indicated the inspectors were able to save about 1.6 hours per day using HeadLight. The time savings accounted for the following: the amount of time spent generating daily inspection reports; the time saved from not having to travel off site to perform administrative tasks to generate and submit these daily reports; and time saved from being able to search through project reference documents (standard specifications, special provisions, plans, etc.) provided to inspectors in an electronic format.

In terms of data quality, it was observed that inspectors:

- Collected an average of 2.1 times more inspection information;
- Collected a larger variety of observation types (33 percent increase in the number of photos collected and directly included in daily reports);
- Collected more complete data (all observations included date, time, and location data);
- Collected more consistent observations (automated inclusion of inspection observations to daily inspection reports eliminated the potential of transcription errors); and
- Improved the timeliness and availability of inspection observations and daily inspection reports [5].

HeadLight Inspection System

HeadLight, a cloud-based, mobile project inspection system software developed by Pavia Systems, Inc., was chosen for evaluation based on prior user requirement research [18]. HeadLight was provided as an application on the Apple iPad Air tablet computer and supported by Pavia Systems. Each iPad Air was outfitted with a waterproof, protective casing and a hand-strap to carry the device in the field and allow for connectivity and operation from any DOTD project office. The technology's three main components include: mobile client, web client, and cloud-based web service. Figure 1 shows a screenshot of the HeadLight mobile and web client.

The mobile client application is installed on the mobile hardware (iPad Air). The mobile client: (1) provides a set of tools for capturing inspection information; (2) automatically integrates the captured information, such as text and photo observations, directly into daily work reports and allows project inspectors to generate and submit these reports directly from the field; and (3) enables project inspectors to access all project reference documents from the field such as project plans, special provisions, specifications, and other project manuals.

The web client application is viewable by office personnel on a web browser. The web client allows project engineers, management, and others with permission to access field information and inspection reports collected and generated by the mobile client through a secure web interface.

The cloud-based web service manages the data and information amongst mobile clients and provides a centralized, secure storage architecture by which the data is made available to both the web client and the SiteManager database system that resides within DOTD.

Figure 1. Screenshot of HeadLight mobile and web client

Objective

The overall objective of this project was to understand the impacts on DOTD for leveraging e-construction innovations, more specifically a mobile project inspection system called HeadLight.

The specific objectives of this research are as follows:

1. Measure increase in available time spent on field inspection.
2. Measure change in quality and quantity of inspection data.
3. Measure timeliness of submission of daily diary documentation.
4. Measure leading indicators for improving claims abatement.
5. Understand information requirements needed for effective maintenance of constructed assets.
6. Map relevant maintenance information requirements to data collected during construction phase.

Early on, the research team determined that for the HeadLight tool to be evaluated properly, a Materials Module would also have to be developed and piloted. The objectives were then revised and Objectives 5 and 6 were then removed with the addition of the creation and pilot of a Materials Module.

Scope

To meet the objectives of this project, DOTD evaluated and used a new e-construction technology called HeadLight. Field inspectors and their project teams initially piloted HeadLight over 12-18 projects across the state. The final pilot project count is 182 users of HeadLight on over 50 projects in four districts over the 18-month program.

As the project kicked off with its initial pilot program, field personnel stated that for adoption of any e-construction technology, the entire workflow process would have to be e-construction related. This included integration with SiteManager Materials. From this observation, the scope was revised to remove the asset management portion of the project and add in the creation of a Materials Module.

During the pilot program period, data captured and compiled by inspectors, information in daily diary documentation, data and information in legacy systems, and participant surveys were used to quantify improvements offered by HeadLight as compared to current practices. This empirical data was then evaluated using the following data quality and process change evaluation metrics: time savings, data volume, data variety, data timeliness, and data availability.

These quantified metrics were used to better describe the likely benefits of cloud-based, mobile technology, evaluate its adoption implications, and include or implement the resulting benefits in business process models. In addition, qualitative feedback from pilot program participants and novel applications of the technology was gathered to identify potential business process impacts alongside the introduction of the technology.

Methodology

This research evaluated the impacts to DOTD business processes, field data collection, and information dissemination resulting from the use of the HeadLight mobile inspection system through empirical field testing and observation. The impacts were determined by comparing the process and methods of the traditional inspection process with the HeadLight process using several evaluation metrics. This section discusses the following:

- Personnel roles involved in this pilot program
- The traditional inspection workflow process
- The HeadLight inspection workflow process
- HeadLight materials
- Data collection
- Evaluation metrics and methods

Personnel Roles Involved in the Pilot Program

The pilot program focused on four main personnel roles identified within DOTD: project inspectors/engineering technicians/senior inspectors, office/field engineers, project engineers, and management.

Project Inspectors/Engineering Technicians/Senior Inspectors

This group is responsible for determining whether the work is performed in accordance with the specified contract requirements. The inspector does not have the authority to accept work but has the authority and responsibility to reject work or materials until an acceptance determination can be made by the project engineer. Duties include: performing inspection observations, sampling and/or testing of materials, and generating documentary evidence to support that all activities and materials are in compliance with the approved plans and specifications [19].

Office/Field Engineers

This group's duties include assigning document attributes for content manager and making certain complete electronic documentation is maintained throughout the project in SiteManager and other DOTD databases. They may also do the following tasks: verify labor compliance and certified payroll, conduct Equal Employment Opportunity (EEO) interviews on Federal-aid projects, verify contractor pay estimates, and other administrative tasks [19].

Project Engineers

Project engineers are in charge of their field office and are accountable for all project-related activity associated with that field office. Project engineers supervise inspection staff, perform inspection and testing as needed, and assist the district area engineer with administrative duties [19].

Management

Management comprises personnel not within a particular field office but are involved when items escalate or conflict resolution is necessary. Titles can vary and examples may include: chief engineer, chief construction engineer, district area engineer, and headquarters area engineer [19].

Table 1 shows the total number of DOTD personnel that participated in the HeadLight pilot project. It is important to note that the analysis and results presented in this report is based on a subset of this participant population.

Field personnel (who are defined as inspectors, engineering technicians, and senior inspectors) participated in a two-hour introductory HeadLight mobile client training session, performed inspection on projects using HeadLight, and participated in research surveys before and after the field testing period.

Office personnel (who are defined as office and field engineers, project engineers, and management) participated in a two-hour introductory web client training session, reviewed inspection observations and daily work reports, and participated in the research surveys before and after the field testing period. This report addresses results from the field testing and participant surveys only; training activities were not experimental variables, although these activities certainly contribute to the outcome.

Table 1. Breakdown of the participants by role

Personnel Role	Total Number of Personnel Involved in the HeadLight Pilot Project
Project inspectors, engineering technicians, and senior inspectors	121
Office and field engineers	17
Project engineers	27
Management	17

DOTD Project Inspection

DOTD project inspection includes inspection and documentation of all work items and project activities DOTD inspectors are responsible for in the field during active construction and maintenance projects. The purpose of this documentation is to communicate the facts of what transpired on the job site, which includes the activities, materials, and test results and whether they conform to agency plans, specifications, and general quality standards. Examples of documentary evidence include: safety, accidents, traffic control, materials, construction practices, equipment, personnel, environmental, and weather conditions. Additionally, project inspectors document contract items such as change orders and pay or work items that were worked on and to what extent in order to determine subsequent payment. DOTD personnel are required to observe and document general project progress and activities occurring in the field. Inspectors are required to generate and submit Daily Work Reports (DWR).

Traditional DOTD Inspection Workflow

For the traditional inspection process, information is recorded in a physical notebook as written text in the field and then transcribed into one of several legacy computer systems to generate DWRs recording inspection information about what project-related activities transpired. This process typically occurs at the end of an inspector's work day; whereby, they typically travel back to the project engineering office to perform this task. The data and information gathered by the inspector is not available to other project stakeholders until after it has been input into the legacy system.

HeadLight Inspection Workflow

The HeadLight inspection workflow enabled inspectors to record all data and observations directly via a mobile device. Data input was captured via HeadLight whether the inspector was in a connected or disconnected environment, effectively letting the inspector use the mobile technology just as they would a traditional field notebook. As observations were collected throughout the day, they were synchronized via the cloud with a central server, making that data and information available to any stakeholders with the appropriate permission level. At the conclusion of their day, the inspector was then able to directly create a DWR from the field via HeadLight and avoid returning to the office or logging into a legacy application such as SiteManager. An integration with the existing legacy systems at DOTD was performed such that the DWR and work item data captured in HeadLight was automatically transferred to DOTD approval and payment systems without additional user intervention.

HeadLight Materials

During initial deployment of the mobile inspection platform, stakeholders identified a compelling need to include material sample tracking, test results, and a sampling plan in HeadLight in order to align with the job functions and workflows that are performed in the field. This also aligned with existing efforts within DOTD to improve and standardize the material sampling and tracking workflows. As a result, the research team developed several new material sampling and tracking capabilities that allowed inspectors further ability to complete their job from the field. This included development of a newly identified gap in the workflow for creating and managing material sampling plans. The materials workflows identified were comprised of the following: Sample Tracking, Test Results, and Sample Plan.

Data Collection

The research team collected inspection data that was produced using the traditional workflow and HeadLight workflow as well as conducted user surveys to pilot program participants.

Inspection Data

To assess the impact of HeadLight on the DOTD project inspection process, the research team extracted data and logs from the software system used in both the Traditional and HeadLight workflow process. To calibrate results for both project and user variability, two cohorts (project-based and user-based) were identified that best represented the project and user variety found across the state to evaluate impacts on both project and individual performance.

Project-based Cohort. The project-based cohort analysis and results presented in this report are based on a subset of projects selected from the pilot project group when using HeadLight. A subset of projects with similar characteristics described below not involved in the HeadLight pilot were used as a basis of comparison to evaluate the impact resulting from the use of HeadLight. Projects were primarily selected based on opportunity (i.e., project was active during the pilot program window).

To account for potential variability in the inspection workflow process between DOTD districts, the same number of projects were selected from each participating district for traditional and HeadLight projects.

To the extent possible, traditional projects with contract costs and durations similar to those of the HeadLight projects were selected. The intent of this criteria was to ensure the projects compared were similar in size and scope as these factors can affect the volume and types of inspection observations collected by inspectors.

User-based Cohort. To examine the impact of HeadLight on a personnel basis, inspection observations and DWRs generated using the HeadLight process by a subset of inspectors were analyzed. Inspection observations and DWRs generated using the traditional inspection method by these same individuals were extracted and used as the basis for comparison. The inspectors were chosen using the following criteria: duration of HeadLight use and minimum number of DWRs submitted.

Inspectors that used HeadLight for at least two months were selected. A two-month use period was selected because it provided an adequate and reliable sample size of inspection observations to perform basic statistical comparisons.

As this report examines the timeliness of DWR submissions, inspectors that have generated and submitted at least 10 DWRs were selected.

Survey Questionnaires

Survey questionnaires were administered to participants before and after the deployment of HeadLight to obtain quantitative and qualitative data associated with the use of HeadLight. Survey questions were developed and administered through the SurveyMonkey online survey service. The pre-deployment and post-deployment survey questions are included in Appendix A and B of this report.

Evaluation Metrics and Methods

This research focused on measuring the change in productivity and data quality when a mobile technology system is used in place of a traditional inspection information collection and documentation process.

Productivity

Productivity is defined as the time spent on data entry associated with DWR elements and work items. These activities were chosen as Snow et al. identified cloud-based, mobile technology having the largest productivity improvement on these tasks [18]. The research team identified a measurable item of time spent creating DWRs and measured this through the use of surveys. The research team specifically asked inspectors the following: (1) estimate the general amount of time expended in performing tasks involved in generating and submitting DWRs using both the traditional and HeadLight inspection processes, (2) estimate the average amount of time taken to travel from the field to the project engineering office to generate and submit DWRs using the traditional method, and (3) explain whether the use of HeadLight was perceived to have increased their overall efficiency in inspection and data collection.

HeadLight allows inspectors to generate and submit DWRs from anywhere in the field. Field personnel utilizing HeadLight have implied that they were able to stay in the field while creating DWRs, allowing more opportunities for inspection and observation compared to the traditional method where the inspector would travel back to the office and transcribe the DWRs upon return.

Data Quality

Data quality is defined as the volume, variety, availability, and timeliness of inspection data. These items were used as metrics to measure data quality as these are standard metrics used to evaluate software applications. Data volume is the overall quantity of observations regardless of form, and data variety describes the number of observation types (e.g., narrative, photo, and video). Data availability is defined as the accessibility of project inspection information to project engineers and management, and timeliness describes the speed at which data become available to others [20, 21, 22, 23].

Availability and timeliness were chosen as metrics because there are functions beyond project inspection, such as processing payments and managing construction schedules, which rely on timely access to inspection data. Furthermore, project engineers and management need timely access to inspection data to be aware of site conditions, ongoing construction activities, and potential issues that may need to be managed.

Surveys were used to determine the result of HeadLight on general data quality changes and availability and accessibility of inspection observations and DWRs. Specifically, researchers asked participants of the post-deployment survey questionnaire to assess whether the use of HeadLight: (1) improved the quality of the inspection data and information, and (2) improved the project's ability to identify and resolve issues, disputes, and/or claims. Researchers also asked participants to qualitatively assess how easy/difficult it was to access observations and DWRs using a series of five-point Likert scale (i.e., very easy, easy, neutral, difficult, very difficult) questions.

Analysis of inspection data was used to quantify the volume of project observations collected per inspector per day, the variety of observations collected, and timeliness of DWR submission and approvals.

The number of observations for both the traditional and HeadLight inspection processes were used to quantify the volume of observations per inspector per day. Traditional inspection data included in this analysis includes: DWR narrative remarks, personnel, equipment, and work item observations. The HeadLight inspection data included in this analysis includes: additional media observation types including images, videos, and audio. The average daily number of inspection observations collected from each inspector working on the analyzed projects was calculated and used to determine the average volume of observations collected by each project on a per inspector basis.

The total number of observation types collected from the traditional and HeadLight workflow from the project-based cohort were used to quantify the variety of observations collected. Observations included in this analysis include the following: narratives/text, weather, personnel, equipment, work items, images, videos, and start/stop times related to contract work hours or construction activities.

For timeliness of DWR submission and approvals, the amount of inspection reports that were available to project engineers and management staff within 24 and 72 hours of the DWR date were analyzed. To assess the timeliness of reports submitted using HeadLight, researchers examined the record in the HeadLight web-client to record the actual report submission and authorization dates.

Discussion of Results

Table 2 outlines the 12 HeadLight inspection project, and Table 3 outlines the 12 traditional inspection projects included in the analysis of this report. For the user-based cohort, data associated with DWRs generated from 30 inspectors was reviewed and compared to DWR data generated using the traditional method. The projects and numbers of DWRs generated using the traditional method from these 30 inspectors are shown in Appendix C.

Table 2. HeadLight projects included in the analysis of this report

Contract Number	Project Name	Cost (dollars)	Duration (days)
H.003263.6	I-20 Overpass Rehabilitation (Bossier City)	$3,886,358	250
H.009012.6	LA 10 & LA 67 Intersection Widening	$1,230,523	56
H.009485.6	LA 404: Bayou Choctaw Bridge	$2,799,794	150
H.010660.6	Tucker RD/Dyer RD/Denham RD Bridges	$1,944,212	247
H.010864.6	I-10: District 07 Cable Barrier	$7,129,861	129
H.011088.6	W. Prien Lake Road Relocation	$10,096,918	435
H.011111.6	I-49N, Segment K - Phase 2	$137,764,876	1,290
H.011449.6	Greenwood Rest Area Renovations	$2,147,192	269
H.011616.6	LA 101: LA 14 - US 90	$2,081,227	97
H.011914.6	I-49 CB: Natchitoches P/L to LA 3132	$5,171,012	200
H.011926.6	I-10 & I-59: Median Cable Barrier	$2,777,777	105
H.012176.6	I-10: LA 99 - Acadia P/L	$13,769,670	150

Table 3. Traditional projects included in the analysis of this report

Contract Number	Project Name	Cost (dollars)	Duration (days)
H.001073.6	KCS Railroad Overpass	$3,135,584	225
H.001278.6	Intersection Improvements Youree Drive at Kings Highway	$7,749,916	556

Contract Number	Project Name	Cost (dollars)	Duration (days)
H.003495.6	I-49N, Segment K - Phase 1 (I-220 to MLK Drive)	$31,569,922	909
H.003729.6	Toomey Rest Area Improvements	$16,394,500	720
H.005693.6	LA 447 / I-12 Interchange	$6,707,947	331
H.007939.6	Indian Bayou Bridge & Approaches	$5,752,419	450
H.009461.6	I-10 Clean, Paint and Miscellaneous Repairs	$18,464,550	432
H.010055.6	Cherry Witchie & N. Carpenter Road Bridges	$2,649,176	325
H.010670.6	LA 27 & LA 1256: 0.97 Mi S LA 1133 - I-10 Int	$8,285,821	277
H.011111.6	I-49N, Segment K - Phase 2	$137,764,876	1290
H.011224.6	US 190: Guardrail/Rutting Rep. (Phase 1)	$9,086,306	350
H.011703.6	LA 64 & LA 1209: CP, Overlay, & PCCP	$2,739,434	290

The following sections present results that highlight differences in inspector productivity and inspection data quality between the traditional and HeadLight inspection processes.

Productivity

Figure 2 and Figure 3 show the responses to questions related to productivity from the survey questionnaires. These figures are based solely on the responses from field personnel. The results indicate that the use of HeadLight reduced the range of time spent by inspectors in generating and submitting DWRs. The distribution of responses shown in Figure 2 indicate a majority of the inspectors using the traditional inspection process spent between 5 to 30 minutes generating DWRs. A majority of the inspectors using HeadLight (87.2 percent) were able to generate DWRs in 15 minutes or less. Figure 3 shows the time spent commuting is also significant. Ancillary evidence from discussions with field personnel is that the 15 minutes to create a DWR is now spent in the field instead of *after* the commute time back to the office leading to more time being spent in the field making, and/or, taking observations.

Figure 2. Survey results comparing the time taken to create DWRs between the traditional and HeadLight processes

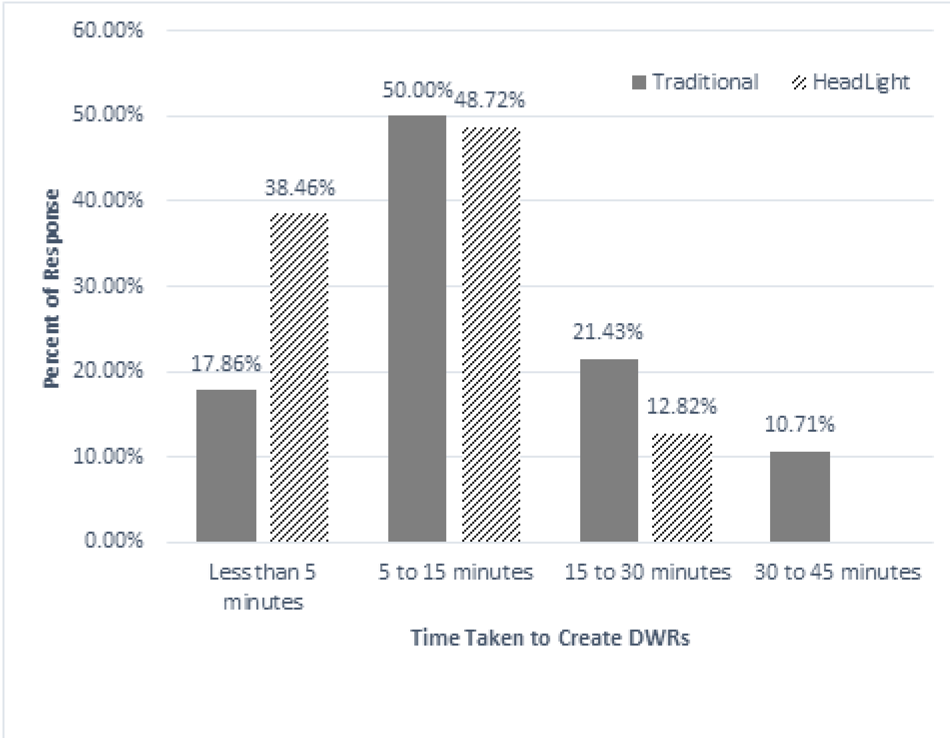
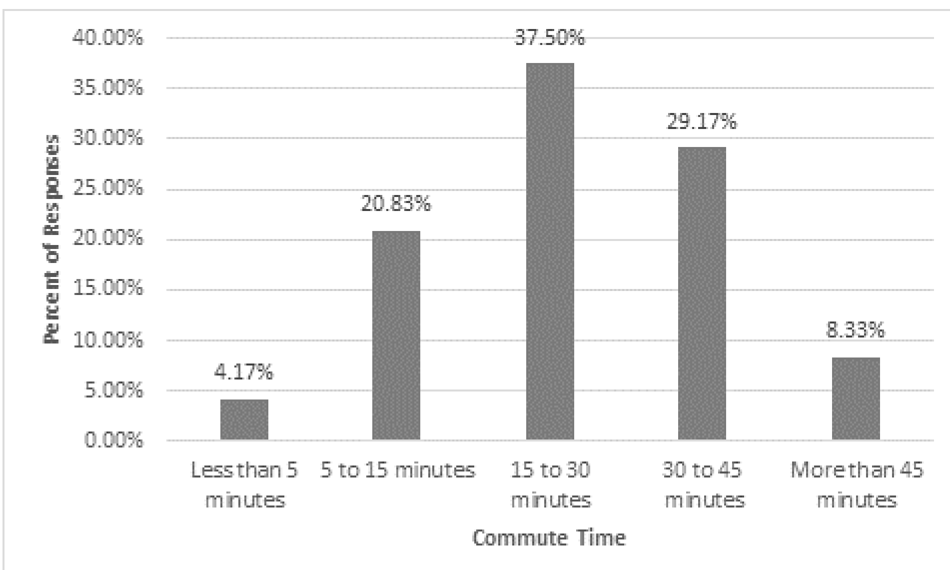


Figure 3. Survey results showing the typical commute time from field to office when submitting DWRs using the traditional process



The results shown in Figure 3 indicate that inspectors using HeadLight were able to create their DWRs more quickly compared to the traditional inspection method. The distribution of time spent creating DWRs using the HeadLight process narrows from less than 5 minutes to 30 minutes compared to less than 5 minutes to 45 minutes using the traditional process. Approximately 38 percent of the inspectors were able to generate DWRs in less than 5 minutes, and approximately 87 percent of inspectors were able to generate DWRs in 15 minutes using HeadLight. In comparison, about 18 percent of inspectors generated DWRs in less than 5 minutes and 68 percent generated DWRs within 15 minutes using the traditional inspection method. Using 15 minutes as the basis for comparison, the percentage change is calculated as 28 percent. In other words, inspectors using HeadLight experienced a productivity gain of 28 percent for activities involving the generation and submission of DWRs. Earlier work by Yamaura and Muench supports this finding [5].

Inspectors using HeadLight were able to reduce the time spent to generate and submit DWRs as the system allowed them to do so from anywhere in the field. If data connectivity was an issue onsite, the data collected in HeadLight was automatically synchronized to the cloud-based web service when connectivity was restored. This savings is realized by staying on-site longer and leaving the office for home when returning instead of working on transcribing DWR information equating to about an hour per day of additional inspection time per employee. This savings is significant when considering Department-wide adoption; 450 people at one additional hour per day leads to 2,250 hours per five-day work week or approximately 117,000 hours per year.

Table 4 shows the results of the survey questions asking inspectors whether they perceived time savings from the use of HeadLight and if its use increased their overall efficiency in inspection and data collection. Approximately 65 percent of respondents indicated that the use of HeadLight increased the amount of time they spent in the field compared to their traditional inspection method; 30 percent perceived no change in the time spent working in the field; and 5 percent believed they spent less time in the field when using HeadLight. Approximately 67 percent of the respondents perceived efficiency improvements when using HeadLight compared to the traditional inspection method. Approximately 18 percent of respondents believed there was no change in efficiency, and 15 percent of respondents believed the HeadLight process was less efficient compared to the traditional inspection method.

Table 4. User perception of time savings

Survey Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Using HeadLight has allowed me to spend more time in the field compared to my previous inspection process	2.50%	2.50%	30.00%	37.50%	27.50%
Number of Responses from Field Personnel	1	1	12	15	11
Using HeadLight has increased my overall efficiency in inspection and data collection	0.00%	15.38%	17.95%	41.03%	25.64%
Number of Responses from Field Personnel	0	6	7	16	10

Data Quality

Inspectors using HeadLight collected and shared an average of 1.9 times more inspection observations compared to the traditional inspection process. When the data is normalized to exclude observations that vary depending on the timing of work and project characteristics, inspectors using HeadLight collected and shared an average of 3.0 times more inspection observations compared to the traditional inspection process.

The use of HeadLight also resulted in inspectors collecting a larger variety of inspection observation types compared to observations collected using the traditional process. The use of HeadLight paired with the tablet computer's capabilities allowed inspectors to directly collect and include media observations within their DWRs. Increase in the use of photo observations was a trend observed throughout majority of the projects that used HeadLight. A composition analysis of observations indicates photo observations accounted for 7.5 percent of the observations collected on a typical day, which is an increase over traditional inspection methods that did not include photo observations directly into the DWRs.

The availability of inspection observations that included date, time, and location data improved significantly with the use of HeadLight. Survey respondents indicated that over half of the observations included in traditional DWRs often missed time and location information for specific work activities and issues. Figure 4 provides an example that applies the collection of location data to map the locations of observations collected. The collection of these types of metadata allow personnel to view inspection observations using a spatial approach.

Figure 4. Spatial view of all data in HeadLight

Table 5 presents the results of the survey questions asking participants to evaluate the changes in inspection data quality when using HeadLight over the traditional inspection process. Field personnel were asked to assess the general data quality changes resulting from the use of HeadLight. Office personnel were asked to assess the general changes to inspection data quality as well as whether these changes impacted their tasks in determining and resolving issues, disputes, and claims on projects.

Table 5. General data quality change survey responses

Survey Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The use of HeadLight improved the quality of the inspection data and information (completeness, availability, timeliness, etc.)?	2.50%	10.00%	20.00%	37.50%	30.00%
Number of Responses from Field Personnel	1	4	8	15	12
The quality of information in the daily work reports (more complete, more variety, more detailed observations, etc.) has improved with the use of HeadLight.	5.00%	10.00%	15.00%	55.00%	15.00%
Number of Responses from Office Personnel	1	2	3	11	3
The daily work reports created using HeadLight provides enough information for me to address issues, disputes, and claims that occurred on the project.	0.00%	0.00%	10.00%	70.00%	20.00%
Number of Responses from Office Personnel	0	0	2	14	4
The use of HeadLight improved my ability to identify and resolve issues, disputes, and/or claims?	5.00%	5.00%	40.00%	30.00%	20.00%
Number of Responses from Office Personnel	1	1	8	6	4

The following sections present results for each of the metrics that evaluate changes in inspection data quality.

Project Total Volume per Inspector

Figure 5 shows the amount of inspection observations captured using the traditional process on a daily basis. Figure 6 shows the amount of inspection observations using the HeadLight process on a daily basis. The dotted reference line represents the average amount of observations collected per day by each project, and the dashed reference line represents the average amount of observations collected per day by all 12 projects. It is important to note the data presented in Figure 5 and Figure 6 show the total number of inspection observations collected per day for the entire project and does not account for the differences in the number of inspectors working on the project each day.

Figure 7 uses the data depicted in Figure 5 and Figure 6 to show the average amount of inspection observations collected per day per inspector for each project. Each data point in Figure 7 represents the average volume of observations collected per day per inspector. The boxes in this figure represents the middle 50 percent of the data. The left side of Figure 7 includes all types of inspection observations while the right side omits contractor personnel, contractor supervisors, equipment, and work item observations. The volume of these types of observations can vary widely depending on the timing of work (e.g., the amount of work activities can vary between winter and summer construction seasons) and project characteristics (e.g., scope of work, contract cost, resources available on projects, etc.). Omitting these types of observations normalizes the data for more accurate comparisons. Table 6 shows the average amount of observations collected per day by project and by inspector for the traditional and HeadLight processes. The factors shown in this table are calculated from the normalized values.

Table 6. Average volume of observations summary table

	All Observations		**Observations Normalized**		
Unit of Comparison	**Traditional**	**HeadLight**	**Traditional**	**HeadLight**	**Factor[a]**
By Project	15.50	24.56	6.61	12.64	1.91
By Inspector	3.82	8.78	1.54	4.68	3.04

[a] Calculated as HeadLight observations/traditional observations using the normalized values.

Figure 5. Volume of inspection observations collected by date per project for the traditional method

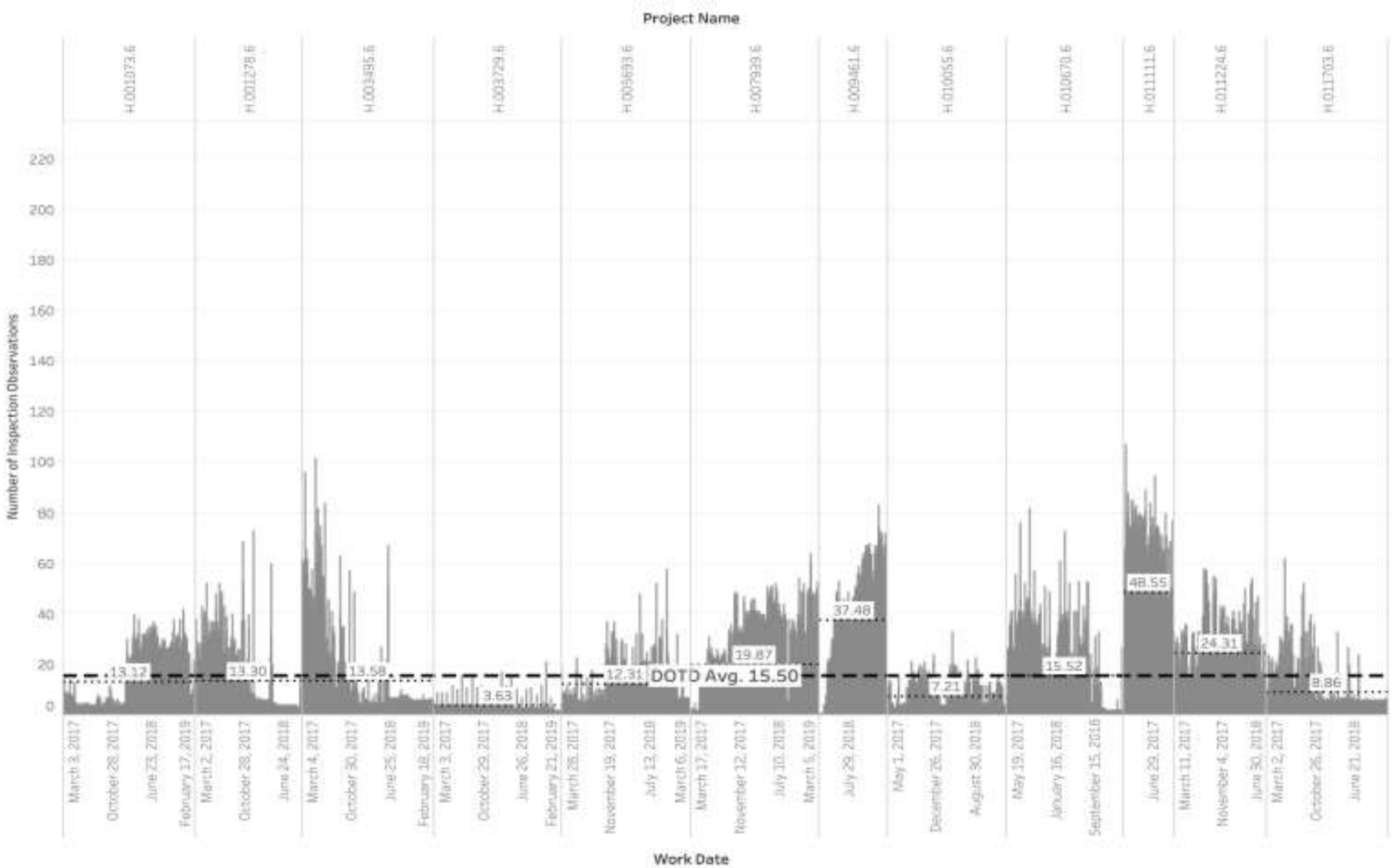


Figure 6. Volume of inspection observations collected by date per project for the HeadLight method

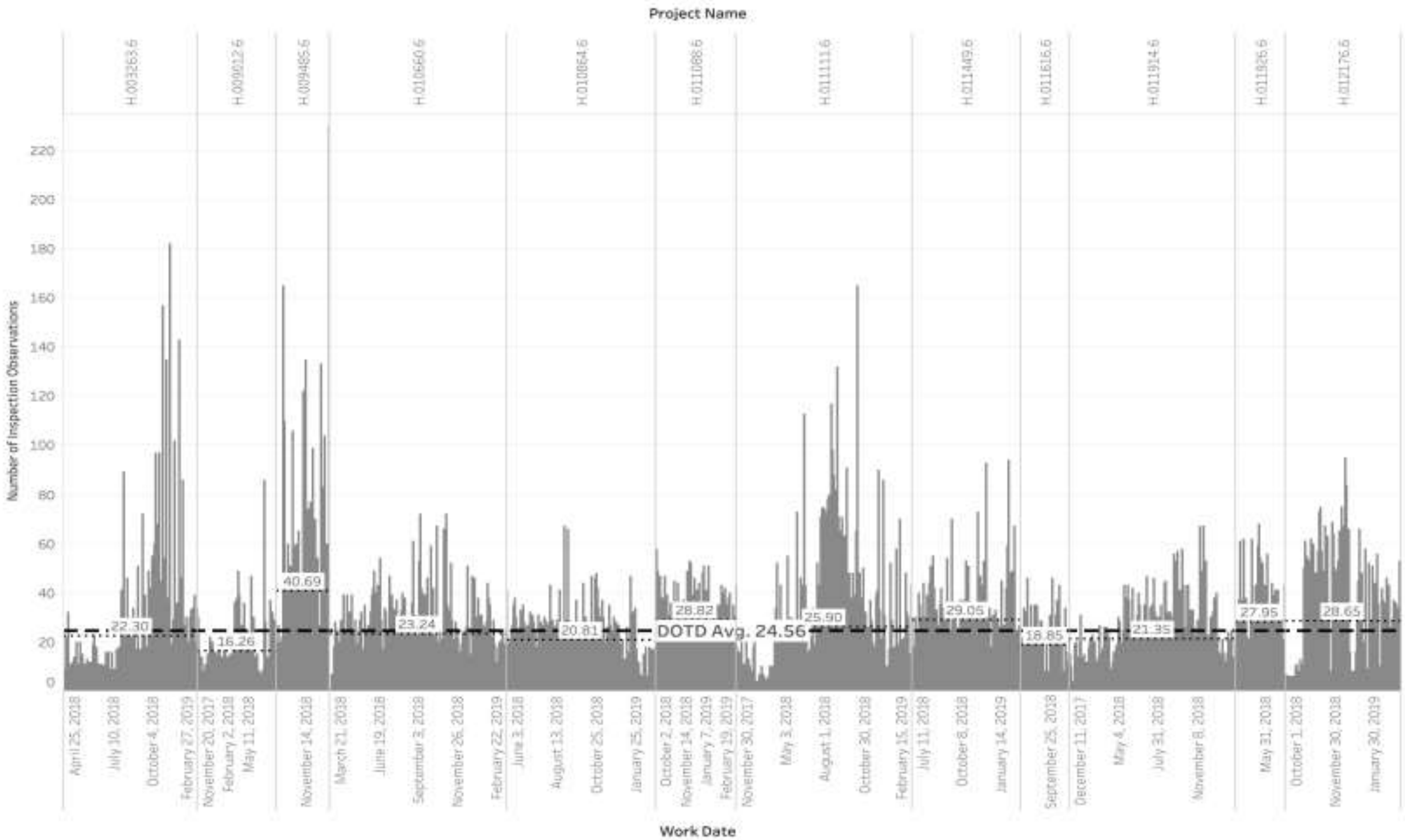
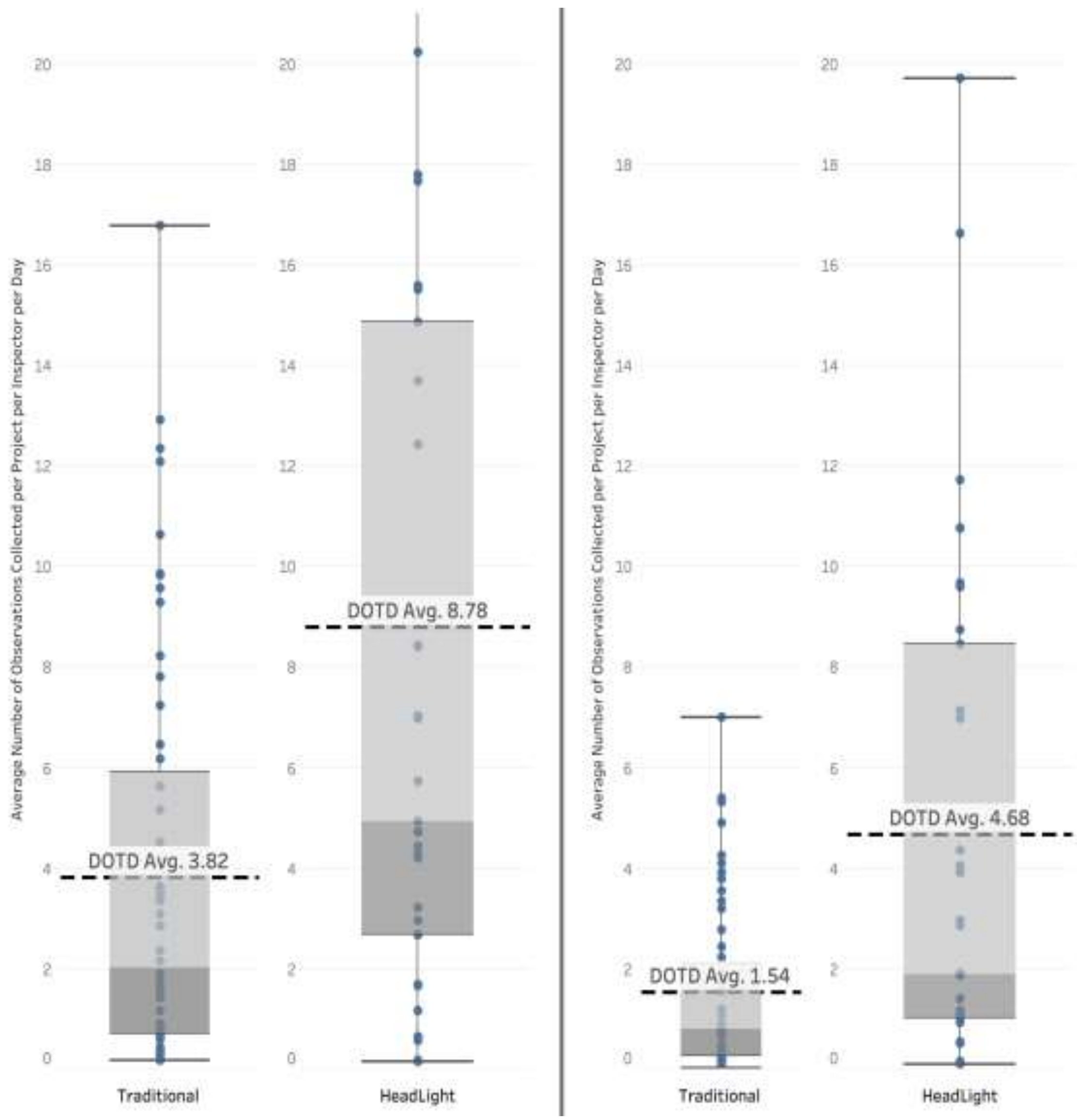


Figure 7. Comparison of average volume of inspection observation collected per project per inspector per day. The comparison on the right omits personnel, equipment, and work item observations (normalized)



Variety

Figure 8 shows the difference in quality of information on a DWR produced using the traditional versus the HeadLight process. Note the significant increase in information for the HeadLight process. The DWRs created in HeadLight were designed to directly include new types of media such as image, audio, and video observations. Image observations were presented in the diary section of the DWR while the video and audio observations are presented in weblinks. Figure 9 shows the variety of observations including data, geospatial information, and media collected within the HeadLight tool.

Figure 8. Comparison of quality of information within existing report format between traditional process (left) and HeadLight process (right)

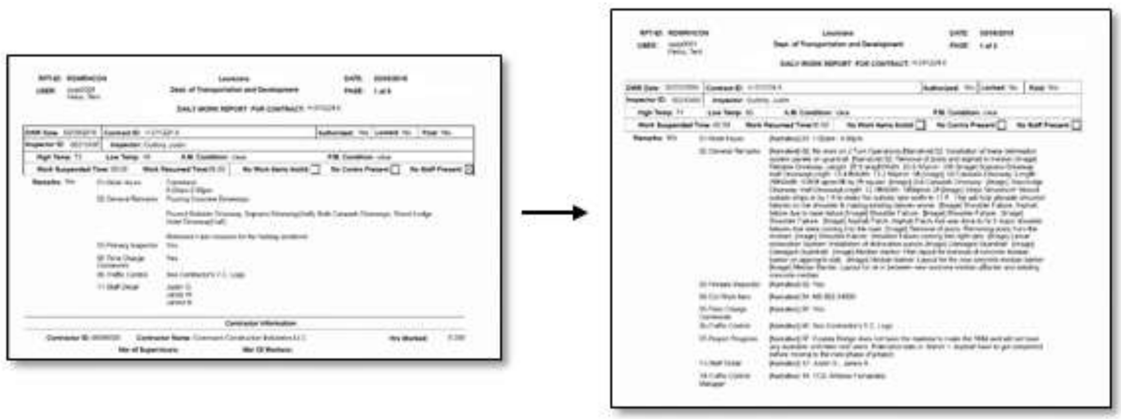


Figure 9. Example of additional observations, data, geospatial information, and media collected using HeadLight

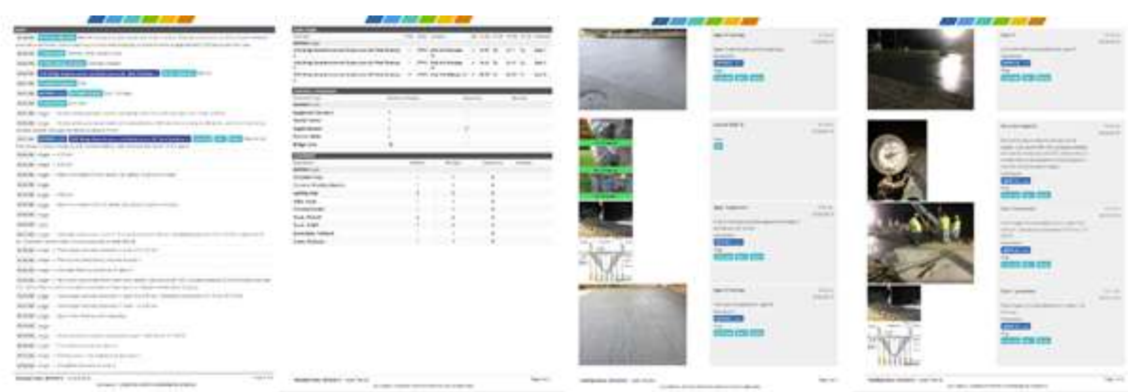


Table 7 identifies the new types of observations and total amounts of these observations collected using HeadLight throughout the pilot program. Date/time stamp and location data are included in this table as every observation collected using HeadLight is tagged with these metadata. DOTD personnel collected 81,367 HeadLight observations during the pilot program. Although weather observations were collected using the traditional inspection process, the weather observations collected in HeadLight provided more detail (e.g., wind speed, precipitation, etc.) and reported the conditions at the inspector's specific location compared to the traditional inspection process, making them a new type of observation.

Table 7. New observation types and total count of observations collected using HeadLight

New Observation Types	Total Count of Observations Collected
Date/Time Stamp	81,367
Location Data	81,367
Image	5,957
Weather	6,734
Video	253
Start/Stop Work	198
Temperature	46
Audio	10
File	9
Density Measurement	6

Availability

Table 8 shows the results of the survey questions that asked office personnel to rate the ease or difficulty in searching and accessing inspection observations collected by field personnel. Additionally, 24 office personnel were asked to estimate the average amount of inspection observations in traditional DWRs that contained specific time and location (e.g., station offset, Global Positioning System (GPS) coordinates, mile post number, etc.) data for issues or other important events. The results indicate that an average of 42 percent of inspection observations collected using the traditional method included this time and location related data. This study assumes that all observations collected in HeadLight provide the date, time, and location data as HeadLight automatically captures this metadata for each observation.

The results from Table 8 also suggest the searchability and accessibility of inspection observations improved significantly with the use of HeadLight. One-third of the respondents found it difficult to search and access specific information using the traditional inspection method. No participants indicated any difficulties searching and accessing inspection observations using HeadLight, and 60 percent of respondents stated that it was easy to perform these tasks using HeadLight.

Table 8. Survey responses for data availability and accessibility

Survey Question		**Very Difficult**	**Difficult**	**Neutral**	**Easy**	**Very Easy**
How easy is it for you to find inspection information related to a specific work activity, issue, or conflict?	Traditional	8.33%	25.00%	33.33%	33.33%	0.00%
	Responses	2	6	8	8	0
	HeadLight	0.00%	0.00%	40.00%	40.00%	20.00%
	Responses	0	0	8	8	4

Timeliness

This section presents the results of the change in timeliness of inspection documentation on a project and personnel basis.

DWR Submission and Authorization – By Project. Figure 10 shows the percentage of DWRs that were submitted within 24 and 72 hours from the report date for the 12 projects representing the traditional inspection process. The dashed reference line represents the average submission percentage for all 12 projects combined. Figure 11 shows the same information but for the 12 projects representing the HeadLight process. Figure 12 shows the amount of days between the DWR report date and report submission date for traditional projects. Figure 13 shows the amount of days between the DWR report date and report submission date for HeadLight projects. Figure 14 compiles this data and compares the average agency-wide distribution of the days between the DWR date and its submission date for traditional and HeadLight projects. The shaded box-regions represent the middle 50 percent of the data, and the dashed reference lines represent the average submission time for all projects combined. Table 9 shows the average number of days between the DWR date and its submission date for the traditional and HeadLight inspection processes and provides the factor of difference between the two values.

Figure 10. Percentage of DWRs submitted with 24 and 72 hours for the traditional process

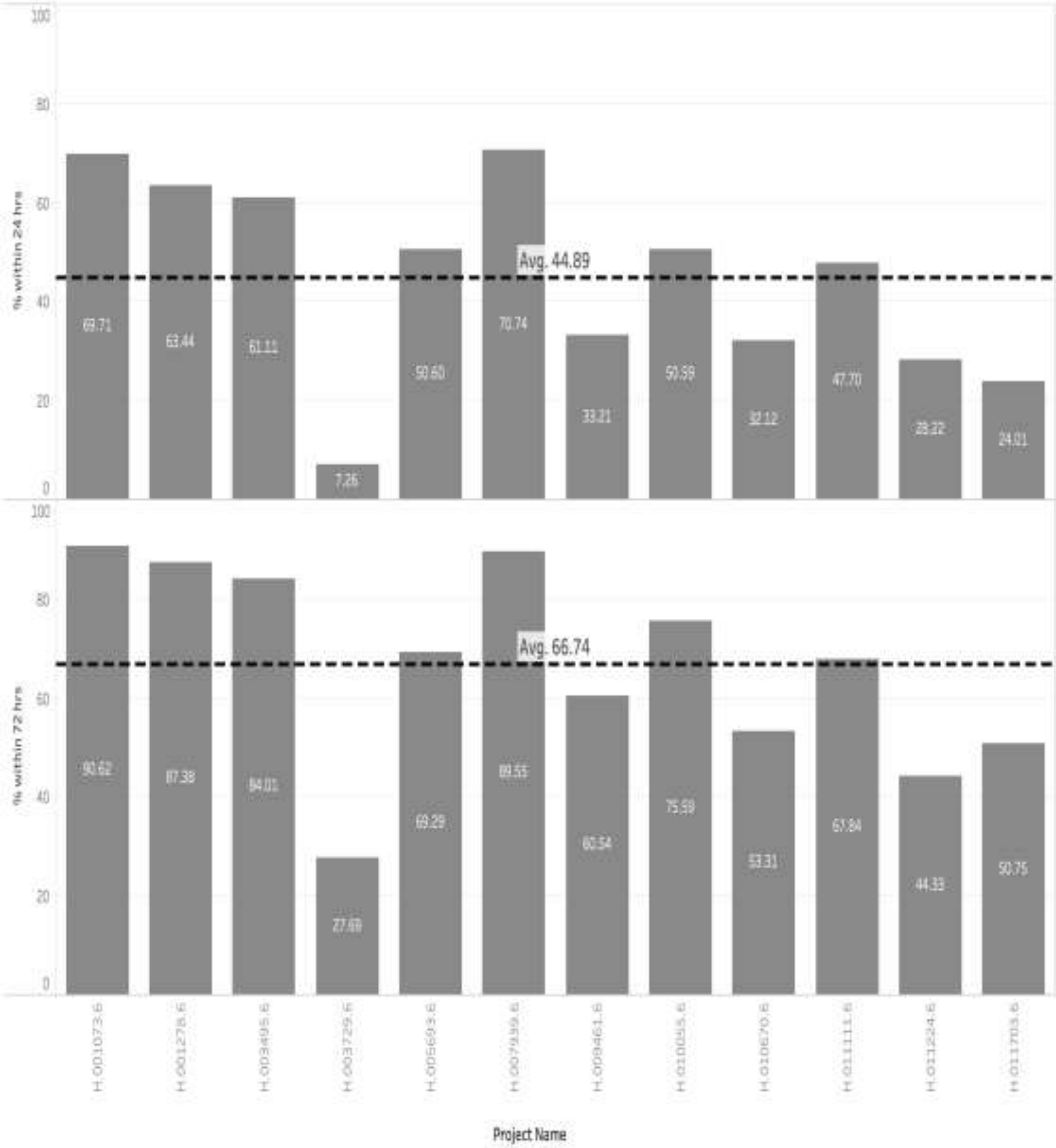


Figure 11. Percentage of DWRs submitted within 24 and 72 hours for the HeadLight process

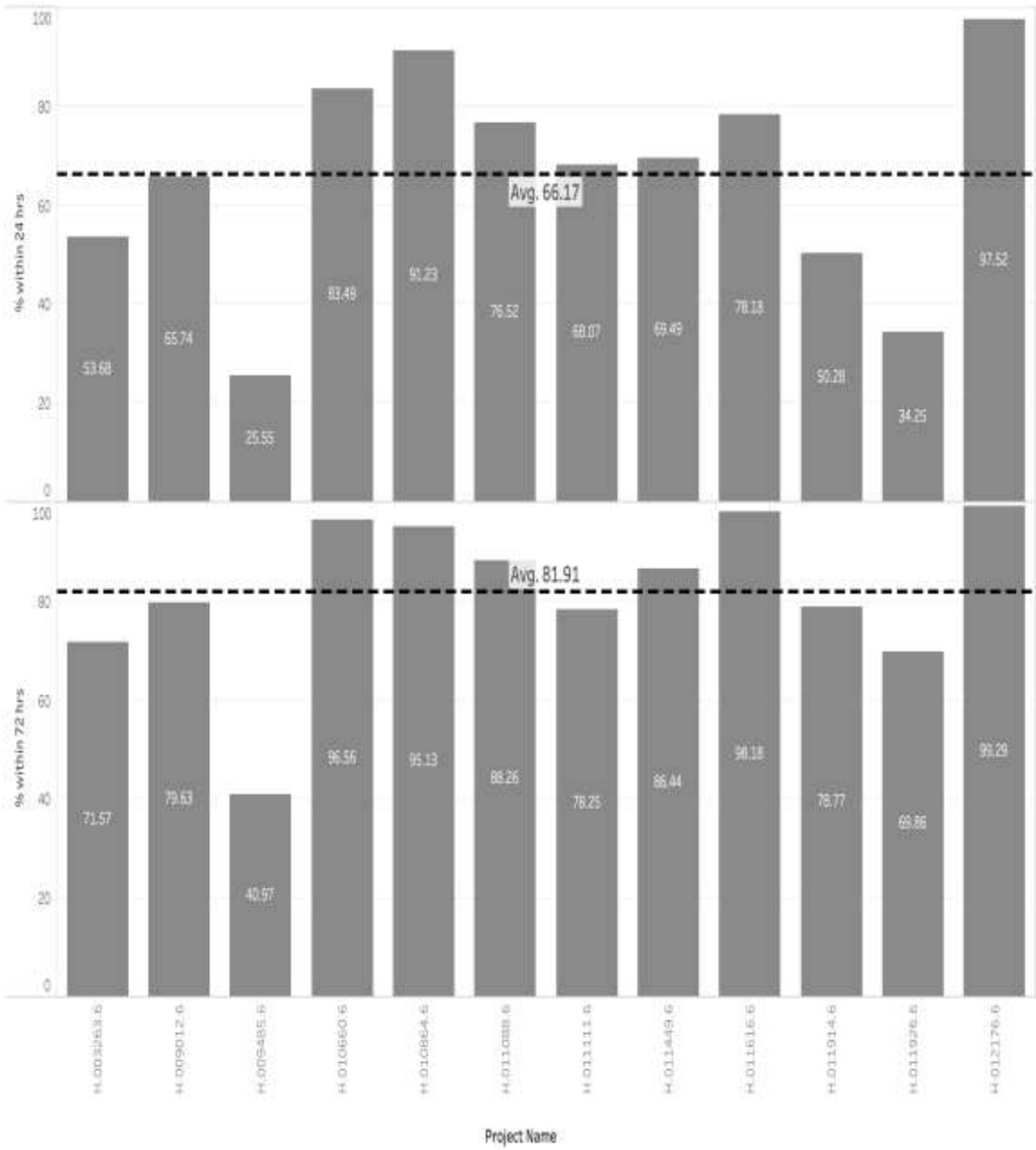


Figure 12. Timeliness of DWRs submitted per project for the traditional process

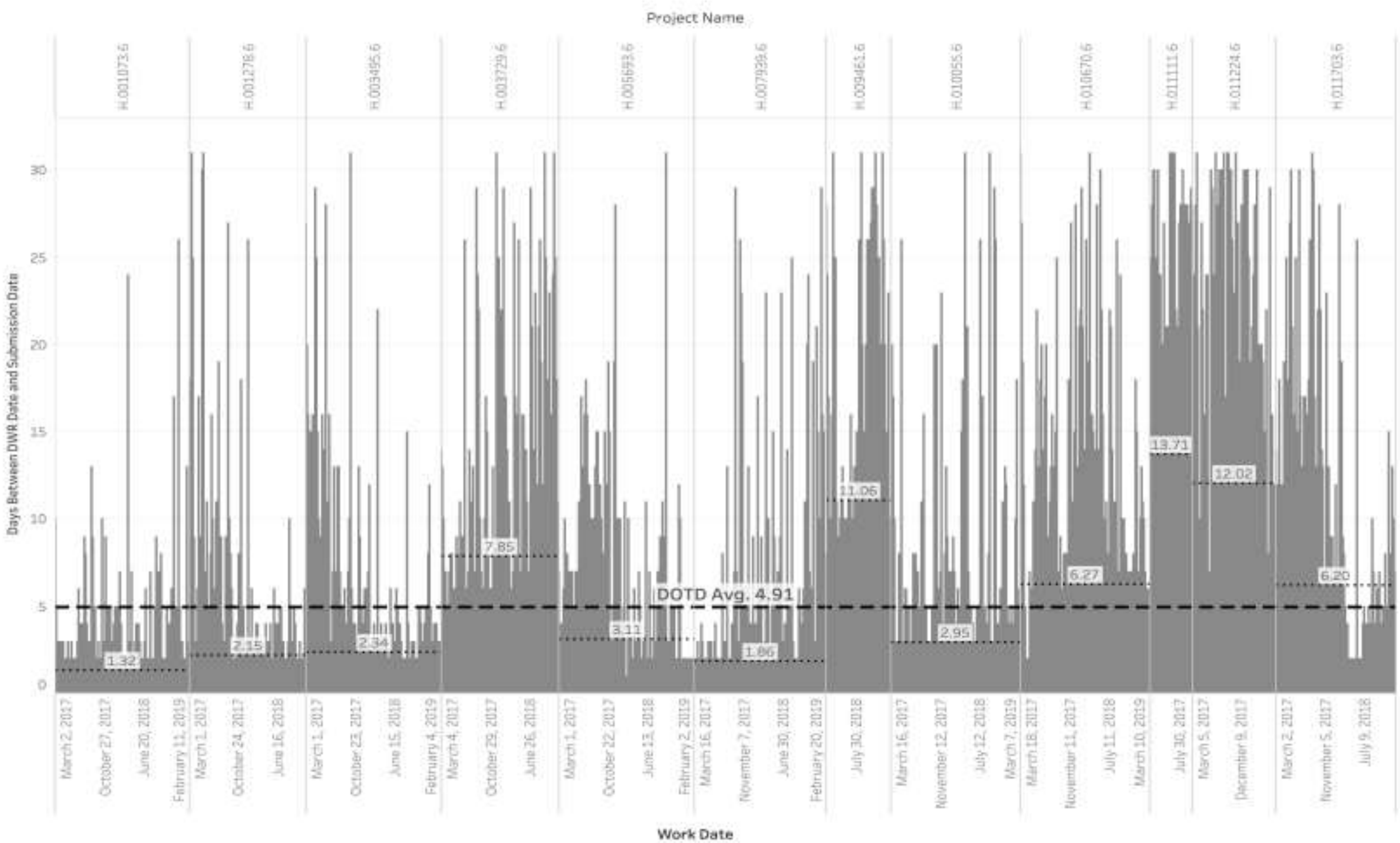


Figure 13. Timeliness of DWRs submitted per project for the HeadLight process

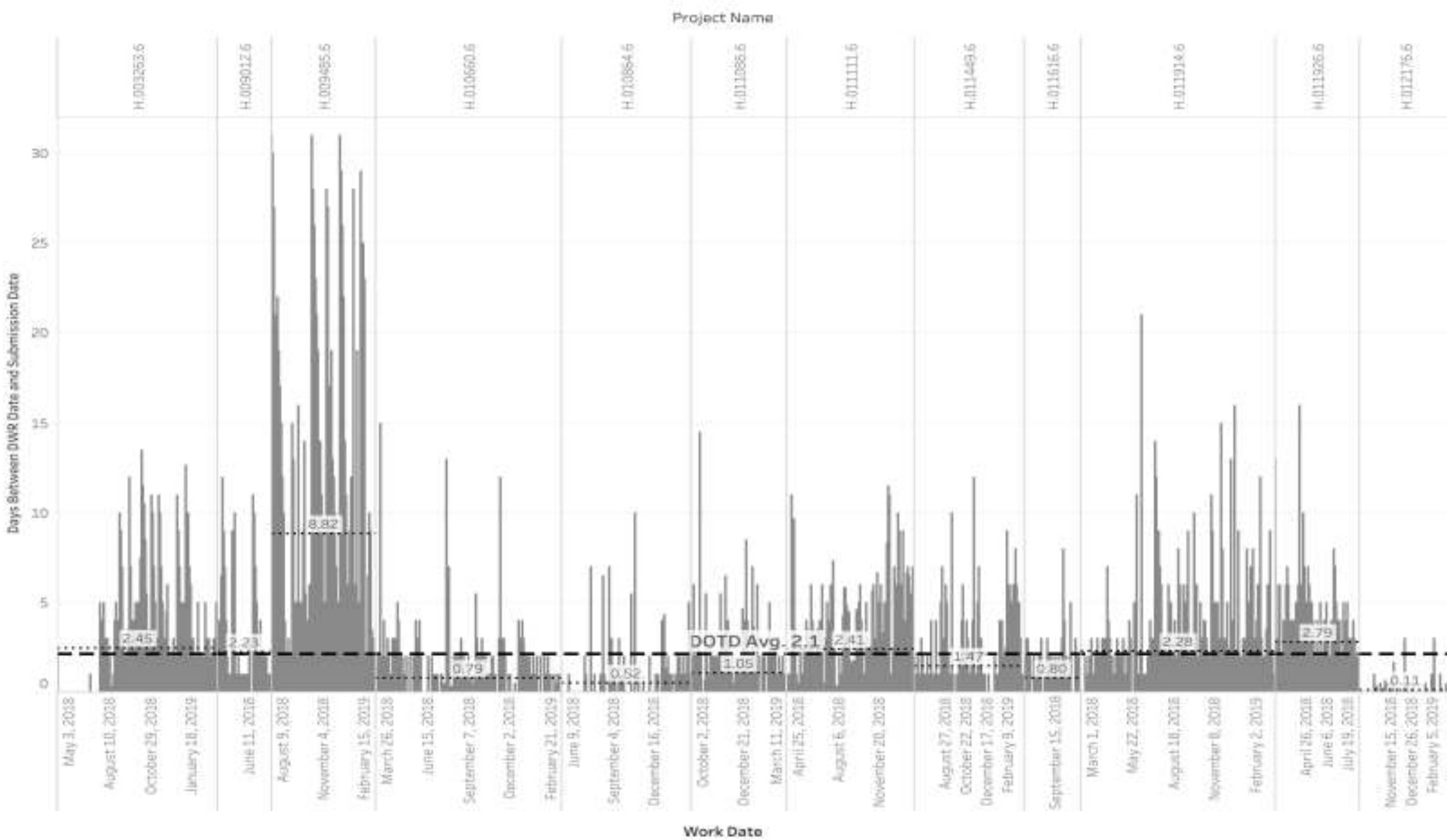
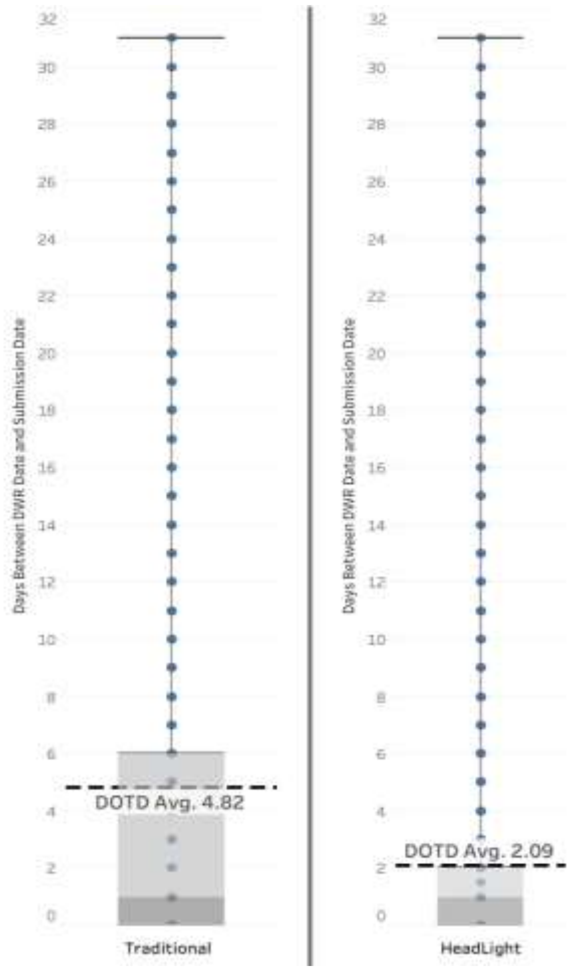


Figure 14. Comparison of DWR submission timeliness



DWR Submission – By Inspector. Figure 15 and Figure 16 show the distribution of the days between the DWR report date and when they were submitted for the traditional and HeadLight inspection processes. The dashed reference line represents the average submission time for all 30 inspectors combined. Table 9 shows the summary of the average timeliness of DWR submissions for the project and user cohorts.

Figure 15. Timeliness of DWRs submitted per inspector for the traditional process

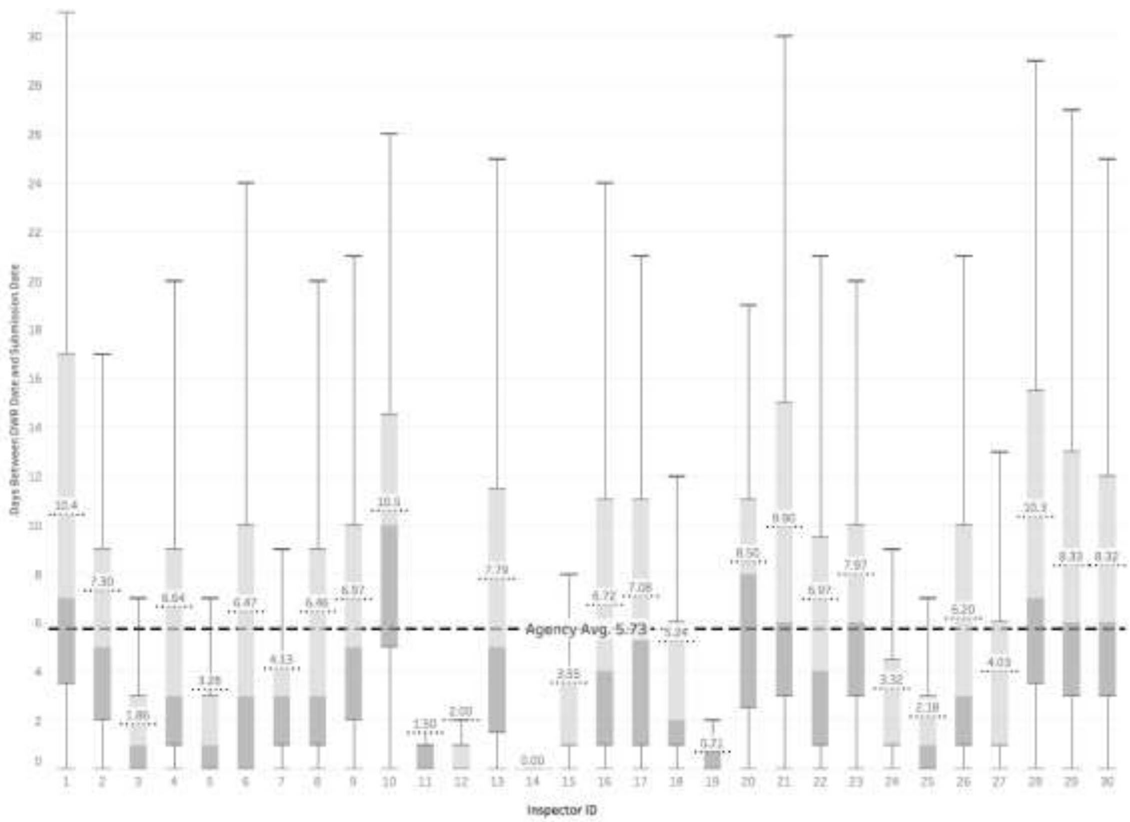


Figure 16. Timeliness of DWRs submitted per inspector for the HeadLight process

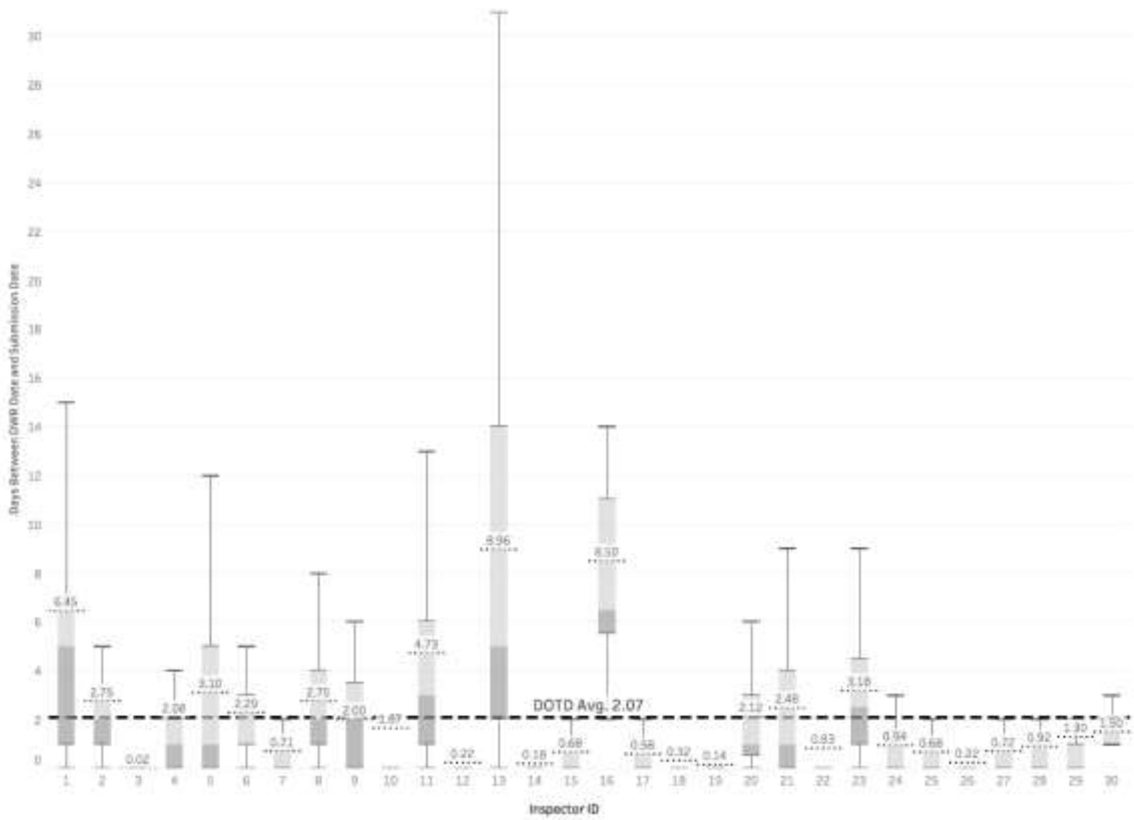


Table 9. Average timeliness of DWR submissions summary table

	Timeliness of DWR Submission (days)		
Unit of Comparison	**Traditional**	**HeadLight**	**Factor[a]**
By Project	4.91	2.10	2.34
By Inspector	5.73	2.07	2.77

[a]Traditional value divided by the HeadLight value.

Data analysis indicates the use of HeadLight improves the overall timeliness of DWR submissions. Additionally, it improved the timeliness of individual inspection information availability over the traditional process by enabling office and management personnel access to real-time inspection observations collected throughout the day on each active jobsite. Although harder to quantify, the data stored via HeadLight is available in one central database. This data is secure and readily searchable by project, observation type, time, location, project inspector, etc. Timeliness of DWRs created using the traditional process historically was inconsistent. In some cases, office personnel indicated it could take anywhere from 3 days to 1 week to obtain the reports. On average, inspectors using the traditional process submitted their DWRs 5.7 days after the report date. Using HeadLight, the same inspectors submitted DWRs, on average, 2.1 days after the report date.

Materials Module

The Materials Module was developed in response to a compelling need to include sample tracking, test results, and sampling plan workflows in HeadLight in order to align with the job functions and workflows that are performed in the field. This also aligned with existing efforts within DOTD to improve and standardize the material sampling and tracking workflows. As a result, the research team developed several new material sampling and tracking capabilities that allowed inspectors further ability to complete their job from the field. This included development of a newly identified gap in the workflow for creating and managing material sampling plans. The materials workflows identified were comprised of the following: sample tracking, test results, and sample plan.

Sample Tracking

The sample tracking provides inspectors the capability to create, track, and manage samples within HeadLight. This function allows field and office users to seamlessly create samples as needed from the field and relate them to the appropriate material. To enable tracking, a wireless label printer is used to create Quick Response (QR) codes in the field and affix to samples and other various documents. Each time the material changes possession, the QR code is scanned using the camera on the HeadLight enabled mobile device and logged into HeadLight. This provides user-based, geospatial, chain of custody tracking for DOTD samples and materials. Figure 17 shows a picture of samples and corresponding QR codes for tracking purposes.

Figure 17. Picture of printer, samples, and corresponding QR codes for sample tracking in HeadLight

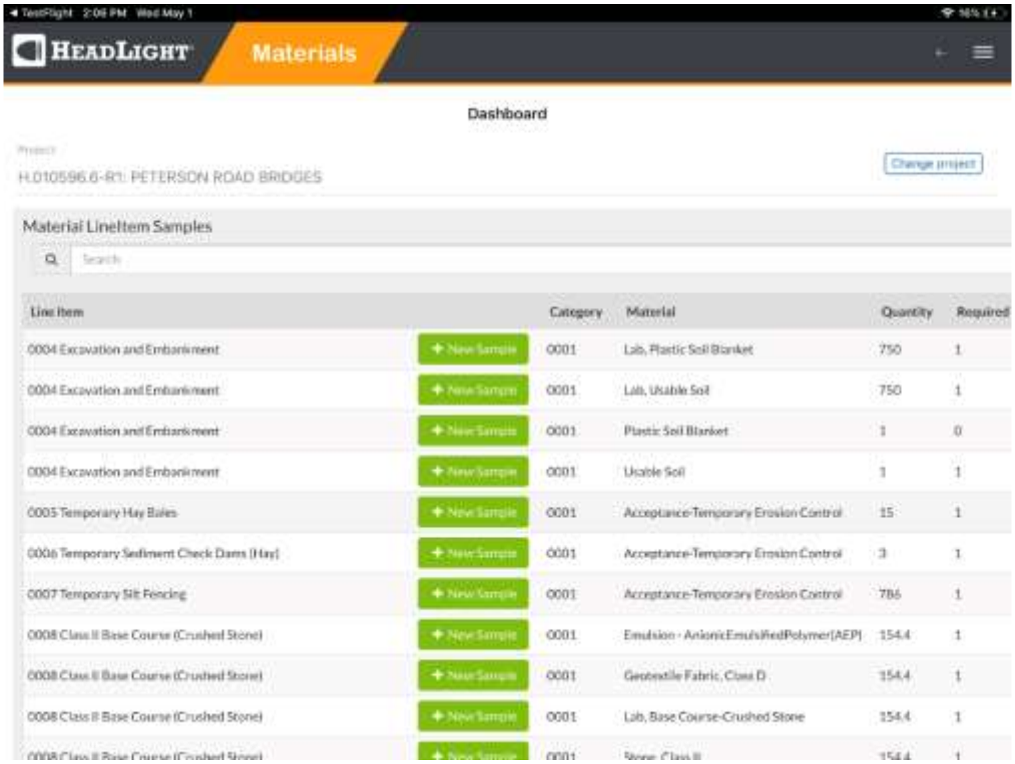
Test Results

This system allows users in the field or lab to capture test results by entering the data into forms that closely mirror the paper forms inspectors are currently using. For the purposes of this research study, only a subset of the test forms were developed such that common asphalt, concrete, and soil sample testing could be performed easily and rapidly in the field.

Sample Plan

The sample plan management module was developed to provide engineers and technicians a means to predefine which tests are required for specific bid line items and materials on a particular project. This function was currently performed ad hoc through various systems, and the research project focused on identifying a standardized workflow and accompanying business processes to improve consistency across DOTD. Figure 18 shows a screenshot of the sampling plan dashboard in HeadLight.

Figure 18. Screenshot of the sample plan dashboard used by inspectors to determine field sampling requirements



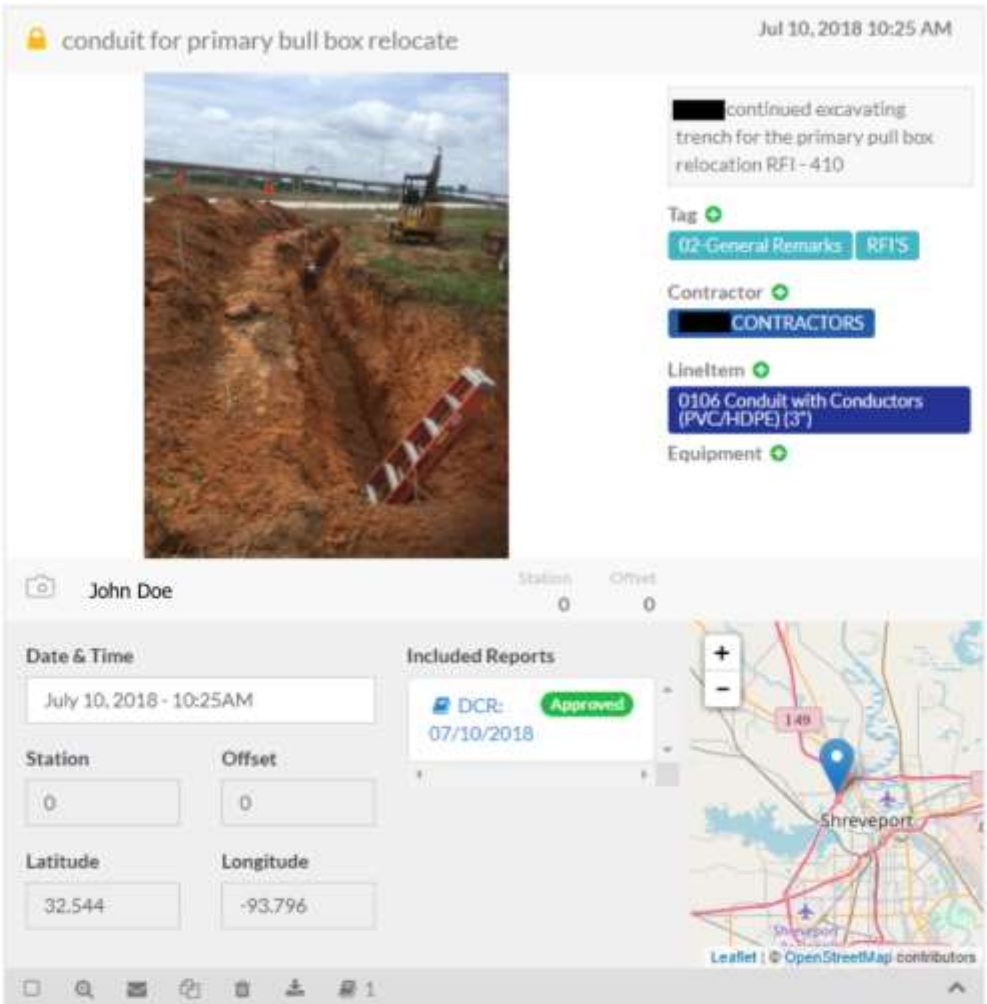
Observed Value of HeadLight

During the pilot program, the research team observed notable use cases of HeadLight that demonstrated the impact of e-construction inspection and its potential benefit to the Department. These use cases included the following: improved coordination and decision making between field and office personnel, more thorough documentation and cataloging of work activities with deficiencies and corrections made, standardization of the inspection workflow process, and the use of HeadLight inspection data as a training resource.

Improved Coordination and Decision Making

Researchers observed several cases where real-time dissemination of inspection observations collected in HeadLight helped office personnel identify and address safety and work activity issues. For example, a project engineer reviewing inspection observations at the project engineering office noticed a photo of a trenching operation that was being performed without the use of appropriate temporary shoring. The project engineer identified the time, location, and the creator of the observation (Figure 19) and was able to quickly coordinate with the field personnel to address this trench safety issue.

Figure 19. Photo observation shoring the trench safety issue



In another example, a new section of the drainage structure did not fit properly with the previously installed drainage runs. Field access to previous inspection observations and project reference documents helped resolve this drainage structure installation issue in a timely manner. This was accomplished since the DOTD inspector and materials engineer were able to search through and review the HeadLight records for observations dealing with this specific drainage structure on site. This information was then reviewed with the contractor and the drainage structure supplier onsite – with the issue being resolved within several hours before it became a claim or change order.

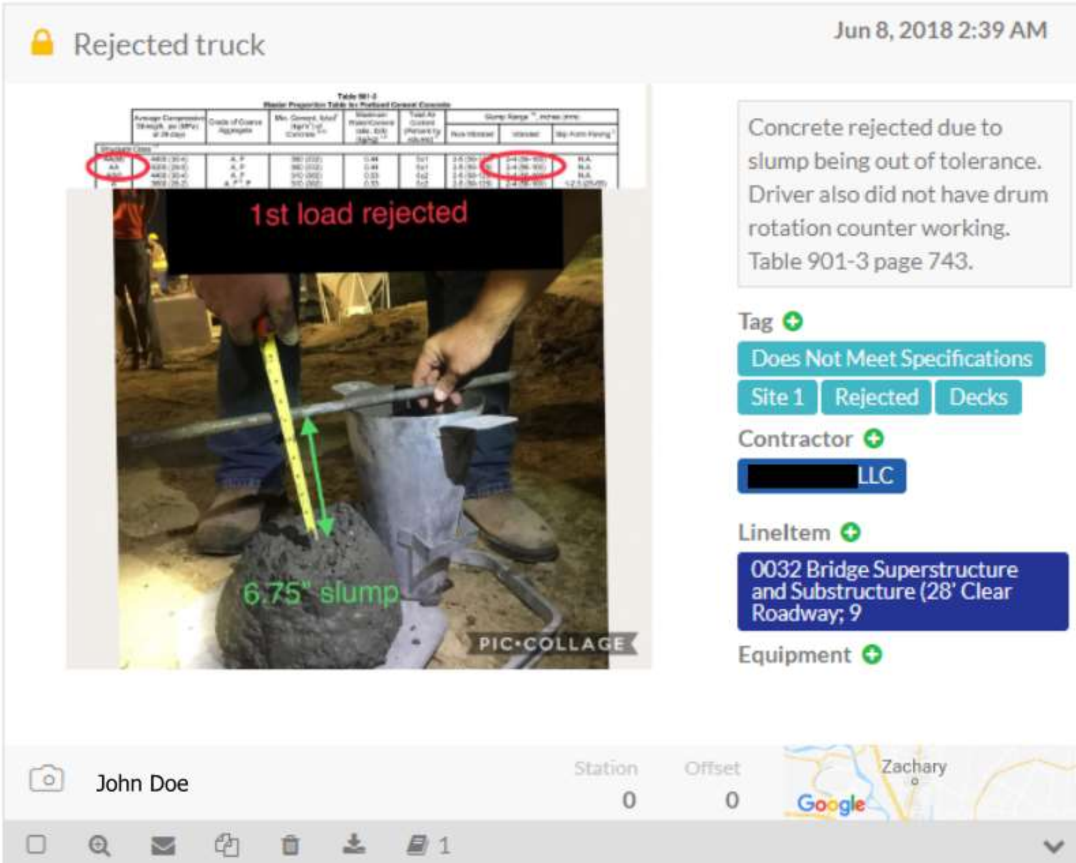
Both examples demonstrate the value of being able to access real-time inspection observations from the field by the project engineering office and the value of accessing inspection data to support field decisions in a timely manner.

Additionally, improved coordination and communication may lead to a reduction in claims. While all of the pilot projects had no claims submitted, wider adoption and use of the technology will assist the Department in realizing the reduced claims benefit if it truly exists.

Thorough Documentation of Deficiencies and Corrections Made Using Visual Observations

In some cases, inspectors included annotations to photo observations or combined photos of work activities with annotations and/or images of project reference documents (e.g., plans, standard specifications, etc.) to provide additional context to the observations. Figure 20 shows a photo observation with annotations showing the measured slump and a table specifying acceptable values. This photo observation provides information on the quality control test performed, the acceptable tolerance of the test result, the actual result of the test, and the decision to reject the batch of concrete in one concise observation.

Figure 20. Photo documentation of a failing concrete slump test



Standardization of the Inspection Workflow Processes

The HeadLight pre-deployment survey found the traditional workflow process involved in collecting, storing, and disseminating inspection observations and documentations differed from one inspector to another. The survey respondents shared the following methods used to collect inspection observations in the field (some inspectors used more than one method shown below):

- Record inspection observations on paper (e.g., field notebook, pieces of paper, etc.);
- Record inspection observations using mobile device (e.g., tablet computer, smart phone, etc.);
- Record inspection observations using a media device (e.g., camera, video recorder, etc.); and
- By memorization.

The survey respondents shared the following methods used to generate DWRs (some inspectors used more than one method shown below):

- Transcribe inspection observations into an electronic DWR template (e.g., OneNote, Microsoft Excel, Microsoft Word, etc.), then upload to SiteManager;
- Enter inspection observations into SiteManager; and
- Transcribe inspection observations by hand into a paper DWR form, then upload to SiteManager.

The observed variability in the documentation process can affect factors such as the data's searchability and availability. For example, the contents within a DWR uploaded to SiteManager as a PDF may not be searchable compared to DWRs generated using SiteManager directly. Inspection observations are not available until the information is entered into SiteManager is another example. A photo taken on a digital camera or a smartphone may not be available until it has been uploaded onto a shared drive. The use of HeadLight, paired with capabilities of the mobile device, has standardized the resources available to the inspectors (e.g., cellular/data connectivity, GPS sensors, cameras, microphones, etc.). The use of HeadLight also standardizes the processes involved in collecting and disseminating the inspection data. Inspection observations were automatically uploaded to the cloud-based web service and made available for review using the mobile or web client. A universal DWR format was implemented during the pilot program which also standardized the formatting and layout.

Use of Inspection Data Retained in HeadLight as a Training Resource

The 12 pilot projects analyzed in this report generated a total of approximately 50,000 HeadLight observations. These observations, all stored in one central location and accessible through mobile or web clients, can now be used as a training resource throughout various departments within the Department. Construction processes, issues and the methods used to resolve them, contractor performance, and other topics are stored in these observations. Sorting and reviewing inspection observations for these types of topics provides for a collection of historic lessons-learned that can be used to continuously train Department personnel.

Centrality, Security, and Searchability

HeadLight automatically integrates and stores all inspection information in a secure central repository that allows complete searchability for each project. Uploading information from the field and storing information in a central repository allows DOTD to retain all collected information even in cases when the mobile client (tablet computer) is lost or damaged.

Examination of the traditional DOTD practices indicated that information from the project inspectors' notebook, photos and other media, and inspection reports were all stored in different locations. The field notebooks were typically in the inspectors' possession, photos and other media were typically shared via email or a shared network drive, and inspection reports were accessible in SiteManager.

Multiple Uses of Collected Data

A key component to collecting project inspection information with HeadLight is this same data and information can be leveraged by other divisions within the Department. For example, a project inspection observation photo may document a drainage asset and its placement. This observation will be automatically time and location stamped and correlated to the bid item. Additionally, its fabrication inspection information can be documented using HeadLight's QR code functionality. Such information can be valuable to asset management, environmental, and maintenance divisions for their respective functions over the entire life of such an asset.

Technology Impact on Business Process

The piloting of HeadLight impacted several traditional business processes. Resolution of these business process impacts led to an overall improvement for end-users and workflows. To accomplish this, the changes required discussion and coordination amongst stakeholders to ensure consistent application of the new business processes. The research team observed one of the key contributing factors to existing inconsistency amongst traditional workflows and processes was the inflexibility of existing tools. This inflexibility led to the subsequent workarounds and variability in existing processes to get the desired outcomes. Introducing HeadLight helped uncover many of the variations in existing processes by surfacing the inconsistencies in the existing data, thus enabling the stakeholders to identify and address where and why these inconsistencies were occurring from the outset.

As an example, the research team observed that inspectors were frequently entering incomplete data and information into SiteManager Materials for items. This would include recording that a material sample was taken; whereby, the inspector would make up information for fields that were required to save the record even if such information was not yet available to the inspector by way of workflow. The research team and stakeholders were able to identify these process gaps by allowing inspectors and project teams a feedback loop during the pilot projects so as to quickly identify and adjust either the technology, or the business process, accordingly. This effort is ongoing and critical to alignment across the Department for broad scale implementation and consistent use of any technology.

Technology Considerations

While the research team interacted with the pilot program participants, several notable hardware and software considerations were observed. Mobile devices, although rapidly changing in form and capabilities, present several reliability issues when used in construction environments. Hardware issues included screen-glare from the sun and cellular reception issues on projects in remote locations.

Software issues included reliability and synchronization. Some participants reported they encountered reliability issues, such as glitches and technical bugs, during the first several weeks of the pilot program. These reliability issues were reported to the technical support team and were addressed through continuous updates of the software. This feedback loop was critical in maintaining project inspection operations and managing user resistance. Temporary synchronization issues of field data and reports were also encountered when inspectors worked in poor cellular and data connectivity areas. Although not specifically measured in this study, this can result in delayed dissemination of data collected by inspectors.

Additional technology considerations include the ability of the Department to discontinue the use of laptops in the field. The current mobile devices have access to the statewide email server, DOTD Intranet, Louisiana Employees Online, and Falcon. Additionally, construction plans and specifications can be downloaded in pdf form to the mobile devices. Other third party applications such as sound and vibration measurement, surveying tools, and distance measuring can be installed and exported directly into HeadLight as an observation. These time-saving applications as well as discontinuing service on a great number of laptops will lead to considerable savings for the Department.

Conclusions

This research project evaluated the e-construction inspection tool HeadLight, documenting its impacts compared to that of the traditional paper-based inspection process. The results of this study warrant the following conclusions:

- Project inspectors using HeadLight increased their productivity without increasing their work hours. Inspectors using HeadLight experienced a 28 percent increase in productivity when creating and submitting DWRs. The increase in productivity for Department-wide adoption is estimated to exceed 117,000 hours per year.
- Project inspectors using HeadLight collected more, and a larger variety of, inspection information. Inspectors collected and shared 1.9 times more observations while increasing the number of photo and other media observations. This contributes to a more complete record of the project which provides value to DOTD. When the data is normalized to account for the variation in the collection of personnel, equipment, and work items observations, inspectors collected and shared three times more observations using HeadLight.
- Project inspectors using HeadLight provide more complete and consistent data. All HeadLight observations are tagged with time and location metadata, and DWRs are automatically generated from daily observations eliminating omission and transcription errors. Also, the duplication of information across traditional DOTD sources is eliminated.
- The use of HeadLight improved the timeliness of DWR submissions. Compared with traditional processes, HeadLight provided substantial improvements in submission rates within 24 (45 to 66 percent) and 72 hours (67 to 82 percent).
- HeadLight enabled improved accessibility of inspection information throughout the project offices. Compared to the traditional process, HeadLight improved the timeliness of inspection information availability to office personnel by enabling real-time access to inspection information collected throughout the day on each active jobsite. Through survey questionnaires, office personnel indicated they were able to find inspection information related to a specific work activity, issue, or conflict, more easily compared to the traditional process.
- HeadLight provided data centrality, security, and searchability. Compared to the traditional process, information collected using HeadLight was automatically

integrated and stored in a central repository and improved the accessibility and searchability of the information.

- Data stored in HeadLight provides a wealth of material for future training of new employees, and the material can be used to train existing employees for particularly unique construction scenarios.
- HeadLight improved communication amongst project teams and contractors; potentially reducing project claims and change orders. It was observed that none of the projects using HeadLight had a lost claim that occurred during this pilot study. While more research is warranted, this suggests that HeadLight provided both DOTD and contractors an improved communication platform to resolve issues before they became claims and disputes.
- Successful implementation of technology requires consistent business processes and application of technology. It was observed during the study that limitations in SiteManager and SiteManager Materials led to unintended consequences in business process standardization and implementation. When implementing new systems, both business process and technology capabilities should be considered to lead to successful outcomes.
- The Materials Module is fully functional and further streamlines the e-construction inspection process.

Finally, this research project showed substantial, quantifiable gains when HeadLight was used in place of traditional inspection processes. It is anticipated that these gains will be more considerable when the technology is further leveraged using big data analytics.

Recommendations

Based upon the findings and conclusions, the research team recommends the Department fully adopt the use of HeadLight. Additionally, the impact of e-construction to other job functions within the Department should be considered including: managing force account work, contract management functions, emergency management, construction audit, and asset management. Further investigation to determine the impact of HeadLight on the quantity and size of change orders and claims should be carried out.

Acronyms, Abbreviations, and Symbols

Term	Description
AASHTO	American Association of State Highway Transportation Officials
DOT	Department of Transportation
DOTD	Louisiana Department of Transportation and Development
DWR	Daily Work Report
EEO	Equal Employment Opportunity
FHWA	Federal Highway Administration
GPS	Global Position System
LTRC	Louisiana Transportation Research Center
PC	Personal computer
PDA	Personal digital assistant
QR	Quick Response
SPTC	State Pavement Technology Consortium

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Appendix A

Headlight Pre-Deployment Survey Questions

Q1: What LADOTD district and section do you work for?

Q2: Do you work primarily in the field (inspector, technician, etc.) or in the office (engineer, project manager, etc.)?

Field User Questions

Q3: What is your primary work role?

Q4: How long have you been working in your current role?

Q5: I am comfortable with technology. (Likert rating scale)

Q6: How would you rate your skills with an iPad? (Likert rating scale)

Q7: Which of the following do you use to collect inspection observations out in the field?

- On paper (field notebook, survey notebook, sheet of paper, etc.)
- Mobile device (smart phone, tablet, etc.) or laptop
- Media devices (camera, video recorder, decibel meter, etc.)
- By memory

Q8: How do you create your daily work reports?

Q9: If you use an electronic form/template to create your daily/weekly inspection report, please list the program(s) you use.

Q10: On average, how long does it take you to create a daily/weekly inspection report?

Q11: How easy is it for you to create daily/weekly inspection reports? (Likert rating scale)

Q12: On average, what percentage of daily/weekly inspection reports are submitted within 24 hours of the report date?

Q13: From where do you submit your daily/weekly inspection reports?

Q14: If you have to travel away from the field to submit your daily/weekly inspection reports, how long is your typical commute time?

Q15: How easy is it for you to know when your daily/weekly inspection report has been reviewed? (Likert rating scale)

Q16: How easy is it for you to know when your daily/weekly inspection report has been accepted? (Likert rating scale)

Q17: How easy is it for you to find out what revisions are needed if your daily/weekly inspection report needs to be revised? (Likert rating scale)

Q18: When your supervisor asks you for more detailed inspection information, select the topics that get the most inquiries. (Please select more than one answer if applicable)

- More detail on personnel and equipment information
- More detail on material quantities and verification
- More detail on force account and change order work
- More detail regarding the date, time, and location of a specific work activity

Q19: On a typical work day, how much of your time is spent directly inspecting work in the field? (Exclude time spent on administrative work and travel time)

Q20: How easy is it for you to find out the type of testing, testing frequency, and other information related to materials testing/verification for each material being placed on site? (Likert rating scale)

Q21: How easy is it for you to track the location and status of each material sample collected for testing? (Likert rating scale)

Q22: How easy is it for you to access the result(s) of materials tested? (Likert rating scale)

Office User Questions

Q23: What is your primary work role?

Q24: How long have you been working in your current role?

Q25: I am comfortable with technology. (Likert rating scale)

Q26: How useful is it for you to know the work activities being performed on each active project throughout the day? (Likert rating scale)

Q27: How useful is it for you to know the decisions made on each active project throughout the day? (Likert rating scale)

Q28: On average, how long does it take you to create a monthly payment report/estimate (include time taken to gather information, process information in the payment database, and other tasks involved in creating a monthly estimate report)?

Q29: How easy is it for you to find inspection information performed by a specific contractor/subcontractor or for a specific work item? (Likert rating scale)

Q30: How easy is it for you to find inspection information regarding force account items and change order work? (Likert rating scale)

Q31: How easy is it for you to find inspection information regarding a specific dispute, claim, or conflict? (Likert rating scale)

Q32: How easy is it for you to create a material sampling plan (type of testing, testing frequency, and other information related to materials testing/verification) for each material being placed on site? (Likert rating scale)

Q33: How easy is it for you to access the material sampling plan (type of testing, testing frequency, and other information related to materials testing/verification) for each material being placed on site? (Likert rating scale)

Q34: How easy is it for you to track the location and status of each material sample collected for testing? (Likert rating scale)

Q35: How easy is it for you to access the result(s) of materials tested? (Likert rating scale)

Q36: How easy is it for you to share the test results and material certification/verification status for every work item to the Contractor or other stakeholders outside of your organization? (Likert rating scale)

Q37: The daily/weekly inspection reports typically contain all the necessary information for me to complete my tasks. (Likert rating scale)

Q38: When information is missing from the inspection reports, what is typically missing? (Please select all that apply)

- Detailed personnel and equipment information (equipment specific information, name of personnel, types of hours worked, etc.)
- Detailed material quantity and verification information
- Detailed force account and change order work information
- Date, time, and location of a specific work activity

Q39: On average, what percentage of daily/weekly inspection reports get submitted within 24 hours of the report date?

Q40: If a daily/weekly inspection report is not submitted within 24 hours of the report date, when are they typically available for review?

Q41: How easy is it for you to know when daily/weekly inspection reports are ready for your review and/or acceptance? (Likert rating scale)

Q42: The daily/weekly inspection reports provide enough information for me to address issues, such as claims and disputes, which occur on projects. (Likert rating scale)

Q43: On average, what percentage of your work day do you spend searching for information to address issues, disputes, and claims?

Q44: When issues or other important events occur, how often does the daily/weekly inspection report state the specific time and location (station/offset, GPS coordinate, mile post number, etc.) of the issue/event?

Q45: On a dispute or claim, how much time has typically passed from the date of the incident to the time you were notified of the issue?

Appendix B

HeadLight Post-Deployment Survey Questions

Q1: What is your primary work role?

Q2: What LADOTD District and Gang do you work for?

Q3: How long have you been working in your current role?

Q4: Do you primarily work in the field (inspector, engineering technician, etc.) or in the office (engineer, project manager, etc.)?

Field User Questions

Q5: Using HeadLight has allowed me to spend more time in the field compared to my previous inspection process. (Likert rating scale)

Q6: On a typical workday, how much of your time was spent working in the field when using HeadLight?

Q7: After you have collected all of your observations for the day, on average, how long did it take you to create daily work reports using HeadLight?

Q8: When using HeadLight, on average, what percentage of daily work reports were submitted within 24 hours of the report date?

Q9: Using HeadLight has increased my overall efficiency in inspection and data collection. (Likert rating scale)

Q10: Compared to your previous process, how easy was it for you to create daily work reports using HeadLight? (Likert rating scale)

Q11: Compared to your previous process, how easy was it for you to search and access specific inspection information using HeadLight? (Likert rating scale)

Q12: The use of HeadLight improved the quality of the inspection data and information (completeness, availability, timeliness, etc.)? (Likert rating scale)

Q13: Implementing HeadLight has improved my quality of life in the work space. (Likert rating scale)

Q14: Are there any other comments you would like to share about HeadLight and/or its implementation process?

Q15: Did you participate in the pilot of HeadLight Materials (mobile sampling, testing, and sample plan creation)?

Office User Questions

Q16: On average, what percentage of daily work reports were submitted within 24 hours of the report date when inspectors used HeadLight?

Q17: With Headlight, if a daily work report was not submitted within 24 hours of the report date, when were they typically available for review?

Q18: The daily work reports created using HeadLight provides enough information for me to address issues, disputes, and claims that occurred on the project. (Likert rating scale)

Q19: How easy was it for you to find inspection information related to a specific work activity, issue, or conflict using HeadLight? (Likert rating scale)

Q20: The quality of information in the daily work reports (more complete, more variety, more detailed observations, etc.) has improved with the use of HeadLight. (Likert rating scale)

Q21: Reviewing and accepting daily work reports and other inspection information is easier and more efficient using HeadLight. (Likert rating scale)

Q22: The availability and timeliness of inspection data and information has improved with the use of HeadLight. (Likert rating scale)

Q23: The observations and daily work reports generally contained all the necessary information for me to complete my tasks. (Likert rating scale)

Q24: Implementing HeadLight has improved my quality of life in the work space. (Likert rating scale)

Q25: The use of HeadLight improved my ability to identify and resolve issues, disputes, and/or claims? (Likert rating scale)

Q26: Are there any comments you would like to share about HeadLight and/or its implementation process?

Q27: Did you participate in the pilot of HeadLight Materials (mobile sampling, testing, and sample plan creation)?

HeadLight Materials Module Questions

Q28: Compared to your previous process, how easy was it for you to create a material sampling plan using HeadLight?

Q29: Did HeadLight help you save time creating a sample plan as compared to your traditional method?

Q30: Compared to your traditional method, how easy was it for you to access the material sampling plan using HeadLight? (Likert rating scale)

Q31: Compared to your traditional method, how easy was it for you to find out the type of testing, frequency, and other information related to materials testing/verification for each material placed on site using HeadLight? (Likert rating scale)

Q32: Compared to your traditional method, how easy was it for you to create a material sample using HeadLight? (Likert rating scale)

Q33: Did HeadLight help you save time creating a material sample as compared to your traditional method?

Q34: Using HeadLight has increased my overall efficiency with work related to materials testing and verification. (Likert rating scale)

Q35: Are there any comments you would like to share about HeadLight Materials?

Q36: Please indicate your level of interest in using HeadLight Materials (mobile sampling, testing, and sample plan creation) on a trial basis.

Appendix C

Traditional Projects and Number of DWRs Submitted by Inspectors Analyzed in this Report

Inspector ID	Contract ID (Traditional Projects)	Number of Records
1	H.011111.6	132
2	H.011914.6	87
2	H.012300.6	21
3	H.012176.6	186
4	H.010060.6	307
4	H.011111.6	41
4	H.011449.6	190
5	H.001795.6	453
5	H.003263.6	166
6	H.011583.6	21
6	H.011914.6	461
7	H.011449.6	105
8	H.000687.6	11
8	H.008369.6	11
8	H.009596.6	64
8	H.010619.6	100
8	H.010994.6	183
8	H.011926.6	203
8	H.012379.6	24
9	H.010660.6	15
10	H.010278.6	244
10	H.011111.6	211
11	H.011111.6	203
12	H.011111.6	43
13	H.009485.6	235
13	H.010680.6	183
13	H.012727.6	132
14	H.011111.6	14

Inspector ID	Contract ID (Traditional Projects)	Number of Records
15	H.010243.6	206
15	H.012176.6	54
16	H.011088.6	131
17	H.010864.6	69
17	H.012189.6	27
18	H.011088.6	115
19	H.012176.6	7
20	H.011449.6	74
21	H.003263.6	502
21	H.012360.6	434
21	H.013252.6	11
22	H.011088.6	319
23	H.010054.6	429
23	H.010864.6	16
23	H.011616.6	49
23	H.012181.6	144
23	H.012189.6	106
24	H.000517.6	220
24	H.010054.6	15
24	H.010243.6	103
24	H.011616.6	15
24	H.012176.6	53
25	H.000517.6	234
25	H.011616.6	120
25	H.012189.6	142
26	H.009614.6	127
26	H.010054.6	73
26	H.010864.6	294
26	H.012181.6	184
27	H.011088.6	305
27	H.011350.6	242
27	H.012577.6	63
28	H.010660.6	380
28	H.011575.6	311

Inspector ID	Contract ID (Traditional Projects)	Number of Records
28	H.012647.6	334
28	H.013193.6	32
29	H.009012.6	431
29	H.010660.6	98
30	H.000687.6	793
30	H.000689.6	16
30	H.003452.6	98
30	H.008369.6	212
30	H.010994.6	11
30	H.011024.6	37
30	H.011075.6	15
30	H.011926.6	66

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