Project Inspection Using Mobile Technology — Phase II

Assessing the impacts of mobile technology on project inspection

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16. ABSTRACT:

As mobile technology becomes widely available and affordable, transportation agencies can use this technology to streamline operations involved within project inspection. This research, conducted in two phases, identified opportunities for process improvement using mobile technologies and measured the outcomes from incorporating mobile tools as a part of project inspection work. The research also identified additional factors to characterize the use of mobile tools for project inspection.

The research approach focused on measuring three main projected outcomes, which include productivity, data quality, and data availability. Additional characteristics were observed to evaluate other aspects of using mobile tools for project inspection, in particular as it relates to recommendations toward how an agency may approach deployment of mobile technology. A pilot program was established where a mobile technology solution was used via field trials to measure these outcomes.

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Executive Summary

As mobile technology becomes widely available and affordable, transportation agencies can use this technology to streamline operations involved within project inspection. This research, conducted in two phases, identified opportunities for process improvement using mobile technologies, which led to the development and implementation of a mobile technology solution. This research measured the outcomes from incorporating mobile tools as a part of project inspection work and identified additional factors to characterize the use of mobile tools for project inspection.

The research approach focused on measuring three main projected outcomes, which include productivity, data quality, and data availability. Additional characteristics were observed to evaluate other aspects of using mobile tools for project inspection, in particular as it relates to recommendations toward how an agency may approach deployment of mobile technology. A pilot program was established where a mobile technology solution was developed and implemented via field trials to measure these outcomes.

Based on the results of the study, the report concludes that project inspectors using mobile technology experienced significant productivity gains from the traditional inspection process, saving an average of approximately 1.78 hours a day per inspector. The quality of inspection information collected by inspectors also improved dramatically by using mobile technology as inspectors collected 2.75 times more information, that was more complete, and provided a diversified composition of information collected. The availability of inspection information improved as mobile technology enabled timely access of all inspection information collected and stored them all in a central repository. Learning to use the mobile technology was not a barrier to adoption, as inspectors on average were comfortable using the mobile technology within 2.7 days.

The research findings also indicate that proper software integration of the tools found in mobile devices were critical to achieve the productivity, quality, and availability benefits described within this report. Designing features and capabilities specifically for the job functions within project inspection was shown to be a critical factor in having a successful adoption of the mobile technology. This was supported from the fact that all participants of the pilot program responded that they would prefer to use mobile technology to perform inspection activities compared to their traditional process. Agencies should broadly deploy mobile technology within the inspection process and continue to identify and include remaining inspection job functions within mobile technology to achieve maximum productivity, quality and availability of inspection information. Further study to evaluate the impacts of improved quality and availability of inspection information on the agency's decision making process should be made.

Introduction

As the accessibility of mobile technology continues to increase, transportation agencies can use this technology to streamline operations where opportunities exist for process improvement.

The overall objectives of this State Pavement Technology Consortium (SPTC) research project were to examine the business process of project inspection within Departments of Transportation (DOTs) and how widely available and affordable mobile technologies can be used as a tool to streamline this process and make useable the information that is generated and demanded during inspection in the field for the DOTs. This research was conducted in two separate phases.

Phase I examined the project inspection business process within Washington State DOT (WSDOT) and Texas DOT (TxDOT), identified opportunities for improvement using mobile technologies, recommended an approach to achieve that improvement, and defined activities for a pilot program.

Phase II of this research developed and implemented a mobile technology solution using the findings from Phase I. In the development stage, the research team worked with the DOTs to define measurable elements to be evaluated as part of the testing, which allowed points of comparison with the corresponding current project inspection practices. Live field use of the mobile technology solution was then deployed and evaluated during a pilot program in WSDOT, TxDOT, and Minnesota DOT (MnDOT). Measures and findings from the pilot program were used to evaluate the effectiveness of the mobile technology solution and provide considerations and recommendations for deployment of mobile tools for the inspection workforce.

Research Objective

The purpose of this SPTC Phase II research project is to assess the impacts mobile technology can have for a transportation agency's project inspection business process. The goals of this research are:

1. Develop mobile tools that incorporate the solution capabilities and other specific needs identified in the Phase I report
2. Measure the outcomes projected from the Phase I report for users of the mobile tools
3. Identify additional factors to characterize the use of mobile tools for project inspection
4. Provide considerations and recommendations for deployment of mobile tools for the inspection workforce

Definitions

The following section presents key definitions and concepts related to the discussion contained within this report.

Project Inspection

The scope of project inspection considered under this research report corresponds to inspection of state transportation agency highway construction and maintenance projects. This includes inspection of all bid items and project activities DOT project inspection personnel are responsible for in the field during active construction and maintenance projects. Examples of such elements include pavement construction, traffic control, bridge construction, noise walls, work zone safety practices, guardrails, signage, electrical, and earthwork.

Roles

This research focused on three main roles identified within the participating agencies. While some variance between job titles existed across agencies, and even within the agency, in order to employ standard nomenclature for this report, the roles and corresponding responsibilities used to represent the various job titles are shown in Table 1. Table 2 shows the agency specific personnel titles that are included in the user groups defined in Table 1. For example, assistant area engineers and area engineers working for TxDOT perform similar roles to assistant project engineers and project engineers working for WSDOT, and have been included under the *Project Engineer* user group.

Table 1: DOT personnel roles and descriptions

Report Nomenclature	Included Roles	Responsibilities
Project Inspector	Project Inspector	Individual who is responsible for performing inspection on projects in the field. This individual does not manage others and is typically the personnel resource dedicated to one or more active projects in the field at a time
	Chief Inspector	Manages multiple inspectors and multiple jobs. These individuals are a resource for Project Inspectors when assistance is needed. They roam between multiple projects at a time.
Project Engineer	Assistant Project Engineer	Assists the Project Engineer and plays similar role to Project Engineer, sometimes asked to handle a subset of the responsibilities of the PE at the project field office.
	Project Engineer	Head of field office. Ultimately accountable for all project related activity occurring through that field office.
Management	Manager	Personnel not within a particular field office, but these individuals are involved when items are escalated or conflict resolution is necessary. Titles can range from State Construction Engineer to Construction Section Director to Assistant Regional Administrator.

Table 2: Common titles used by DOT mapped to report nomenclature

Agency	Project Inspector	Project Engineer	Management
WSDOT	• Inspector • Chief Inspector	• Assistant Project Engineer • Project Engineer	Varies
TxDOT	• Field Inspector • Project Manager	• Assistant Area Engineer • Area Engineer	Varies
MnDOT	• Inspector • Chief Inspector	• Project Supervisor • Project Engineer • Resident Engineer	Varies

Project Documentation

DOT project inspectors in Washington, Minnesota, and Texas are required to produce documentation in the field to record project-related information. The purpose of that information is to communicate the facts of what transpired on the job site including activities, materials, and results and whether they are in accordance with the plans, specifications, and general quality standards (this includes such things as safety, accidents, traffic control, materials, construction practices, equipment, personnel, environment, weather, etc.) of the agency. In addition, project inspectors serve to document contract items such as change orders and pay or bid items that were worked on and to what extent for subsequent payment.

As one component of the documentation required, one commonality amongst all agencies was the requirement to observe and document project progress and activities in the field. For the States of Washington and Texas project inspectors are required to fill out and submit daily reports of activities in the field. In Washington State, these forms are called Inspector Daily Reports, or IDRs. In Texas, they are referred to as Daily Work Records, or DWRs. Project inspectors in Minnesota are also required to record daily activities and submit their observations on a weekly basis. These forms are called Weekly Construction Reports, or WCRs. In all three states, the daily and weekly reports perform essentially the same function. They are to be a “dispassionate record of what transpired in a day”, objectively documenting project related activities including items listed in Table 3.

Table 3: Description of items included in a typical construction report

Item	Description
Basic Form Data	Contract number
	Day and date
	Sheet number X of Y (for paper forms)
	Name of prime and subcontractors
	Name of project inspector
	General project descriptors
Time	Time inspector arrives and leaves site
	Contractors work hours
	Start and stop time of work activities
Location	Location where work starts and ends for the day
	Location where activities or issues occurred
Weather	Documentation of weather conditions
Operations	Information about the day's operations and project progress
	Notable activities or issues that occurred on the job site
Contractor	Identification of the contractor and work crew personnel
Equipment	Identification of major equipment on site and use
Materials	Documentation of calculations and quantities of materials placed

Each agency involved in this research had additional documentation requirements that inspectors completed as a part of their daily activities that were not evaluated as a part of this research due to scope. For example, forms and documents to record pay items other than what is gathered on a typical daily or weekly construction report were not included within the scope of this research. This research assumes that the findings for the daily and weekly construction reports can similarly be applied to the additional agency specific documents to further extend the impacts of using mobile technology from those outlined here.

Mobile Technology

Mobile technology within the scope of this research refers to both hardware and software that can be used in the field to access and gather project related information.

Mobile Hardware

The findings from Phase I indicate that project inspectors need tools such as cameras and laptop computers to effectively collect and document inspection information. Tablet computers with these tools integrated in to the hardware have now become more affordable, more portable, and widely available, making it an appealing device to be used out in the field. For example, integrated cameras can be used to take photographs and videos of specific activities, such as traffic control setups or specific work activities, and then directly made accessible to applications on the same hardware device. The data connectivity capabilities of both wifi and cellular data contained within tablet computers can also facilitate inspectors sharing inspection information with personnel in the office from the field.

Figure 1 shows some key features that are integrated into tablet-based computers.

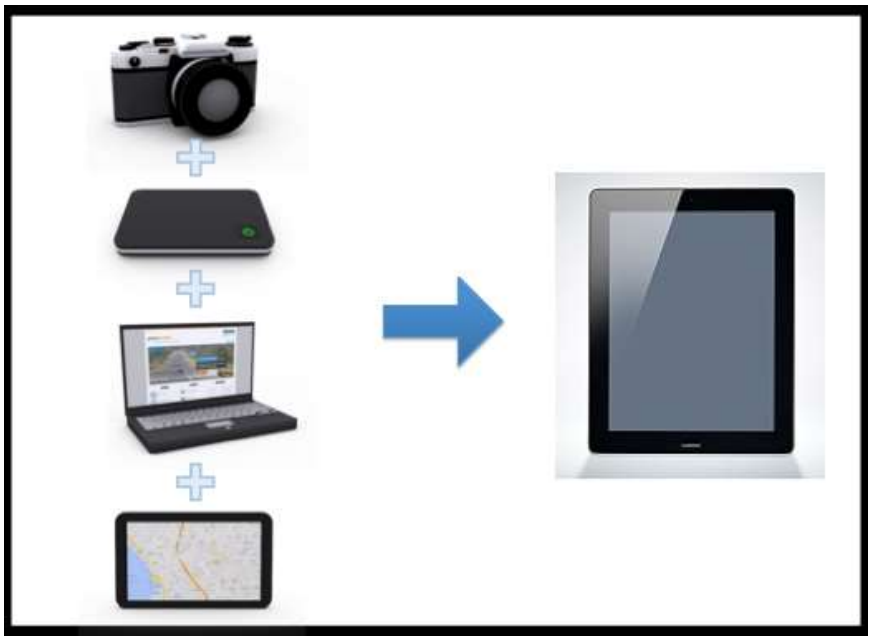


Figure 1: Key features integrated into tablet-based computers

Tablet-based computers contain key features including:

- **Camera** – Built-in cameras are included for capturing images and videos, which helps eliminate the need to carry separate tools such as digital cameras.
- **Connectivity** – Tablet computers can connect to a cellular or Wi-Fi network providing access to online content. This capability allows inspectors to share inspection information to other personnel and allows access to project reference documents from the field.
- **Computing Power** – The processing power of tablet computers enables tasks such as word processing and computing of calculations. The computing power of tablets allows inspectors to document inspection observations and generate daily reports directly from the field.
- **Global Positioning System (GPS)** – The GPS sensors enable tracking of location data. This feature can automatically document location information of inspection observations, which helps improve the accuracy of the location information recorded.
- **Integrated Sensors** – Built-in sensors such as microphones, accelerometers, barometers, and magnetometers can be used as measuring devices in the field.

Integrating these key elements specifically for the purpose of project inspection makes it possible to provide a powerful tool to assist with the collection, documentation, and sharing of project inspection information. For example, a

participant from Phase I was quoted as stating, *"I work 10-12 hours, drive home for 2, do you really want to be sitting in your truck or docking it [laptop computer] for another 20 minutes just to get a picture on a server?"* The quote emphasizes the importance of integrating the mobile hardware and software to achieve the broadest possible benefit.

Additionally, the tablet computers themselves contain a multitude of sensors such as microphones, accelerometers, and magnetometers that can be used directly as measuring devices in the field and incorporate within the inspection information automatically. For example, if calibrated, the microphone can be used as a decibel meter when noise is a needed measurement or the internal accelerometer can be used to measure embankment slope.

Mobile Software

Mobile technology also refers to the software that runs on tablet hardware enabling project inspection specific information to be referenced, collected, and seamlessly stored and/or uploaded from the field in both connected and disconnected environments. The quote shown in the previous section is an example of how using mobile technology, such as a digital camera, is helpful in capturing objective visual information, but can be difficult or time consuming to transfer and store this information with the application inspection data. A critical component to allow the mobile hardware to work together is having well designed mobile software running on the tablet device that can ensure the information collected using the tablet's capabilities is able to be integrated within the agency's inspection process seamlessly and shared in real-time with other members of the agency.

Summary of Phase I

Phase I of the research effort most heavily focused on audience interviews with employees from both WSDOT and TxDOT as well as project documentation and specification review. The interview participants were all agency employees that performed the different project-related roles described earlier within the DOT.

The interviews were structured as a 1-on-1 conversations and took approximately 1.5 hours to conduct, consisting of a set of questions matched to the 3 major role categories: Project Inspectors, Project Engineers, and Management. Table 4 shows the number of interview participants from each agency and their roles.

Table 4: Breakdown of interview participants from Phase I

Role	Total
Project Inspectors	22
Project Engineers	6
Management	4
Total	**32**

The questions were aimed at generating information about each participant's role with respect to DOT projects, what information is collected in the field and used in

their roles, with whom the participants interact in their position, what work activities they spend their time on, what challenges they identify for their respective roles, and what their comfort level is with technology.

The interview responses revealed the following key findings:

- The information collected about projects through inspection activities is valuable
- Not all inspection information is saved to the project file due to information being documented and shared using various strategies
- Collecting visual documentation and inspection information metadata (location information, time stamp, etc.) plays an important role in the impact of project inspection as it often helps to provide clear, objective evidence of items being observed
- Project inspectors need the capability to look up information in the project reference documents (plans, specifications, special provisions, etc.) while in the field
- On average, project inspectors spend over five hours a day performing tasks that mobile technology can accelerate. Those tasks include transposing information into the computer, looking up information in project reference documents, and performing calculations as part of their inspection duties
- Project inspectors identified challenges in documenting information while out in the field, which impacts their ability to submit daily documentation in a timely manner
- Interview participants reported a high level of comfort with the use of technology, both personally and as part of their work

Software Capabilities and Features

To meet the challenges identified from Phase I interviews, various mobile software capabilities for enhancing the job function through introduction of mobile technology were presented. Interview participants were asked to rank capabilities as they relate to solving the challenges that were discussed and identified. Table 5 below shows the results of the capabilities ranking.

Table 5: Ratings given by participants to potential feature capabilities

Rank the following features (1 to 5, 1 not useful, 5 extremely useful):			
Feature	**Min**	**Max**	**Average**
1. Consistent, seamless image capture, allowing inspectors to write notes on image, compress, and upload easily	4	5	4.88
2. Relevant email correspondence can be tagged and saved along with project info	4	5	4.88
3. QR codes for materials acceptance or prefab components	4	5	4.88
4. Updates in real time, where items can be flagged immediately and notifications sent to directly those that need it	3	5	4.75
5. Automatically import weather data based on location (GPS or point on map)	3	5	4.50
6. Perform calculations automatically in the field for FNRs or IDRs	2	5	4.25
7. eSignatures for inspection or quantity reports	2	4	3.00

The ability to use mobile technology to integrate these capabilities into the project inspection process supported the conclusion that these features deployed in an integrated mobile environment would provide value both to project inspection personnel in the field and engineering personnel in project and central offices.

Projected Outcomes of Mobile Technology

There were three main projected outcomes anticipated by adopting mobile technology for project inspection using the capabilities described in the previous sections:

- **Productivity improvements** – defined as the time spent on data entry, searching in project reference documents, and performing calculations.
- **Data quality improvements** – defined as the completeness and consistency of the information collected by the inspector.
- **Data availability improvements** – defined as accessibility and timeliness that information collected by inspectors is available to stakeholders within the agency.

Productivity Improvements

Phase I findings indicated that 62.5% of inspector time is spent performing tasks where mobile technology can be used. Those activities include entering information into the computer, referencing information in the field, and performing calculations in the field. These were all identified as activities that properly designed mobile

technology can impact and accelerate. In addition, some of these activities are currently separated from each other in terms of the inspector's workflow, requiring different tools or being performed in different locations.

From the analysis of the interview responses conducted during Phase I of this research, it was hypothesized that a mobile technology solution employing the hardware and software integration components identified earlier could reduce the inspectors time currently devoted to these responsibilities by one-half, meaning that approximately 31% of inspectors' time and effort could be saved.

Data Quality Improvements

Mobile technology was identified as a way to impact the quality of the information inspectors are recording in the field. Data quality is identified by the completeness and consistency of the inspection information. For this research, *data completeness* is defined as the capturing of all data components associated with an inspection observation needed to objectively portray the actual conditions of the work performed and *data consistency* is defined as the ability to collect and report inspection observations using a consistent single entry process to eliminate the potential for errors and omissions. The *Five C's of Good Report Writing* referenced from the WSDOT *Construction Training Guide for Local Agencies* has been included in Appendix A to provide additional context related to the completeness of inspection reports.

For data completeness, mobile technology provides tools that reliably and automatically supply certain data, such as time and location, directly into inspection observations. In respect to data consistency, inspectors using mobile technology would be able to reduce the potential for creating errors from transcription or duplication of data by using mobile software that communicates directly with agency databases from the field. These findings led to a projected outcome in which the overall data collected using mobile technology was targeted at 50% more complete, as well as 50% more consistent.

Data Availability Improvements

The value of inspection information is significant when decisions are made based on the information collected in the field. For example, a participant in Phase I was quoted as stating, *"Real-time info from the field would be great. With a dwindling crew and bigger workload, that information is important"*. Statements like this characterized the importance for all roles involved in the decision making process to have inspection information available.

Phase I identified two factors in which mobile technology can assist in improving data availability. First, the inspection information collected by inspectors using mobile technology is made available in real-time to specific stakeholders throughout the organization, improving the timeliness of the inspection data availability. Second, inspection information availability is also improved as information captured using mobile technology is archived directly to a central repository, allowing the

agency to collect the information once, but use it many times throughout the organization. These findings led to the hypothesis that data dissemination time could improve by 50% using mobile technology.

Research Approach

This research focused on measuring the projected outcomes identified in Phase I of the research by conducting a field pilot of a mobile technology system designed and developed specifically for project inspection to evaluate the impact of using mobile technology.

The projected outcomes were measured for the common agency documentation processes involved in creating daily and weekly construction reports. Inspectors in each participating agency have additional varied functions that are performed in the field such as recording pay items and other materials data that would benefit from mobile technology although were not directly evaluated. This research assumes that the measured impacts of mobile technology on daily and weekly construction reports can be extrapolated to these additional functions performed by inspectors at each agency. For example, if these additional functions were incorporated into the mobile technology, it is expected that commensurate gains in productivity, quality, and availability would be achieved.

The data sources and projected outcomes measured are discussed in the following sections.

Data Sources

The following data sources were used to evaluate the key outcomes:

- **Direct Measurements** – Measured timing of tasks using a stopwatch and counted the amount of inspection information collected directly from the mobile device and from measurements made by research assistants out in the field.
- **Benchmarking** – Reviewed a sample set of inspection reports created by the same participants prior to the Phase II research using each agency's traditional process to establish baseline characteristics of the reports. In addition, current agency practices used to record inspection information and to create construction reports were observed.
- **Participant Interviews** – Administered post-pilot participant interviews for all project roles defined earlier to evaluate key measures using participant responses.

The following section describes the approach taken to evaluate the outcomes identified in Phase I.

Productivity

Phase II of this research focused on measuring discrete activities related to productivity as shown in Table 6.

Table 6: Metrics used to evaluate productivity

Measurable Element	Data Source
Time spent creating construction report documents from observations made	*Direct measurements* and *benchmarking*
Time spent searching for content in project reference documents	*Direct measurements* and *participant interviews*
Time spent traveling off site to complete or submit documentation	*Participant interviews*

For each of these measures, this research evaluated the change in time spent to complete tasks from the traditional process to that using mobile technology to determine whether the use of mobile tools helped save them time and effort and quantify the change in productivity. It should also be noted that the size and location of the projects has a direct impact on the measures above. To normalize for this, the research team measured the traditional process using the same project documents that were used for HeadLight.

Data Quality

Findings from the Phase I research emphasized the importance of being able to properly collect inspection information. Table 7 shows the data quality metrics that were used to evaluate the change in data quality resulting from the use of a mobile technology specifically designed for project inspection.

Table 7: Metrics used to measure data quality

Elements Measured	Data Source
Amount of observations collected per inspector per day	*Direct measurements, benchmarking, and participant interviews*
Composition of observation entries made per inspector per day	*Direct measurements, benchmarking, and participant interviews*
Completeness of daily reports	*Direct measurements* and b*enchmarking*
Amount of metadata collected for each observation	*Direct measurements* and b*enchmarking*

The amount of observations collected per inspector per day were measured to determine the change in the amount of information resulting from the use of mobile technology. Another important aspect that contributes to data quality is using a variety of observation types to represent the construction activities performed onsite. For example, including visual references such as photographs can

significantly improve the way inspectors describe the progress of work or issues that may arise. The various types of inspection information collected in daily reports were tracked to evaluate changes in composition of the daily reports.

Metadata in this research is defined as temporal and special data associated with every observation recorded. Metadata was tracked to evaluate the amount of inspection observations that provided time and location data, as this information impacts the level of data completeness.

Data Availability

The data availability metrics that were used to evaluate the change in data availability resulting from the use of mobile devices is shown in Table 8.

Table 8: Metrics used to measure data availability

Measured Elements	Data Source
Timing for availability of inspection observations and daily reports	*Benchmarking* and *participant interviews*
Percentage of daily reports submitted within 24 hours and 72 hours	*Direct measurements*
Storage location, format, and accessibility of inspection observations and daily reports	*Benchmarking* and *participant interviews*
Changes in how participants accessed observations	*Participant interviews*
Changes in how participants accessed daily reports	*Participant interviews*

The focus of this evaluation was on the participants that needed to access information contained within the system so was limited in scope to Project Engineers and Management.

The timing of when inspection observation and daily reports was tracked to evaluate the velocity of information within the agency as the findings from Phase I characterized the importance for all roles involved in the decision making process to have inspection information available immediately. In addition, direct measurements of the timeliness of daily report submissions were measured to evaluate changes in daily report submission timing resulting from the use of mobile technology designed for field report submissions.

The storage location of inspection observations and daily inspection reports was tracked as a way to determine availability of information as all roles involved in the decision making process need to know where to find these sources of information and have a reasonable means to access them. Changes in how participants accessed inspection observations and daily reports were also measured to qualitatively evaluate the impact of using mobile technology.

Additional Characteristics Observed

There were several additional characteristics that were observed to evaluate other aspects of using mobile tools for project inspection, in particular as it relates to recommendations toward how an agency may approach deployment of mobile technology. These additional dimensions include:

- **Learnability and Support** – The time it took participants to become comfortable with the mobile technology developed was measured. The importance of providing on-site and on-call support for the pilot program was also evaluated. These two factors can help determine the success of agency users adopting mobile technology.
- **Usefulness of Capabilities and Features** – Phase I of this research identified and ranked the potential usefulness of certain capabilities and features through participant interviews. Participant interviews were then conducted in Phase II to reassess the usefulness of the capabilities once implemented and used during the field pilots.
- **Overall Usefulness of Mobile Technology** – Through participant interviews conducted in Phase II, the overall usefulness of a mobile technology specifically designed for project inspection is measured both quantitatively and qualitatively. The participant's responses can help identify areas within the mobile technology that can be improved to better assist with project inspection processes.
- **Safety** – The use of mobile technology and its impact on participant's safety was briefly examined. Any existing safety concerns were identified through the Phase II interviews.
- **Data Searchability** – The impact of being able to search for specific contents in inspection observations and daily reports were examined. This dimension is of particular interest to project engineers and management who use inspection data to make project decisions or deal with claims related issues.

Research Methodology

To measure the projected outcomes of this research, the research methodology involved several stages:

- **Mobile Technology Development** – This stage focused on development of the mobile technology that provided the capabilities and features identified during the Phase I research.
- **Field Evaluation of Mobile Technology –** This stage involved implementation of the mobile technology via a field trial (pilot program) which included the following activities:
    - Benchmarking of all key measures described in the research approach
    - Conducting training sessions to all participants on use of the mobile solution
    - Conducting field tests

    - Providing technical support during the pilot program
    - Conducting post-pilot participant interview sessions
- **Results and Discoveries** – This stage involved analysis and evaluation of benchmark data, key measures, and interview responses to compare the elements of the pilot solution with the corresponding current project inspection practices.

Mobile Technology Development

In developing the mobile tools to improve the current inspection data collection process, selecting the appropriate tablet-computer device and designing the appropriate software were two important factors.

Mobile Hardware

To meet the requirements of the study, the Apple iPad Air was selected as the mobile hardware for the pilot program. The iPad Air integrated all of the key hardware requirements needed to assist with the collection, documentation, and sharing of project inspection information.

Additionally, each iPad Air was outfitted with a protective casing to provide resistance to drops and protection from the elements such as dust and rain. The case is also waterproof, allowing the device to be submersible in water up to 6 feet. A hand-strap was outfitted on the back of the device to allow inspectors to safely carry the device out in the field. These ruggedized capabilities were all combined to provide the inspectors with a complete mobile inspection unit. Figure 2 shows an iPad outfitted with the protective case.

Source: LifeProof

Figure 2: Apple iPad Air outfitted with the protective case

Android tablets and Microsoft's Surface tablet also met the hardware requirements and were also considered acceptable for the pilot study although the scope of the research mandated that only one mobile hardware platform be selected. As such,

the existing level of support for the iPad and iOS operating system at participating agencies during this study factored in to the decision to select the iPad.

Expansion to other hardware

While iPads were selected as the platform for the pilot efforts, system capabilities can be expanded to include other commonly available hardware options, for example Microsoft or Android tablet devices. The effort to incorporate additional hardware choices for use as inspection data collection units connected to the system as a whole is only an incremental effort rather than a full re-implementation as the pilot system was architected using a modular, robust and flexible platform approach, keeping much of the system's complexity within the central server to allow for cost effective scaling to other hardware platforms.

Software Application

The software system of the pilot solution (HeadLight) was developed and deployed to allow inspectors to record observations collected in the field and produce daily report documentation as described earlier. The software was designed to provide for the capabilities identified in Phase I, in addition to several others described below. Three main components of the HeadLight system include the Mobile Client on the iPad (HeadLight Inspection Unit), Web Client, and the Web Service. Figure 3 illustrates the components and how they interact together.

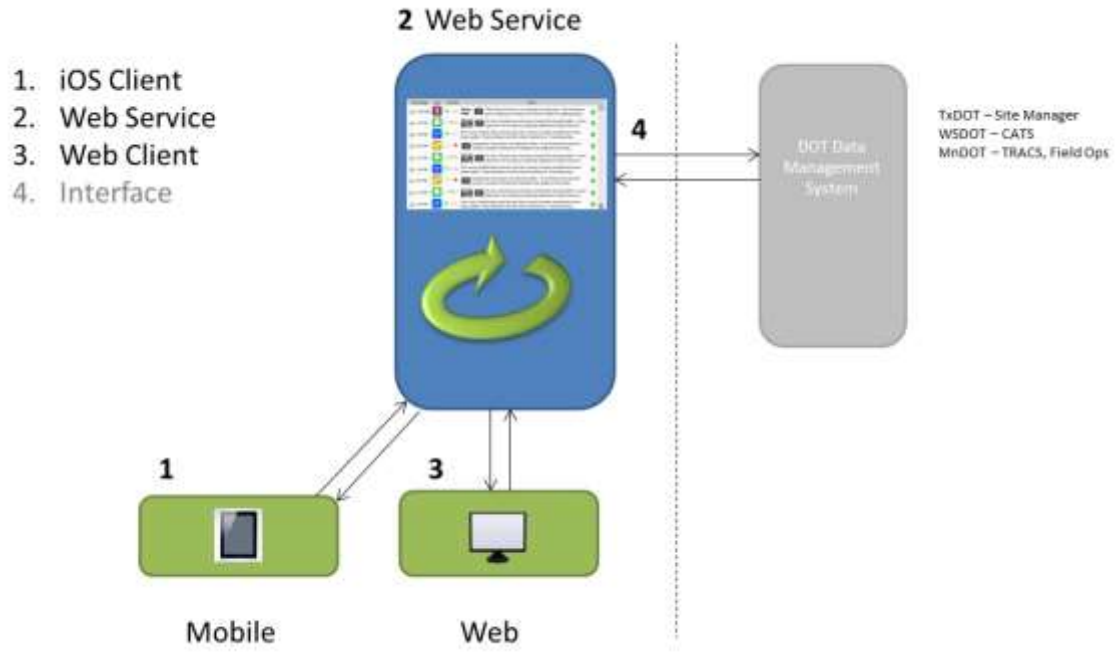


Figure 3: Illustration of the three software components of the HeadLight system

The Mobile Client assists project inspectors by providing a set of observational features and tools to submit documentation directly from the field. The Web Client allows members of the agency access to the information collected by the Mobile

Client through a secured web interface. The Web Service manages the data and information amongst the mobile clients and provides a centralized, secure, storage architecture by which the data is made available to both the Web Client, and other data systems that may reside within an agency such as AASHTO's SiteManager or other proprietary data systems. A description of each component is described below.

Mobile Client

The Mobile Client application was developed to run on the Apple iOS operating system. The Mobile Client included the following key features:

- **Data Collection** – All observation data collected onsite is time and date stamped automatically and can be retrieved using a built in search feature.
- **Photo and video capabilities** – Capture and upload photos and videos to document observations in real-time and automatically include them in the project file.
- **Correspondence Filing** – Email correspondence can be tagged and saved directly into the project file.
- **QR Codes** – Generate QR codes for tracking materials acceptance or prefab components.
- **Real-time Project Updates** – Areas of concern can be flagged on site and notifications sent immediately to those that need it.
- **Current Weather Data** – Real-time weather information is automatically captured based on location.
- **e-Signature Capability** – Signatures for inspection or quantity reports can be electronically signed.
- **Disconnected environment support –** Inspectors can perform work in the field with or without network connectivity.

Disconnected Environment Support

Inspectors that work on projects located in rural areas may not have reliable data connectivity out in the field due to limited data coverage provided by the cellular network providers. The Mobile Client was programmed to contain special logic that allows users to create and save observation and documents even if there is no network connection available. The Mobile Client detects when connectivity becomes available and will automatically synchronize the information with the central repository, enabling inspectors to collect observations and create documents with or without a network connection.

The HeadLight Mobile Client enabled the above capabilities through the following key interfaces:

- **Dashboard** – An interface that provides three project specific information including inspection report notifications, weather conditions, and a map-view showing the locations of all observations entries.

- **Observations** – An interface that enables the collection of inspection information using a set of tools offered by HeadLight. For example, inspectors can use a *video observation* tool to capture a video of a construction activity or a traffic control setup and automatically provide location and time stamp information.
- **Documents** – An interface that enables users to generate documents that inspectors are required to produce. Using the *Documents* activity, inspectors can create daily inspection documents with a touch of a button using HeadLight. These daily inspection documents incorporate observation taken by the inspector for a specified day.
- **Inspector Tool Kit** – An application that allows inspectors to access the electronic versions of the project reference documents such as project plans, specifications, special provisions, and other project manuals.

A further description of how the features were made available to inspectors through these interfaces is described below.

Dashboard

The *Dashboard* interface provides the following project specific information: approvals notification, weather information, and a map-view showing the locations of all recorded observations. Figure 4 shows a screenshot of the *Dashboard* menu on the Mobile Client.

Figure 4: A screenshot of the *Dashboard* menu on the HeadLight Mobile Client

The area on the upper left section of the dashboard shows the approval status on the daily reports generated in HeadLight. Inspectors can see if their daily reports have been approved or rejected by their supervisors. The upper right section of the dashboard shows the weather forecast specific to the location of the project. Precipitation, wind speed, humidity, and high/low temperature information are available. The bottom area of the dashboard depicts a map with the locations of each observation made on the project.

Observations

Each piece of information that an inspector collects or observes is called an Observation. The various types of observations that were available during the pilot program are shown in Table 9.

Table 9: Integrated software features in HeadLight Mobile Client

Observation Types	Description
Photo	Capture and annotate images.
Video	Capture videos and compresses the video to a manageable size.
Audio	Capture observations in the form of audio recordings.
Density	Record the percentage of density of materials placed out in the field.
Text	Record any observation in text form.
Equipment	Record the equipment present on site.
Personnel	Record all personnel present on site.
QR Create/Scan	Generate and scan QR codes for material acceptance or prefabricated components.
Temperature	Record temperatures of materials placed on site.
Weather	Automatically import weather data based on location.
Start/Stop	Record the start and stop times related to contractor work hours or construction activities performed out in the field.
Material	Perform calculations using the calculator tool useful in determining material quantities.
Email	Send emails containing any inspection observations directly from the HeadLight application.

Figure 5 shows how the observation types are presented in HeadLight and Figure 6 shows an example of how photo observations are made.

Figure 5: Example of various observations recordings available on HeadLight

Figure 6: Screenshot of a photo observation being created

Every observation recorded by the inspector will automatically have a time stamp identifying the time of creation and a location stamp identifying the GPS coordinate of the observation location. HeadLight uses data connectivity and GPS features integrated in the hardware to accurately obtain the time and location of inspection observation. Figure 7 depicts screenshots of the application, showing an example of the time stamp capability and location stamp capability.

Figure 7: Top - Example of the time stamp feature. Bottom – Example of the location stamp feature.

HeadLight also provides *eSignature* and *priority flagging* capabilities. The eSignature capability allows inspectors to incorporate eSignatures to any inspection observation. If communication needs to be documented, an eSignature capability

can provide acknowledgement between the project stakeholders. Figure 8 illustrates the eSignature capability.

Figure 8: Example of the eSignature capability

The priority flagging capability allows inspectors to flag a particular observation with a priority level ranging from 0 to 4. For example, high priority observations can be flagged with a priority level of 4, indicating an extreme urgency for members of the agency to review the observation.

Inspection observations collected using the features and capabilities described above can then be used to generate project inspection documentation. The following section describes the document generation process.

Documents

HeadLight includes a *Documents* interface that automatically generates daily reports by incorporating the observations collected from the specified day. The intent of this capability was to eliminate the duplication process of reentering inspection data into a daily report document template. Figures 9 through 11 show an example of a daily report being generated by HeadLight.

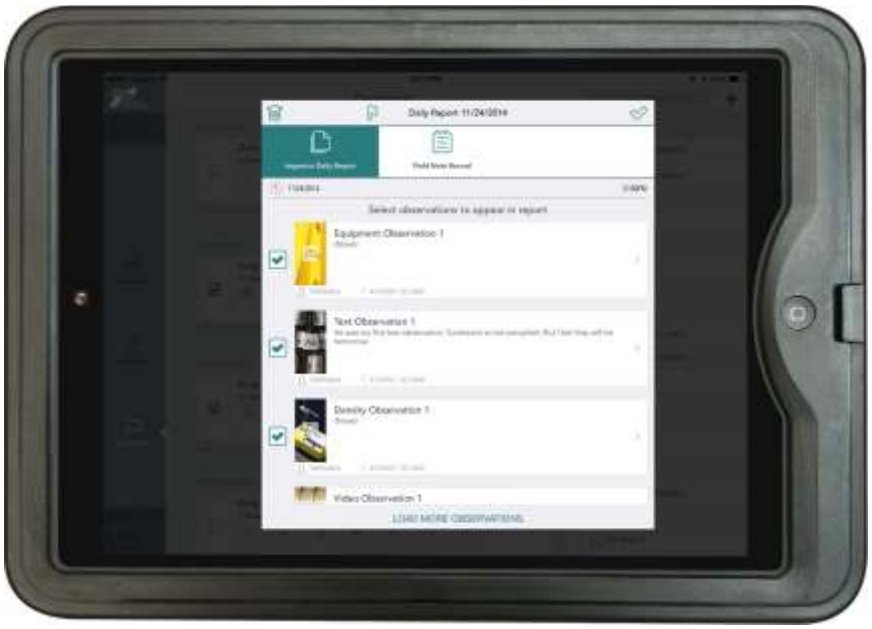


Figure 9: Screenshot of a daily report being generated on HeadLight

Figure 10: Screenshot of a daily report generated on HeadLight

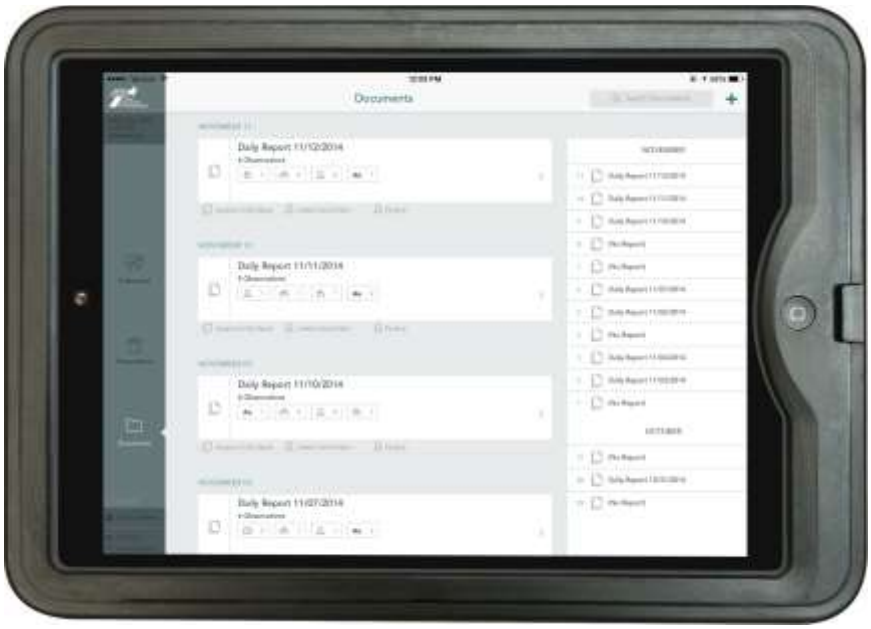


Figure 11: Screenshot of the *Documents* feed interface

Inspector's Tool Kit

An Inspector's Tool Kit application was also provided enabling inspectors to access all project reference documents such as project plans, specifications, special provisions, and other project manuals. The Inspector's Tool Kit utilized a Dropbox account where all of the relevant project documents were uploaded to the account. The intent of this application was to make all project reference documents available to the inspectors on the iPad, accessible anywhere out in the field. Figure 12 shows screenshots of plans using the Inspector's Tool Kit.

Figure 12: Screenshots of plans shown using the Inspector's Tool Kit

Web Client

A web version of HeadLight was developed to allow personnel in the office to access the observations and daily reports generated by the HeadLight Mobile Client. The intent of the web version of HeadLight is to allow all personnel involved in the decision making process to access inspection information in real-time as well as additional reporting and management capabilities.

The Web Client includes the following key features that were used in the pilot program:

- **Observation Feed** – the observations feed allows project engineers and management personnel to review observations coming in from field devices in near real-time.
- **Document Feed** – the documents feed allows project engineers and management personnel to review, print, download, and search inspection reports.
- **Search Capabilities** – the search function feature allows project engineers and management personnel to search for specific key terms through the observations and inspection reports stored in the central repository.
- **Document Workflow and Approvals** – the document workflow and approvals feature allows project engineers and management personnel to view the workflow and the approval status of daily inspection reports by project in the *Documents* feed.
- **Reporting and Administration** – the reporting and administration feature allows project engineers and management personnel to generate reports that map the location of observation entries and observations entries made within a specified date range. The administration feature allows approved users to make changes to the project and user settings within the Web Client.

Observation Feed

Project engineers and office personnel can access inspection observations using the observation menu item. Inspection observations are organized by date and chronologically sorted by time. The menu shows the type, name, description, priority level, and the name of the inspector who created the observation. Figure 13 illustrates the observation menu depicting various observations collected by inspectors.

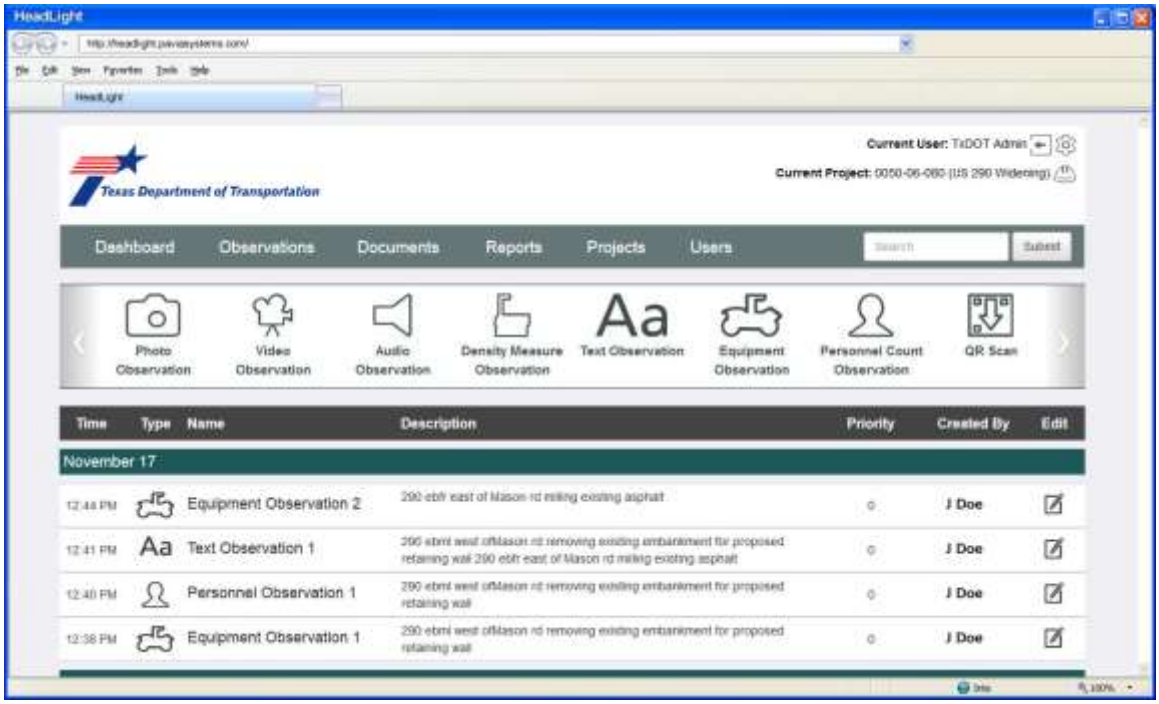


Figure 13: Screenshot of the Observation Menu in the Web Client

Documents Feed

Web Client users can access daily inspection reports created by inspectors by viewing documents feed. Similar to the layout of the observations feed, the daily inspection reports are organized by date and chronologically sorted by time of creation. The page also shows the name of the report, name of the inspector who created the report, and the approval status of the report. Each daily report shown in the feed also can be downloaded in a PDF format. Figure 14 shows the Web Client's documents page.

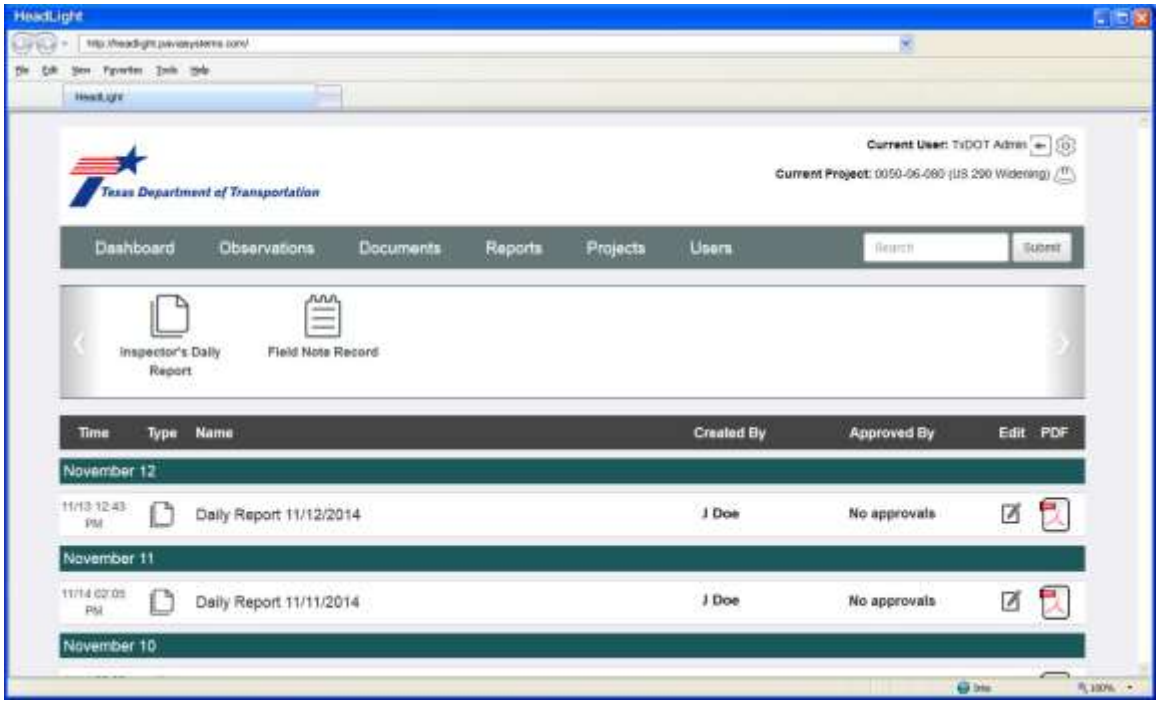


Figure 14: Screenshot of the documents menu in the Web Client

Browse and Search Capability

A search function has been integrated in the Web Client to allow users to search for key terms that may be associated with inspection observations or daily reports. In regards to finding documents and media, a participant from the Phase I interview in reference to their traditional process was quoted as saying, "very important and very time consuming to go back and dig up records." To help address this challenge, Web Client users can search through the entire observation set by project using the search tool in the *observation feed*, or search through daily reports by project using the search tool in the *document feed*.

Document Workflow and Approvals

Project engineers and other supervisors can use the Web Client to view the workflow and the approval status of daily reports by project in the *document feed*. Project managers or chief inspectors can use this feed to approve or reject daily reports created by their inspectors. Figure 15 shows the approval process for a typical daily report using the Web Client. Inspectors using the Mobile Client will receive a notification in their application when changes in approval status are made.

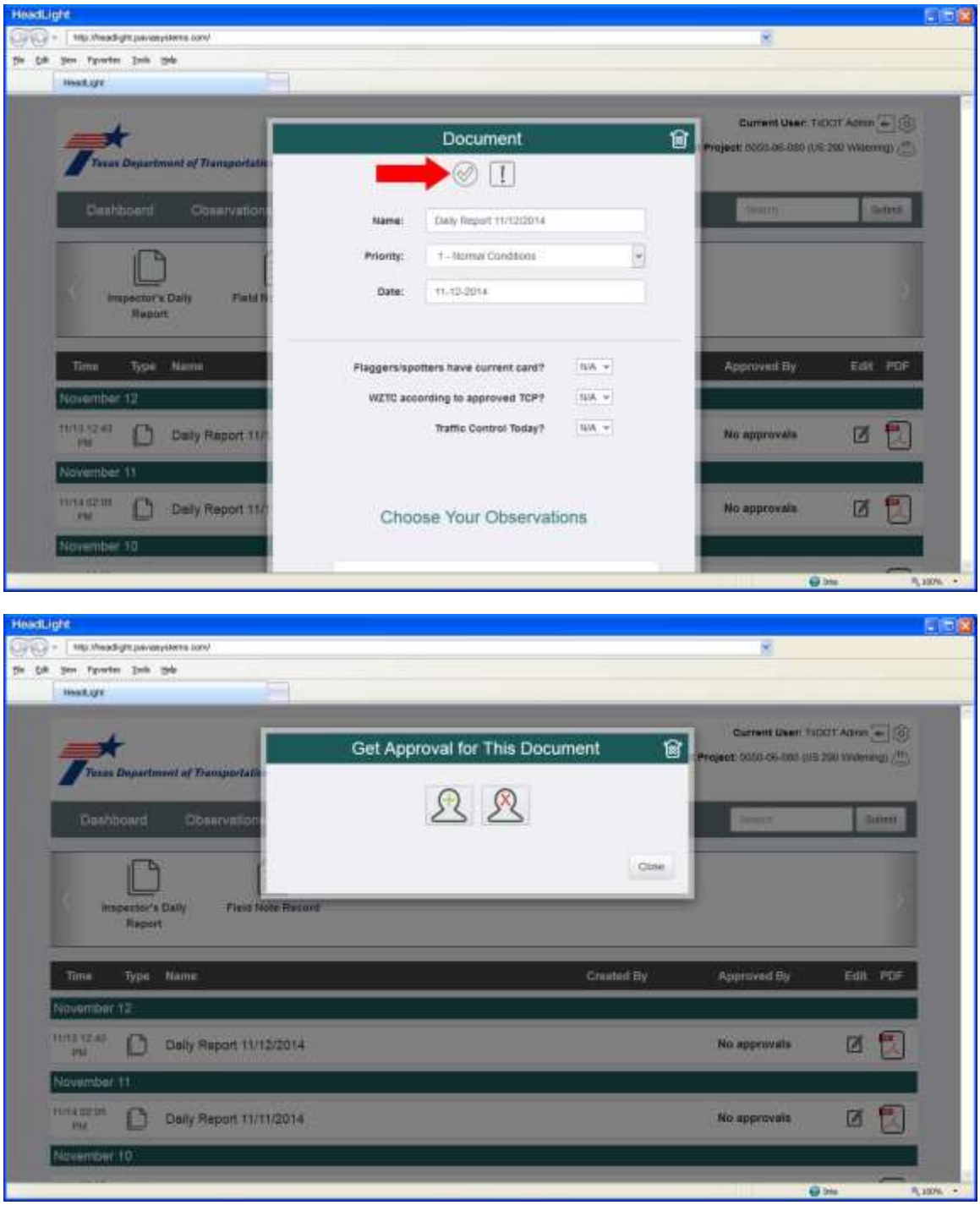


Figure 15: Screenshots of processes involved in approving daily inspection reports using the Web Client

Reporting and Administration

The *reporting* feature allows Web Client users to generate an *Observation Timeline Report* and an *Observation Map Report.* The *Observation Timeline Report* shows observations created on a specified date range on a timeline chart represented by the day and time of day. The *Observation Map Report* plots the location of observations created on a specified date range on a map.

Web Client users, with security permission, have the ability to change administrative status of projects and users. The *Projects* and *Users* administration menus allow users to create, delete, and modify construction projects and user settings to make any modifications as necessary.

Web Service

The HeadLight Web Service synchronizes and integrates all of the data centrally between the Mobile Client and the Web Client. The Web Service essentially manages the information collected from all of the mobile devices as well as the Web Client and centrally stores and manages that information. The web Service acts as a central repository, storing all inspection information and inspection reports. Both the Mobile Client and the Web Client can access and retrieve information stored within the HeadLight Web Service.

Field Evaluation of Mobile Technology

A pilot program was developed to evaluate the mobile technology described above through field use by inspectors on active projects in each of the participating agencies. The pilot program consisted of the following key activities:

- Identifying benchmark characteristics of the current agency project inspection process
- Administering training sessions for the Mobile and Web Client to agency participants
- Field testing of the HeadLight Inspection Units across numerous agency projects and personnel and monitoring usage
- Providing technical support in the field and on the phone to participants
- Conducting post-pilot program participant interviews

The following describes each of these activities in more detail.

Benchmarking Characteristics of the Current Agency Inspection Processes

The following section discusses the benchmark processes analysis used to establish baseline conditions.

Field Activities Analysis

To establish a baseline comparison, this research analyzed the following key processes:

- Processes involved in collecting inspection observation information in the field
- Processes involved in the generation of daily and weekly inspection documents
- Processes involved in searching for content in the project reference documents

To analyze the above processes using current agency practices, a *Baseline Observation Guide* was created (see Appendix B). This guide was used to help research assistants gather information on the method used to collect inspection observations, the types of observations that were typically collected, and the time spent collecting inspection observations. In terms of the daily and weekly reports, the guide helped collect information on where project inspectors were creating their daily or weekly reports, the basic processes involved in creating a daily or weekly report, how attachments such as photos were included, and average length of time taken to create the inspection reports.

The Baseline Observation Guide also was used to record how inspectors typically looked up information in the project reference documents. This included how often an inspector searches for content in the project reference documents, how long the process typically takes, and whether hardcopies or electronics copies of the documents are used.

A *Field Guide* (see Appendix C) was also created to observe the same key processes and measures involved when using the HeadLight Inspection Unit. These two guides were used to compare the processes and key measures of the pilot solution with the corresponding current project inspection practices.

Inspection Reports Analysis

A total of 76 WSDOT IDRs, 28 MnDOT WCRs, and 60 TxDOT DWRs were reviewed to establish a baseline condition of the inspection information. The dimensions considered in analyzing these reports include:

- The amount of information
- The quality of information

The above dimensions analyzed are described below.

Amount of Information

The amount of data captured by inspectors in inspection reports were analyzed by examining the number of observations that were captured from these inspection reports using the traditional process and then compared to the amount of information captured using HeadLight.

Inspection reports that were created using the traditional process were used to establish a baseline reference. Since the formatting of the daily report differs from one DOT agency to another, guidelines were created to account for the number of observations in the reports in a consistent manner with how they were captured using HeadLight. An example of a guideline created to assess the amount of observations included in a WSDOT IDR is shown in Figure 16. The guidelines used to assess the baseline report conditions for WSDOT, MnDOT, and TxDOT are located in Appendix D of this report.

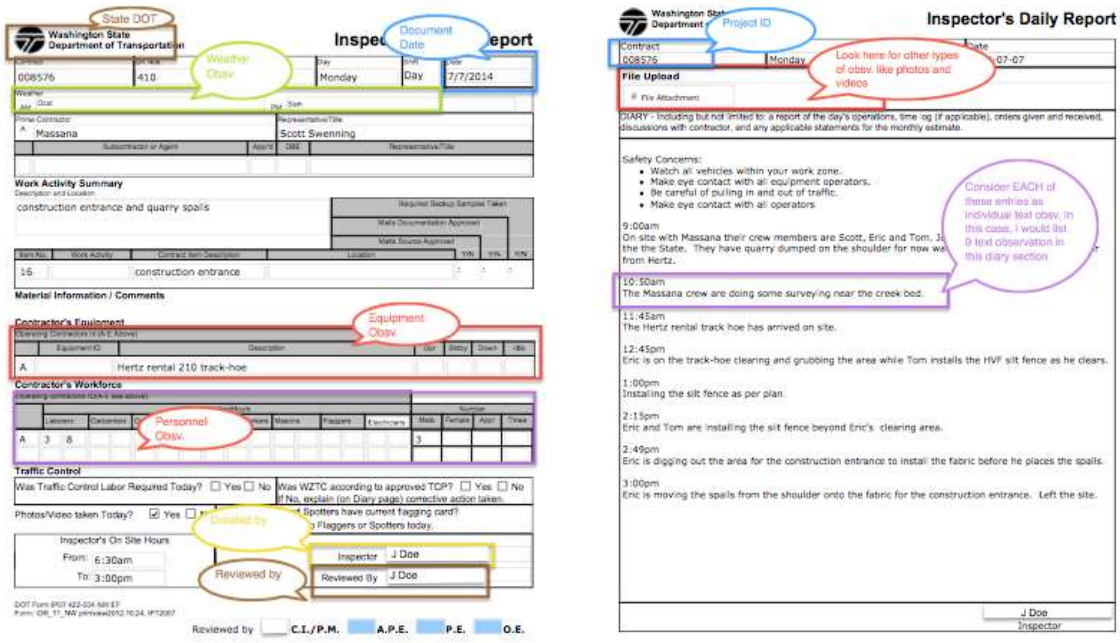


Figure 16: Example guideline used to assess the amount of observations in a WSDOT IDR

As stated previously, inspectors using HeadLight can generate daily inspection documents using the *Documents* feature. Current MnDOT practice has inspectors generating weekly reports. In order to compare these two report formats for MnDOT, the information from each MnDOT WCRs was broken out into individual days.

Quality of Information

To assess the overall quality of the inspection reports created before and during the pilot program, both the composition and the completeness of the inspection reports were analyzed.

The composition of the inspection reports were analyzed by examining the types of observations that were included in inspection reports created using the traditional process and those created with HeadLight.

The inspection reports created prior to the pilot program were also analyzed to determine the tracking of metadata for each observation recorded. This analysis specifically measured the amount of information that had a time and location associated with it that could be recalled directly without prior knowledge to specific project activities as commonly occurs during construction claims. The amount of metadata collected from the baseline inspection reports was then compared to the amount of metadata available in the inspection reports generated by HeadLight.

Mobile and Web Client Training Session

To ensure the effective use of the HeadLight Inspection Units, a two-hour training session was administered. The HeadLight Inspection Units containing Headlight and

the Inspector's Tool Kit were distributed to the inspectors at the start of the training session so they could interact with their mobile tools to expedite the learning process. The topics from the training session included the overview of the pilot program, how to use the iPad for the scope of this pilot program, and how to use the HeadLight Inspection Unit to collect inspection data and to generate daily reports. The outlines distributed to the participants are included in Appendix E. Figure 17 shows one of the training sessions held for the project inspectors.

Figure 17: HeadLight training session in action

In addition to the HeadLight Inspection Unit training session, a HeadLight Web Client training session was held for project engineers and office personnel. This training session focused on teaching how to access, navigate, and search for inspection observations and inspection reports through the HeadLight Web Client for office personnel.

Field Testing of HeadLight Inspection Units

Field testing of the HeadLight Inspection Units was implemented through a one-month testing period for each DOT. Table 10 shows the schedule of the field test for the DOTs.

Table 10: Schedule of field tests conducted in Phase II

DOT Agency	Field Test Period
WSDOT	8/19/2014 to 9/16/2014
MnDOT	9/23/2014 to 10/15/2014
TxDOT	10/21/2014 to 11/14/2014

Table 11 shows the agency projects that were included in the field test. The projects that were selected represented a wide range of project types (earthwork, roadway, structures, etc.) and project sizes.

Table 11: Breakdown of agency projects involved in the field test

Agency	Project Number	Project Name	Cost (dollars)	Duration (days)
WSDOT	8569	Two-way transit & HOV operations, stage 3a - EV Bellevue Way ramps	$7,399,235	290
	8542	WB east channel bridge expansion joint replacement	$1,153,045	20
	8583	High Point St to SR 410 Watson St paving & signal	$2,139,175	100
	8576	SR 410 Scatter Creek Bridge Seismic	$697,344	90
	8584	SR 18 Taylor Creek Scour Protection	$138,990	30
	8565	SR 18 I/C to S 288th ST Seismic Retrofit	$4,644,837	215
	8559	S 272nd ST Vic to Rose ST Seismic Retrofit	$8,504,188	445
MnDOT	2710-42	Railroad Bridge	$5,439,300	279
	2710-2440B	Concrete and Scour Repair	$1,394,800	53
	8282-123	Weigh Scales and Concrete Rehab	$1,946,308	88
	6280-308	I-35E Corridor Project	$119,834,500	694
	2772-99	Noise Walls	NA	NA
	2781-456	Wood Noise Wall	$1,077,000	NA
	2781-458	Micro Surfacing and TMS Improvements	$208,000	20
	1909-95	Turn Lanes	$6,798,653	NA
	1009-24	Bridge Construction	NA	NA
	6280-367	Construct MnPass Lanes	$95,110,192	NA
	2706-226	Louisiana Ave Bridge	NA	NA
	2785-403	Grading, Bit Surfacing, Bit Mill and Overlay, Lighting and Bridges	$5,406,090	NA
	2783-136	4th Street Ramp Design	$12,588,932	NA
	2738-28	Grading, Bit Surfacing, Retaining Walls, Signals, Signing, Lighting, TMS, ADA and Bridge	$17,112,000	289
	1982-182	Bituminous Shoulder Replacement	$1,401,500	33
	8825-471	IDIQ	$5,490,821	NA
	2732-108	Drainage Repair	$91,000	7
TxDOT	0027-12-105	Widening of freeway	$135,868,539	1079
	0500-03-462	Widen Roadway	$77,483,151	1135
	0050-06-080	US-290 Widening	$48,599,234	700
	0271-05-037	Rebuild Roadway	$10,742,565	178
	0050-06-081	Widen Roadway	$85,215,954	960
	0050-08-087	Construct new roadway lanes	$135,455,756	1052
	1006-01-059	Widen Roadway	$7,690,214	322

Field tests began directly after the two-hour mobile application training sessions. During the pilot program, the inspectors used their HeadLight Inspection Units to collect and store all inspection observations rather than their traditional methods. Inspectors also used their HeadLight Inspection Units to generate their daily inspection reports and automatically submit them at the end of their shifts. Research assistants were out in the field during the pilot program shadowing the project inspectors to gather direct measurements of key metrics using the *Field Guide* outlined earlier.

In addition to the uses mentioned above, inspectors used their HeadLight Inspection Units to access and search through content in their project plans, specifications, and other project reference documents. Inspectors also were able to directly access their emails using their HeadLight Inspection Units.

Office Pilot of the HeadLight System

Office personnel, including project engineers and managers, involved in the pilot program used the HeadLight Web Client to access and review inspection observations and inspection reports generated by project inspectors in real-time. Office personnel also used the HeadLight Web Client to generate *Observation Timeline Reports* and an *Observation Map Reports.* Furthermore, project managers and chief inspectors were able to use the HeadLight Web Client to access and approve inspection reports.

Field and Phone Support

On-site and phone technical support were provided to participants during the pilot. To deliver on-site support, research assistants were located out in the field to roam between projects and participants to address any issues that came up and observe and record usage details. Project inspectors were also given a phone number to reach a support-line to answer any questions or help troubleshoot any issues related to the HeadLight Inspection Unit. The phone support was also available to any project engineers and office personnel that needed help with the HeadLight Web Client. These two sources of support were provided to ensure quick and effective use of the hardware and software included in the pilot program.

Post-Pilot Participant Interviews

Project inspectors, project engineers, and management involved in the pilot program were invited to participate in a voluntary post-pilot participant interview session at the conclusion of the field test. The purpose of the interview session was to gather metrics and feedback from the participants and to validate observations made by the research team. The interviews were structured as 1-on-1 conversations and took approximately 1 hour to conduct. Two separate types of interviews were conducted with two sets of questions tailored for the separate audiences: one for the project inspectors (field personnel with HeadLight Inspection Units) and another for project engineers and managers (office personnel using the HeadLight Web Client).

The interviews were designed using a set of questions to guide conversational interactions with participants and were aimed at generating information about different dimensions including changes in user productivity, changes in data quality, changes in data availability, learnability of the system, helpfulness of the support provided, the overall usefulness of features and capabilities of the HeadLight Inspection Units, safety concerns using HeadLight, and the impact of being able to search for specific contents in inspection observations and daily reports. The interview guides for project inspectors and office personnel are included in Appendix F of this report.

Research Participants

Table 12 identifies the Phase II research participants and how they were involved in this study. Table 13 shows the number of participants from each agency.

Table 12: Phase II participants and their involvement in this study

Participants	Involvement in Phase II Activities	Number of Participants
Project Inspectors	Participated in the Mobile Client training session	24
	Performed inspection on projects using the HeadLight Inspection Units	
	Participated in Phase II interview session	
Project Engineers / Management	Participated in the Web Client training session	11
	Reviewed inspection observations and daily reports using the HeadLight Web Client	
	Participated in Phase II interview session	

Table 13: Breakdown of participants by agency

Agency	Project Inspectors	Project Engineers/Management
WSDOT	6	2
MnDOT	9	4
TxDOT	9	5
TOTAL	**24**	**11**

Results and Discoveries

Productivity

The research team evaluated the impact that mobile technology had on productivity by evaluating activities identified as the largest contributors to time spent by inspectors.

Time Spent Creating Inspection Documents

Table 14 shows the amount of time taken to create daily reports using both the traditional agency practices and the HeadLight Inspection Unit.

Table 14: Comparison of average time taken to create IDRs and DWRs

Agency	Average Time Taken to Create Inspection Report per Day		Average Reporting Time Saved Using HeadLight [per day]
	Traditional Process	HeadLight	
WSDOT	37.75 min	0.48 min	37.27 min
MnDOT	15.00 min	0.25 min	14.75 min
TxDOT	27.50 min	0.12 min	27.38 min
All Agencies	**26.75 min**	**0.28 min**	**26.47 min**

Time Spent Traveling Off Site to Submit Documentation

The time savings resulting from the reduction of travelling offsite were captured and results are shown in Table 15. This included a tabulation of individual travel time that was eliminated from participants not having to go back to the office to submit their daily documentation.

Table 15: Average travel-time savings per inspector per day

Agency	Average Travel Time Savings Using HeadLight [per day]
WSDOT	45 minutes
MnDOT	50 minutes
TxDOT	25 minutes
All Agencies	**40 minutes**

It should be noted that the time savings for travel can vary depending on the size of the project, the number of projects the inspector is responsible for, location of the project office, and traffic congestion.

Time Spent Searching for Content

The time spent to look up information was measured in the field when an inspector had to refer to plans or specs for particular pieces of information. It was measured using traditional agency practices and compared to the time spent searching for

content in the Inspector's Tool Kit to identify time savings. As some inspectors use electronic versions of the project reference documents, the traditional agency practice mentioned in this section refers only to the use of hard copies of the project reference documents. Table 16 shows the average time spent looking for a single piece of information and calculates a scalable factor for time savings.

Table 16: Average time taken to search for a content using traditional practice compared to HeadLight

Agency	Average Time Taken per Content Search Instance		Percent of Time Saved Using HeadLight	Factor of Time Saved Using HeadLight
	Traditional Process	HeadLight		
WSDOT	N/A	2.24 min	N/A	N/A
MnDOT	10.50 min	1.21 min	88.46%	8.68x
TxDOT	6.20 min	3.68 min	40.65%	1.68x
All Agencies	**8.35 min**	**2.45 min**	**64.56%**	**5.18x**

The difference in the average time spent looking for content using a HeadLight Inspection Unit between MnDOT and TxDOT inspectors can be explained by the size of the projects. Several TxDOT inspectors worked on sizable projects spanning more than 6 miles long and contract values greater than $135 million. These projects typically have more content in their project reference documents, leading inspectors to spend more time searching through the documents.

Measurements for time taken searching for content using current practices at WSDOT were not available and as such were not included in these results. While no comparison to the current process can be made, on average, WSDOT inspectors spent an average of over 2 minutes to search for any one key search topic. This correlates to the time spent for both MnDOT and TxDOT using HeadLight so similar outcomes were anticipated in terms of time savings.

Table 17 below uses the percent reduction factors shown above to calculate the total average search time savings per day per inspector. The WSDOT analysis below uses the average value of the percent of time saved using HeadLight between TxDOT and MnDOT.

The results show that on average, 40 minutes per day can be saved per inspector by using the Inspector's Tool Kit to search for content in the project reference documents.

Table 17: Total average search time savings per day using the Inspector's Tool Kit

Agency	Average time taken per day searching for content		Total Average Search Time Savings [per day]
	Traditional Process	HeadLight	
WSDOT	65.14 min	23.09 min	42.05 min
MnDOT	39.90 min	4.60 min	35.29 min
TxDOT	107.70 min	63.92 min	43.79 min
All Agencies	**70.91 min**	**30.53 min**	**40.38 min**

Total Time Savings

In addition to the individual components evaluated above, an evaluation of total time savings was measured using participant responses. The average overall time saved per inspector per day for all DOT agencies is shown in Table 18. The table also shows the combined total of the time savings measured from the three key activities discussed above.

Table 18: Average time saved per inspector per day (*WSDOT's combined total uses the average search time saved between TxDOT and MnDOT to account for search time savings)

Agency	Average Time Saved per Inspector per Day [Participant Response]	Average Time Saved per Inspector per Day [Measured Activities]
WSDOT	1.50 hours	2.07 hours*
MnDOT	1.44 hours	1.67 hours
TxDOT	1.67 hours	1.60 hours
All	**1.54 hours**	**1.78 hours**

The difference in time saved between the participant responses and the measured activities is considered acceptable due to the number of uncontrolled variables such as the size and location of the activities on the project and commuting during heavy traffic congestion at the times when observations were recorded. The measured value of the average time saved per inspector per day of 1.78 hours is used to draw conclusions from the results as the participant response values were only used to correlate the measured results.

In addition, there were qualitative responses that the participants gave to describe the time savings and productivity gains:

> *"Total time savings in a day, 2 hours a day. Then [I] can spend that time watching [work] crew instead of other unnecessary activities." – Project Inspector, TxDOT*

> *"Absolutely, it will increase my job performance. More information would be available, and I can spend more time out in the field. State will save on overtime*

cost because a large portion of our overtime is travel time or reports." – Project Inspector, WSDOT

"The program is very user friendly. It makes my life a lot easier out in the field, not having to go back to the office to produce daily and weekly diaries. The more time out in the field, the better for us." – Project Inspector, MnDOT

"[It would save me] 2 days a week. It would save [project managers] a few hours daily, because they have to review and authorize DWRs and review calculations." – Project Engineer, TxDOT

"It saves about 75% of my typical DWR process." – Project Inspector, TxDOT

A complete list of interview quotes organized by key metrics is included in Appendix G.

Project Engineers and Management

While this research did not attempt to quantify the time savings for project engineers and management, the results from several questions in the interviews indicate that there were additional time savings that occurred. These are noted below in Figure 18.

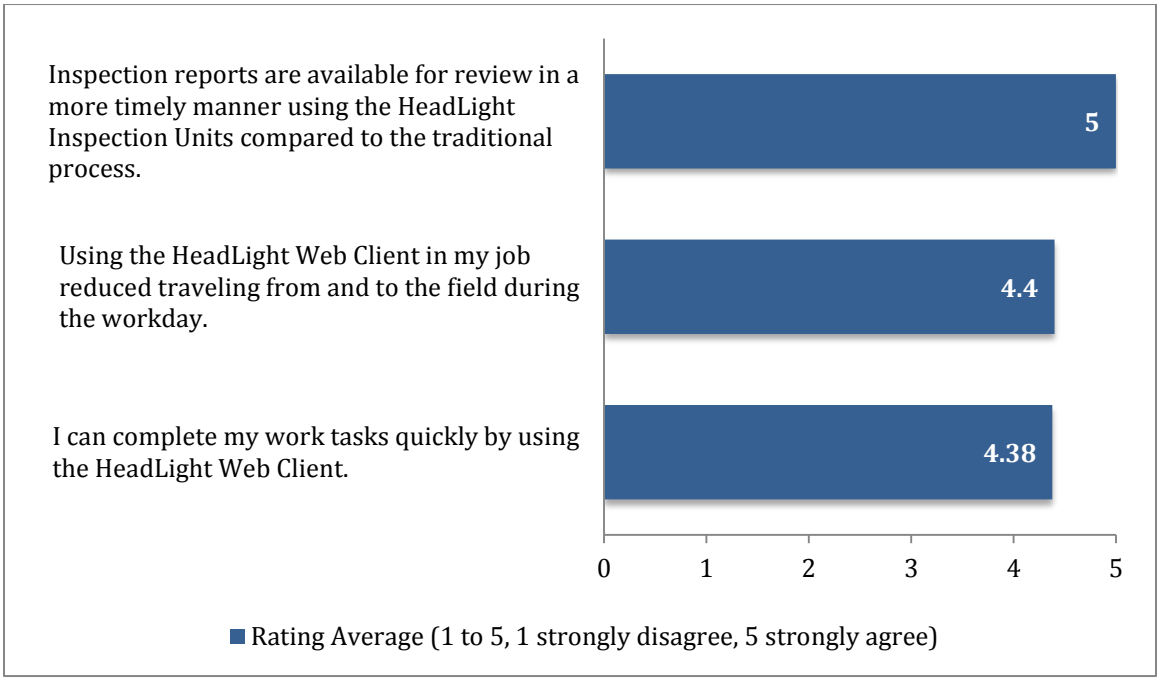


Figure 18: Phase II interview responses from project engineers and managers related to productivity

Data Quality Results

The following sections show the results of the elements measured in terms of data quality.

Amount of observations collected

The amount of observations collected by inspectors using the HeadLight Inspection Units during the pilot program is shown in Table 19.

Table 19: Breakdown of observations collecting using HeadLight

Observation Type	WSDOT	MnDOT	TxDOT	Total (All Agencies)
Photo	778	1,025	460	**2263**
Video	13	45	25	**83**
Text	441	101	364	**906**
Equipment	366	22	841	**1,229**
Personnel	206	45	419	**670**
Temperature	1	7	0	**8**
Weather	412	812	572	**1,796**
Start/Stop	4	68	73	**145**
Material	3	2	0	**5**
Total	**2,224**	**2,127**	**2754**	**7,105**

The results indicate that during the entire pilot period, a total of 7,105 observations were collected from the participating agencies. The results of the comparison of the average amount of data collected per inspector per day between baseline and pilot program conditions are shown in Table 20.

Table 20: Average number of observations made by one inspector per day using HeadLight

Agency	Average Amount of Observations Collected per Day		Relative Increase Using HeadLight
	Traditional Process	HeadLight	
WSDOT	9.3	22.4	2.41x
MnDOT	5.2	19.5	3.75x
TxDOT	6.6	13.8	2.09x
All Agencies	**7.03**	**18.57**	**2.75x**

The results above have been normalized to account for the variation in project size and activity by removing the impact of the large variations in equipment activity or personnel counts that occurred on projects as a part of this study. In addition, not all participants were active each day on the project site so any non-active days were excluded from the rate calculation.

The results indicate that inspectors on average were able to increase the amount of observations collected by 2.75 times using the HeadLight Inspection Units. Figure 19 shows the Phase II interview responses when inspectors were asked about the change in the amount of observation collected resulting from the use of the HeadLight Inspection Units. The results indicate that 82.6% of the inspectors thought they collected more inspection information compared to their traditional

inspection process and 17.4 thought they collected the same amount. Both the measured value above and the inspectors' interview responses correlate and indicate that more inspection observations were collected using the HeadLight Inspection Units.

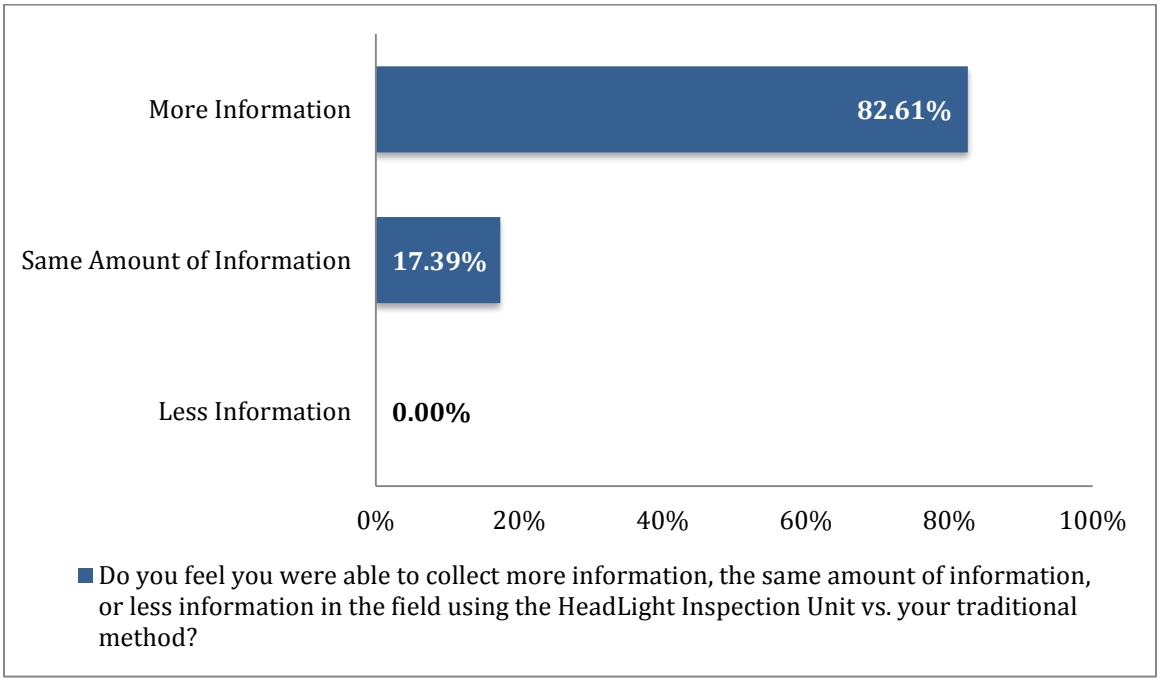


Figure 19: Project inspector responses on the amount of observations collected using HeadLight compared to the traditional method

As an example of a typical inspection observation, Figure 20 shows an actual photo observation created using the HeadLight Inspection Unit during the pilot. The image shows the contractor moving the temporary concrete barriers in position for a new temporary traffic configuration.

Figure 20: Actual photo observation created during the pilot depicting traffic configuration work

In addition, there were several comments made by participants regarding the ability to collect information using HeadLight:

> *"HeadLight reports are more complete." – Project Inspector, TxDOT*
>
> *"[Referencing HeadLight] You're gonna collect more [information] than you can do on the laptop. Everything's right there, camera, video, voice, signature, anything you need to highlight, it's all right there." – Project Inspector, TxDOT*
>
> *"When the pilot first started, I would only take a photo of an activity once. I would not take pictures of the same activity being performed at a different location because I thought it looked the same (redundant, same activity just in a different location). But after talking to [HeadLight Support], he pointed out that taking photos shows progress of work so I started to take more photos and videos." – Project Inspector, TxDOT*
>
> *"Using the HeadLight system… you'll get more information because it's so easy to get the information into their daily report." – Project Engineer, TxDOT*

A complete list of interview quotes organized by key metrics is included in Appendix G.

Composition of Observation Entries

In addition to examining the total number of observations that were collected, this research examined the composition of those additional observations. As defined and identified earlier, there are 13 different types of observations included in HeadLight. The results of comparing the composition of the observation types are shown in Figure 21 through Figure 23 (One for each DOT).

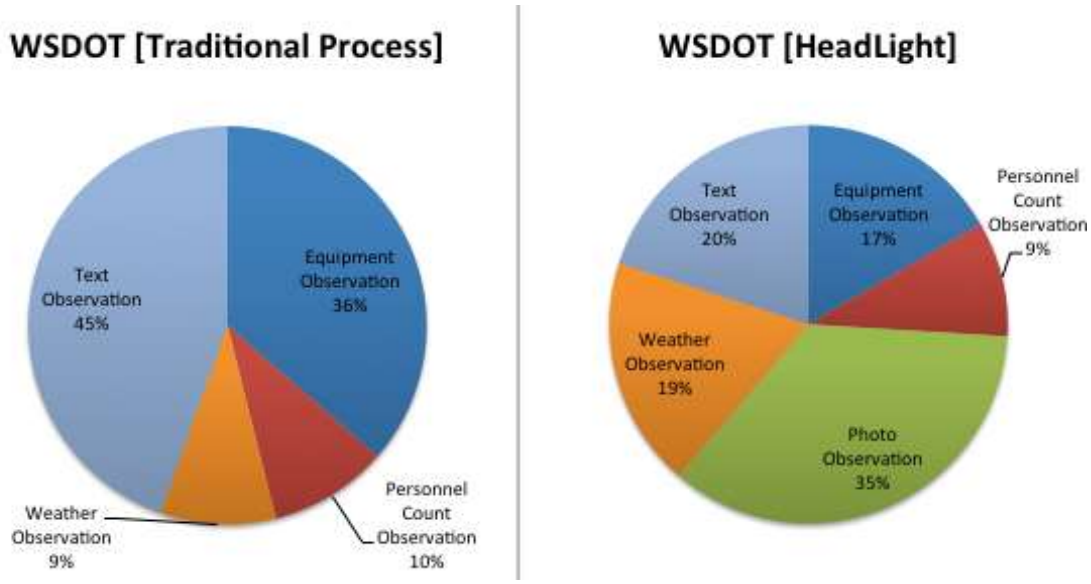


Figure 21: Composition comparison for WSDOT daily reports

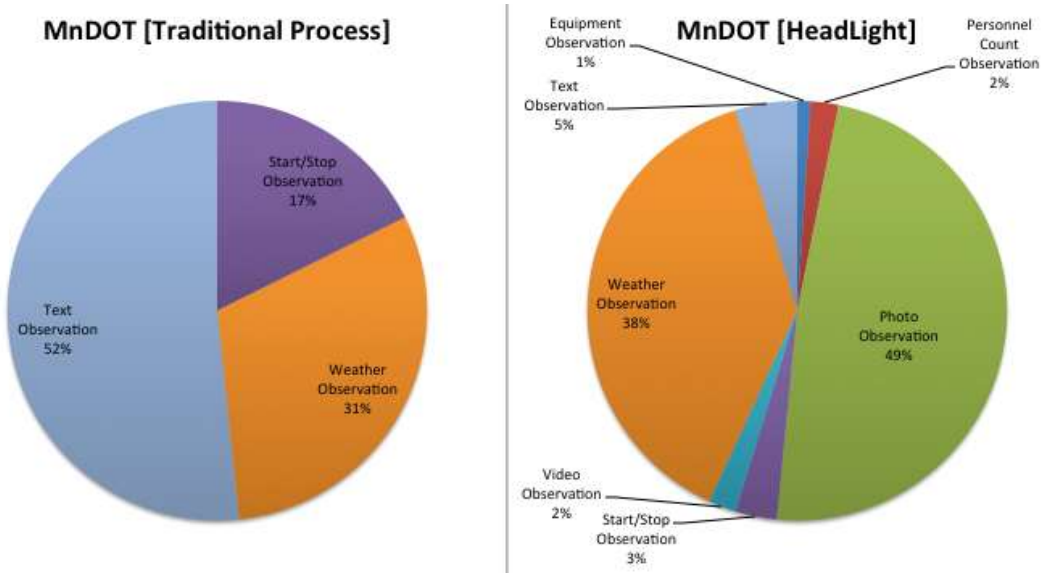


Figure 22: Composition comparison for MnDOT daily reports

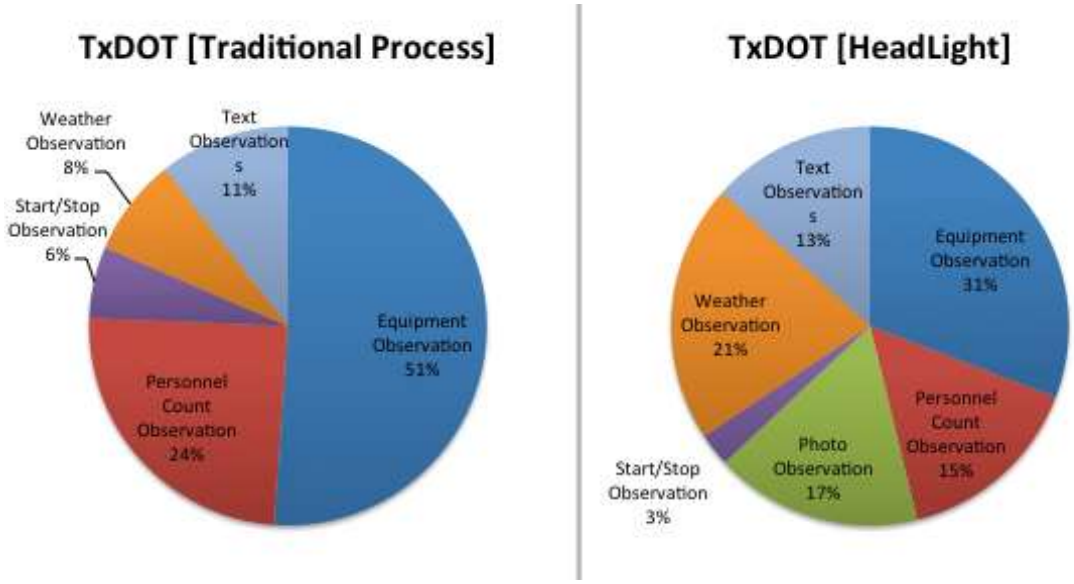


Figure 23: Composition comparison for TxDOT daily reports

The results show that the project inspectors using HeadLight were incorporating a significant number of photo and video observations in their daily inspections reports. Examination of the inspection reports from the traditional process indicated that photos and videos were not directly included in the inspection reports. Inspectors using the HeadLight Inspection Unit were able to directly incorporate photos and links to videos in their inspection reports.

All agencies also saw a significant percent increase in the amount of weather observations captured in a day. This increase was attributed to HeadLight integration with automated weather services, which helped provide users the ability to capture several weather characteristics from their current location including humidity, precipitation, and wind speed in addition to the current weather conditions and outside temperature information at the push of a button.

Overall, the above results indicate that inspectors using the HeadLight Inspection Units were able to use the tools integrated within it to include a variety of observation types in their inspection reports.

Completeness of Daily Reports

The inspection reports created prior to the pilot program were analyzed to determine the tracking of metadata for each observation recorded. Metadata in this research is defined as temporal and special data associated with every observation recorded. Having metadata for inspection observations was identified as a valuable piece of information for agencies to use for recalling information, especially in a claims or dispute situation.

The results of the metadata analysis are shown below in Tables 21 and 22. The term *recallable* used below refers to observations that had a time and location associated with it that could be recalled quickly without prior knowledge to specific project activities. An observation was considered recallable by time if the specific time of observation entry was recorded. An observation was considered recallable by location if specific station location, mile post numbers, or GPS coordinates were recorded.

Table 21: Metadata count for traditional process observations recallable by time

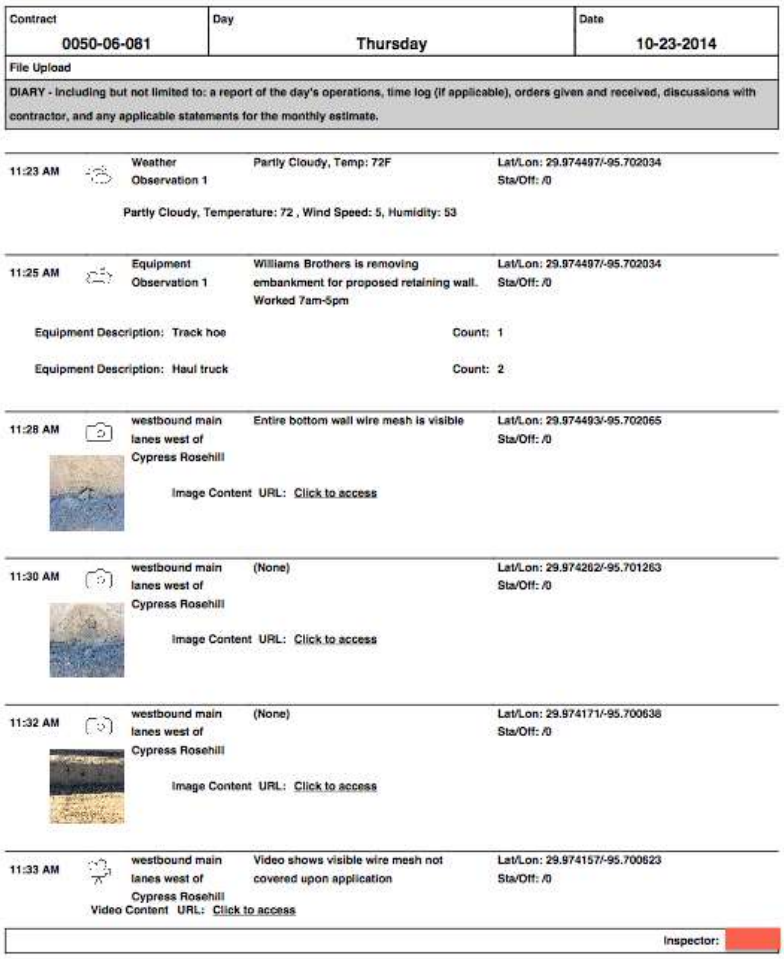
Agency	Observations Recallable by Time	
	Traditional Process	HeadLight
WSDOT	50.4%	100%
MnDOT	2.7 %	100%
TxDOT	0.8 %	100%

Table 22: Metadata count for traditional process observations recallable by location

Agency	Observations Recallable by Location	
	Traditional Process	HeadLight
WSDOT	1.8%	100%
MnDOT	6.1%	100%
TxDOT	18.0%	100%

The results indicate that the amount of metadata collected for each observation was highly variable throughout the participating agencies. Throughout all agencies, only a small portion of observations taken using the traditional process were recallable by station location or milepost designation making it extremely difficult to recall that information without prior knowledge of the project and specific activity location or timing.

All HeadLight observations included a time and GPS location stamp with them as a part of the observation metadata discussed earlier. This allowed all observations to be recalled by time and / or location. Figure 24 shows an example of a daily inspection report created during the pilot. The metadata associated with each observation are shown.



Contract	Day	Date
0050-06-081	Thursday	10-23-2014

File Upload

DIARY - Including but not limited to: a report of the day's operations, time log (if applicable), orders given and received, discussions with contractor, and any applicable statements for the monthly estimate.

11:23 AM	Weather Observation 1	Partly Cloudy, Temp: 72F	Lat/Lon: 29.974497/-95.702034 Sta/Off: /0
	Partly Cloudy, Temperature: 72 , Wind Speed: 5, Humidity: 53		
11:25 AM	Equipment Observation 1	Williams Brothers is removing embankment for proposed retaining wall. Worked 7am-5pm	Lat/Lon: 29.974497/-95.702034 Sta/Off: /0
	Equipment Description: Track hoe		Count: 1
	Equipment Description: Haul truck		Count: 2
11:28 AM	westbound main lanes west of Cypress Rosehill	Entire bottom wall wire mesh is visible	Lat/Lon: 29.974493/-95.702065 Sta/Off: /0
	Image Content URL: Click to access		
11:30 AM	westbound main lanes west of Cypress Rosehill	(None)	Lat/Lon: 29.974262/-95.701263 Sta/Off: /0
	Image Content URL: Click to access		
11:32 AM	westbound main lanes west of Cypress Rosehill	(None)	Lat/Lon: 29.974171/-95.700638 Sta/Off: /0
	Image Content URL: Click to access		
11:33 AM	westbound main lanes west of Cypress Rosehill	Video shows visible wire mesh not covered upon application	Lat/Lon: 29.974157/-95.700623 Sta/Off: /0
	Video Content URL: Click to access		

Inspector:

Figure 24: Metadata shown on an inspection report generated using HeadLight during the pilot

Project Engineers and Management

Data Quality was an important factor identified by Project Engineers and Management through Phase I. Figure 25 and Tables 23 and 24 were compiled using the project engineers and management's responses regarding data quality from Phase II interviews.

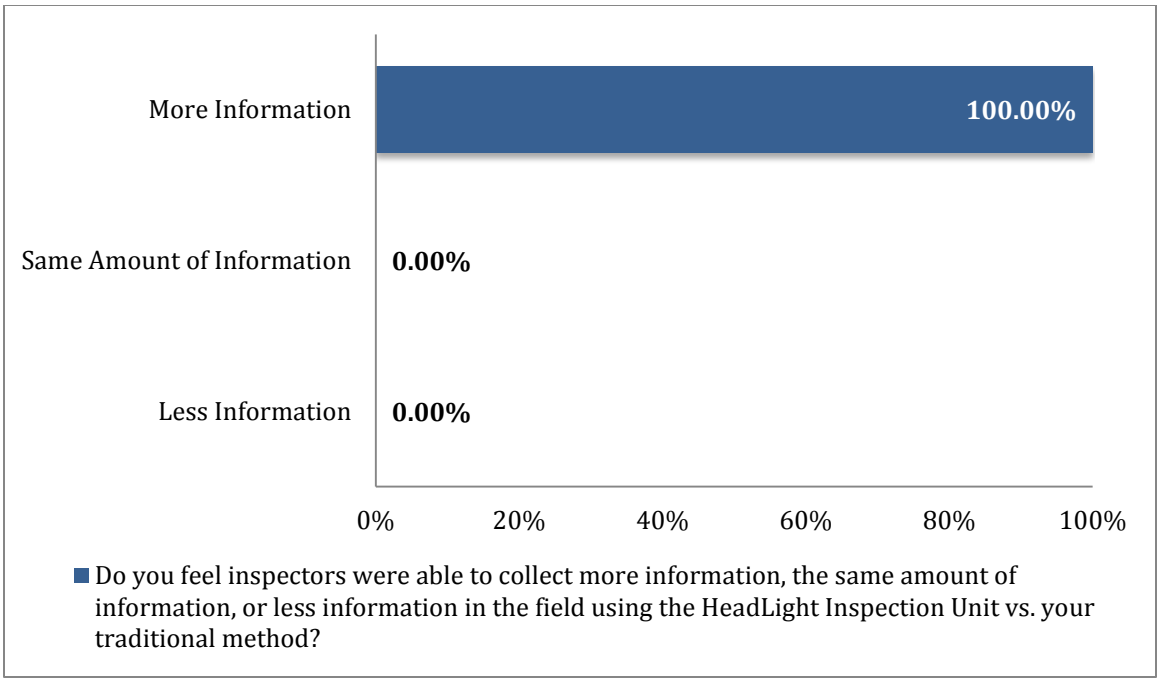


Figure 25: Project engineer and management responses on the amount of observations collected by their inspectors using the HeadLight Inspection Unit

Table 23: Summary of interview responses to how HeadLight changed the way users access observations

Describe how HeadLight Web Client has changed the way you access observations. (Answered: 6 Skipped: 5)	
Responses	**Response**
The quality of the inspection information improved	5 out of 6
No change to the quality of inspection information	1 out of 6
The quality of inspection information worsened	0 out of 6

Table 24: Summary of interview responses to how HeadLight changed the way users review inspection reports

Describe how HeadLight Web Client changed the way you review inspection reports. (Answered: 7 Skipped: 4)	
Responses	**Response**
The quality of the inspection reports improved	5 out of 7
No change to the quality of the inspection reports	2 out of 7
The quality of the inspection reports worsened	0 out of 7

In addition, project engineers and management participants described the quality of daily reports using HeadLight as follows:

> *"I absolutely loved it. You get your inspectors that don't write out as much detail, but those inspectors do a lot of photo observations, when you pair their short little writing with the photo observation, you get a good idea of what's going on. [Contractor] laying down base at frontage road from station x to y. Is*

it first lift of second left? Take a look at the picture, can tell just by the depth." - Project Engineer, TxDOT

"[Information is] very accurate as far as what would go in his daily [using HeadLight]. The information I've seen from the daily reports via HeadLight has more information than the hand written daily reports." – Project Engineer, MnDOT

"Managing and recording what's happening is so much easier with HeadLight than writing stuff in the notebook." – Project Engineer, WSDOT

"More information through observation was created. It was a much more comprehensive diary report. There is significant amount of savings with HeadLight. I could have saved half-million [dollars] on a current claim with this tool." – Project Engineer, WSDOT

"Saves a ton of time. With Site Manager, inspectors don't input observations until end of day. Guys using HeadLight is pops up immediately. I know what's going on exactly to the minute. I know at that point what's going on, vs. finding out a day late after the damage has already been done." – Project Engineer, TxDOT

"I used the app to get locations to see where everyone was at, could see what parts of the job were being covered, and I knew what parts of the job I needed to inspect when driving the jobsite." – Project Engineer, TxDOT

"When I was an inspector, I didn't want to connect the laptop inside the truck, so you write the required information, don't go into much detail as it's at the end of the day, you want to go home. But with HeadLight, just take a picture, and it becomes a part of your observation. It's much easier." – Project Engineer, TxDOT

A complete list of interview quotes organized by key metrics is included in Appendix G.

Data Availability Results

The following sections show the results of the elements measured in terms of data availability.

Timeliness of Inspection Information Availability

Figure 26 and Tables 25 and 26 summarize the responses from project engineers and management when they were asked questions related to data availability.

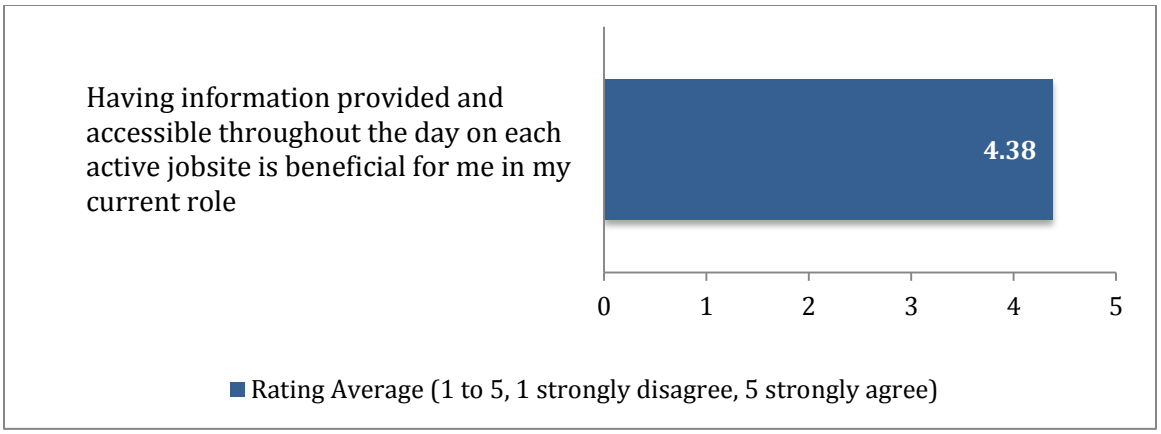


Figure 26: Summary of interview response regarding the benefits of having real-time information

Table 25: Summary of interview responses on how the HeadLight Web Client changed the way project engineers access observations

Describe how the HeadLight Web Client has changed the way you access observations. (Answered: 6 Skipped: 5)	
Responses	**Response**
The availability of the inspection information improved	6 out of 6
No change to the availability of the inspection information	0 out of 6
The availability of the inspection information worsened	0 out of 6

Table 26: Summary of interview responses on how the HeadLight Web Client changed the way project engineers access daily inspection reports

Describe how the HeadLight Web Client changed the way you access inspection reports. (Answered: 7 Skipped: 4)	
Responses	**Response**
The availability of the inspection reports improved	5 out of 7
No change to the availability of the inspection reports	2 out of 7
The availability of the inspection reports worsened	0 out of 7

Timeliness of Inspection Reports

The timeliness of the submission of daily inspection reports during the pilot program for WSDOT is shown in Table 27.

Table 27: Percent of daily inspection reports submitted within 24 hours and 72 hours for both the traditional agency process and the process using the HeadLight system

Agency	Reports submitted w/in 24 hours [Traditional Process]	Reports submitted w/in 72 hours [Traditional Process]	Reports submitted w/in 24 hours [HeadLight]	Reports submitted w/in 72 hours [HeadLight]
WSDOT	55%	73%	81%	92%

It should be noted that this study was only able to compare data related to timeliness of report submission from WSDOT due to a limitation in availability of baseline data for both MnDOT and TxDOT.

Participant's thoughts on the importance of having timely information accessible throughout the day on each active jobsite included:

> *"[With HeadLight] I can resolve issues right away, vs. waiting 2-3 days. [HeadLight] allows me to make decisions from wherever I am." – Project Engineer, TxDOT*
>
> *When asked, how timely were HeadLight inspection reports submitted "By far, easily a day. Inspectors don't put stuff in 'til the end of the day. [I] can go a whole week without getting DWRs from guys, then get [them] all at once. Whereas with HeadLight, you see it every half of the day." – Project Engineer, TxDOT*
>
> *When asked, how timely were HeadLight inspection reports submitted "[I currently] get them every 2 to 3 weeks. HeadLight would help with timeliness. Can do it in the field. If they're busy one week, they sometimes don't even come in the office." – Project Engineer, MnDOT*
>
> *"When I normally do it, I have to carry my rain-write notebook. I have to look at the time and correlate it to my observations. Then I have to get on my computer and change the weather, date, bid items, personnel, etc. Then you get to the [diary portion] IDR. You have to look at your notes, remember what you did out in the field, and then type it all up. With HeadLight, all you have to do is select the observations and sync. That's it and your done. Now I'm two days behind, I won't be able to get to my IDRs until next week. I probably will lose some content for those two days. I have good notes but you don't always remember everything. When you do it on the spot, it flows better and the information is fresh." – Project Inspector, WSDOT*

A complete list of interview quotes organized by key metrics is included in Appendix G.

Accessibility of Inspection Information

A synthesis of both current agency practices as well as those using mobile technology to identify the general availability and location of documents and information to stakeholders was conducted. Table 28 summarizes the comparison of inspection information availability in terms of timing and location.

Table 28: Inspection information availability comparison

Traditional Agency Practice			HeadLight		
Information Source	**Timing of Availability**	**Location Stored**	**Information Source**	**Timing of Availability**	**Location Stored**
Field notebook	Upon Request	Inspector's possession	Observations	Real-time	Central Repository
Photos and other media	Varies, upon submission	Varies, shared drive or email correspondence	Photos and other media	Real-time	Central Repository
Inspection Report	Varies, upon submission	Varies, shared drive or document management system	Inspection Reports	Varies, upon submission	Central Repository

A further examination of the results for both the current agency practice and that using HeadLight is described below to elaborate on some of the process changes observed.

Traditional Agency Description

The interview responses resulted in the following findings describing inspection information availability using the current agency practice:

- All inspectors indicated that information was recorded in their field notebook
- Project engineers and other office personnel refer to inspection reports as their primary source of inspection information
- The submission of the inspection reports can take days to weeks depending on the project inspectors access to the agency's document management system
- Photos and videos are not routinely uploaded into the agency's document management system

All project inspectors that participated in this research indicated that they record inspection observations in their notebook. The notebooks were available to project engineers and office personnel upon request. The post-pilot interview responses from project engineers and office personnel indicated that the inspector's field notebooks were rarely reviewed when specific inspection information was needed. Figure 27 shows an example of an inspector's field notebook.

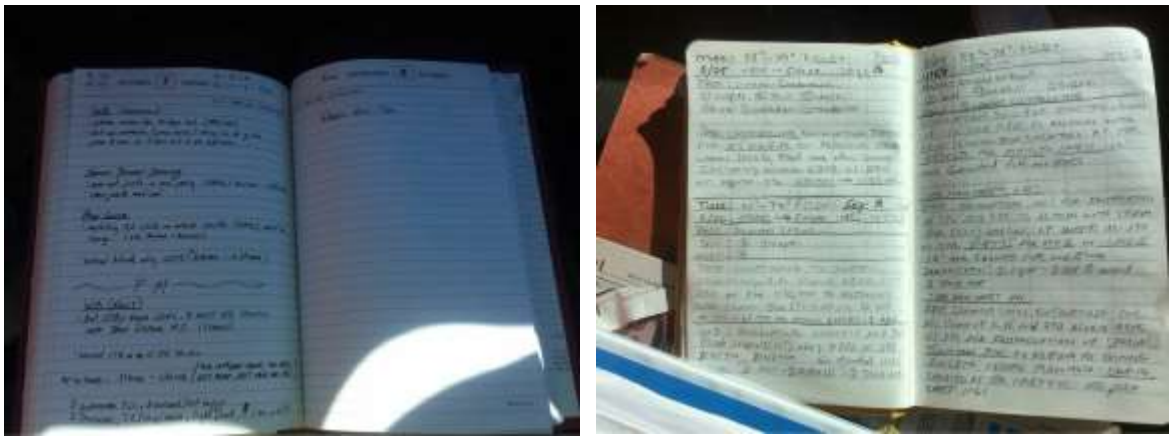


Figure 27: Examples of inspector's field notebook

Project engineers and office personnel refer to inspection reports as their primary source of inspection information. The availability of the inspection reports in the traditional process depends on when the inspectors submit their reports and in what format the reports are submitted. Several project engineers interviewed expressed that it range from several days to several weeks for submission.

Using the traditional process it was observed that photos and videos taken by the inspectors were often not incorporated directly into the inspection reports or uploaded into the agency's traditional document management system. These pictures and videos were typically uploaded to the inspector's computer but were not included within inspection reports or uploaded to the agency's document management system as the process to do so takes a long time or is not supported. Inspectors in this case, shared photos and videos through email correspondence or through the agency's shared network drives, but were not a part of the archived inspection record.

It should be noted that the findings above are based on agency use of the HeadLight system described within this research. The HeadLight Inspection Unit was specifically designed to assist project inspectors with their inspection tasks. The software integrated the key inspection tools that include cameras, GPS sensors, cellular connectivity, and computing processing power and provided features that specifically streamlined the process involved in generating inspection reports.

This is important to note as the interview sessions uncovered that some project inspectors were already using tablet computers prior to this pilot program with mixed results. These tablet computers were used to connect to Virtual Private Networks (VPN) or a virtual desktop to enable inspectors to use them much as they would a laptop to access existing software or upload and share inspection information to their current document management system. While the tablet increased portability from the laptop, without proper software, the same limitations in productivity and quality applied. Inspectors shared that it can take anywhere from 5 minutes to 45 minutes to connect to the VPN using the traditional process and that including images and videos was just as challenging as the traditional

process. In fact, some inspectors shared that they no longer used the iPads in the traditional process as it increased the time it took to complete tasks.

HeadLight Process Description

The accessibility of inspection information collected using the HeadLight Inspection Unit was determined through the Phase II interview sessions. The analysis of the interview responses resulted in the following summary findings describing inspection information availability using the HeadLight system:

- Project engineers and management personnel accessed inspection observations collected by inspectors in real-time using the HeadLight Web Client
- During the pilot program, project engineers and management personnel used inspection observation and daily inspection reports as their primary source of inspection information
- Every inspection observation and daily inspection report was stored in one centrally accessible repository, which improved the accessibility of all the inspection information
- Photos, videos, and any other media collected using the HeadLight Inspection Units along with corresponding metadata were organized and stored in the central repository and were accessible through the HeadLight Web Client and automatically integrated into daily reports
- Incorporating photos and videos into the observation feed and daily inspection reports greatly increased the use of photos and videos and decreased the need to share media through email correspondence and through shared network drives
- Inspectors submitted their daily inspection reports from the field using HeadLight Inspection Units which improved the timeliness of their availability

The synchronization of inspection observations between the HeadLight Mobile Client with the Web Client enabled project engineers and other personnel at the project office to view the observations in real-time. HeadLight Web Client users were able to view photos and videos collected by inspectors to help visualize and understand any activities or issues present in the field. The following quote from a pilot participant emphasizes the importance of being able to access inspection information from any location in real-time:

> *"I must be able to address issues in real time. This is very important. Project sites could be very far away. Currently, phone calls are the way issues are communicated. Visiting sites can take away half the day, having real time info saves this much time. This real time info does not just stop at my desk, it could be available to a specialist in Olympia [HQ] on bridge design. Instantly pass information to the person who needs to make a structural decision."– Project Engineer, WSDOT*

The interviews also revealed that having observations and inspection reports stored in a central repository and accessible in real-time reduced the need for inspectors to upload and share photos and videos through emails or shared network drives. Participants found it helpful to have all inspection information accessible in one central location. Project engineers and management personnel also noticed an increase in inspectors submitting their reports on time, allowing them to see inspection reports in a timely manner.

Additional Characteristics Observed

The following characteristics were observed and recorded from the interview responses from project inspectors, project engineers, and management personnel.

Learnability and Support

Tables 29 through 31 and Figures 28 and 29 show the responses from project inspectors regarding their previous experience with mobile technology, their experience learning how to use the HeadLight Inspection Unit, and their experience seeking support during the pilot program.

Table 29: Inspector's prior use of tablet computers

Prior Use of Technology Questions	
Question	**Yes**
Have you used a tablet computer before the pilot program? (Answered: 24 Skipped: 0)	83.33%

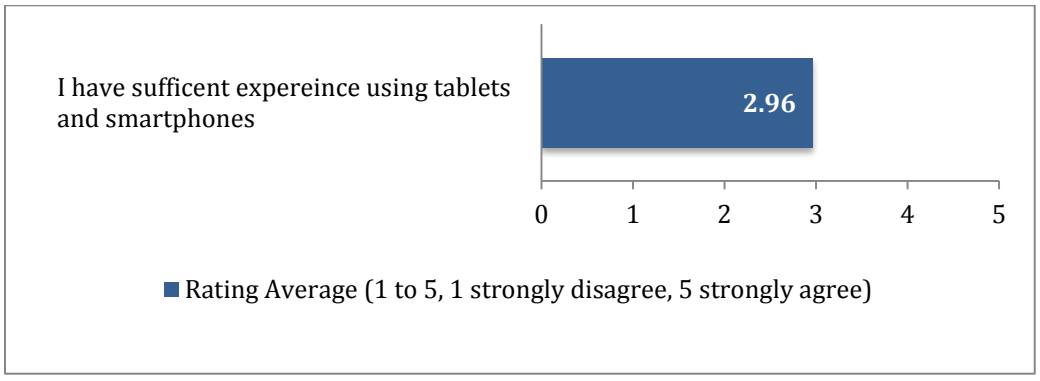


Figure 28: Inspector's past experience using tablets and smartphones

Table 30: Interview response for learnability and support questions

Learnability and Support Related Questions	
Question	**Yes**
Did you get used to using the HeadLight Inspection Unit? (Answered: 23 Skipped: 1)	95.65%
Did you seek help from our support staff or the support call center during the pilot program? (Answered: 22 Skipped: 2)	86.36%

Table 31: Interview response related to how long it took inspectors to become comfortable with HeadLight

Interview Questions	Min	Max	Average
How long did it take until you were comfortable using the HeadLight Inspection Unit? (*Response in days*)	1	10	2.68

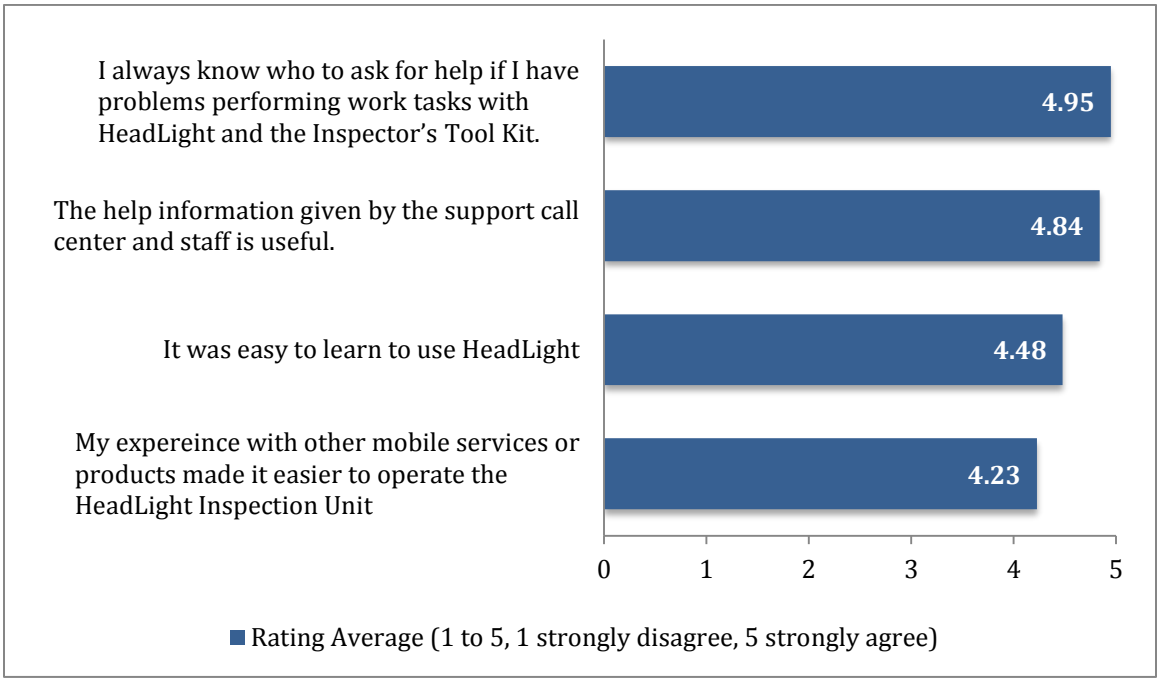


Figure 29: Project inspector's rating responses related to learnability and support questions

In addition, the participant's experience learning HeadLight are shared below:

> *"I was comfortable with [HeadLight] the day after the presentation. I was comfortable with taking pictures and videos. I was able to read emails and all the next day." – Project Inspector, TxDOT*

> *"After the [training presentation], it was very easy to use HeadLight." – Project Inspector, WSDOT*

> *"I've seen a lot [of technology] in my time here. [The Mobile Application Training Session] presentation is the best so far and this product is something that I hope MnDOT adopts. The presenters from previous presentations [implementation of new technology], similar to HeadLight's orientation presentation, would get hung up when we ask construction related questions. Questions were answered in [HeadLight] presentations and during the pilot program. It was great to have people involved that understood our tasks and processes. I was very impressed with the speed of the application as well. I hope*

the speed stays the same if MnDOT adopts this application." – Project Inspector, MnDOT

A complete list of interview quotes organized by key metrics is included in Appendix G.

Usefulness of the HeadLight Capabilities and Features

Figure 30 uses the project inspector's responses to rank the usefulness of HeadLight's features and capabilities.

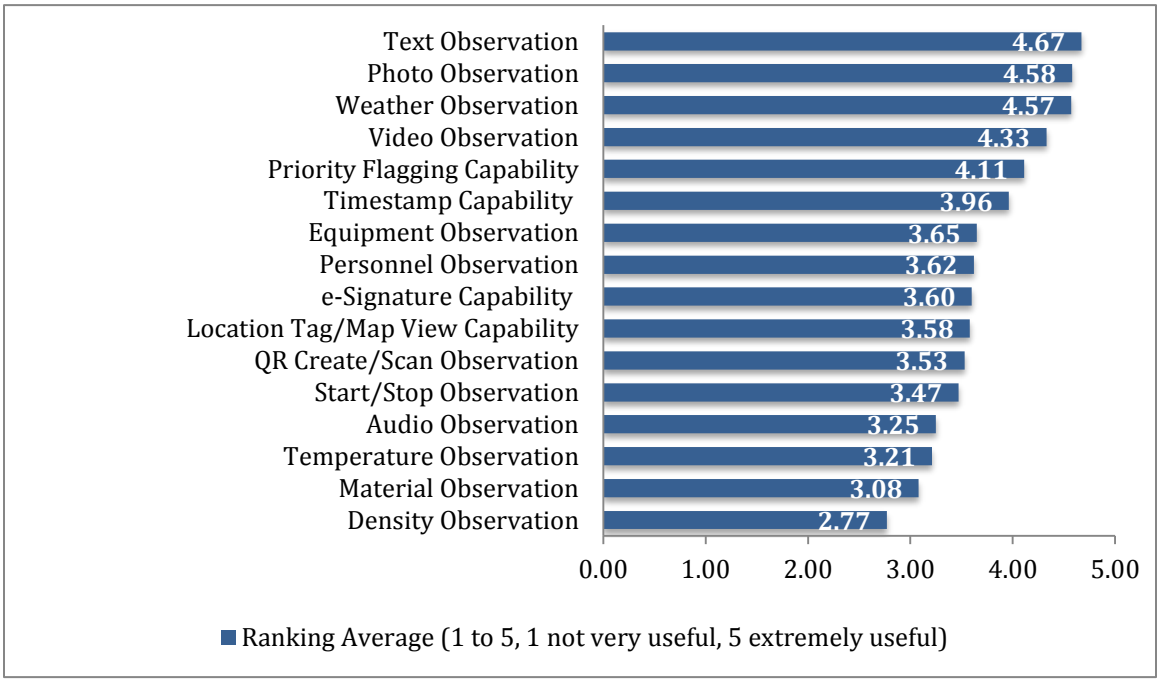


Figure 30: Summary of observation feature ranking from project inspectors

Figure 31 summarizes the responses from project engineers and management personnel interviews to rank the usefulness of HeadLight's features and capabilities.

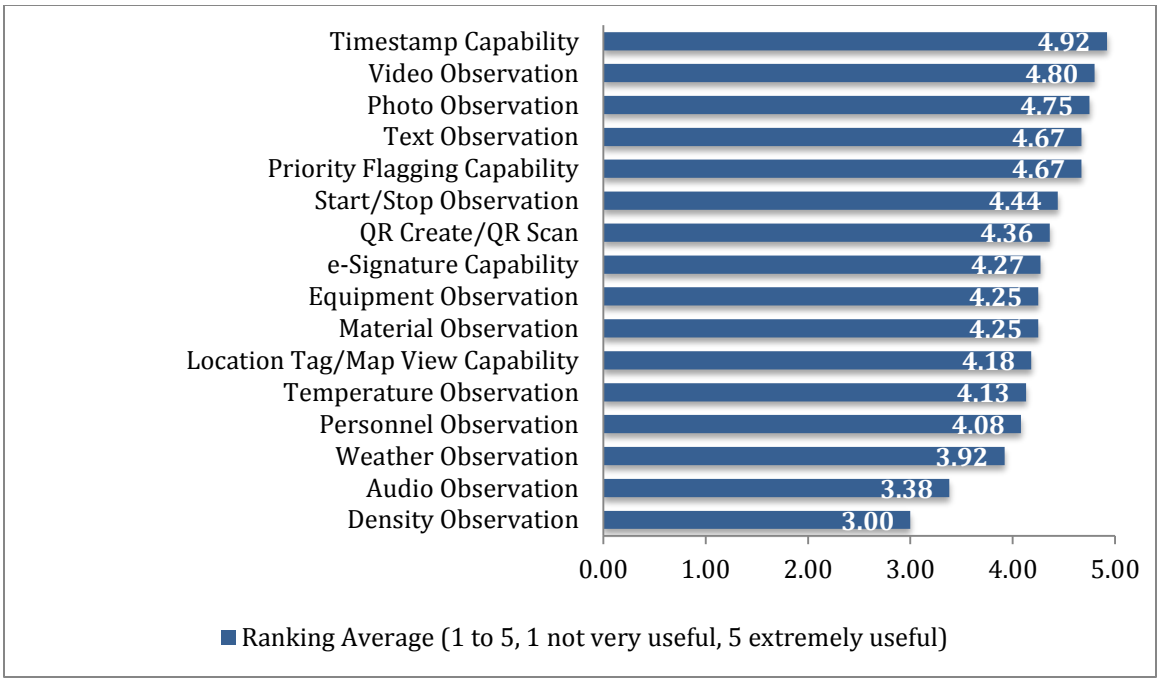


Figure 31: Summary of observation feature ranking from project engineers and management personnel

Table 32 shows the top 5 rated capabilities. The interview responses were aggregated to project inspectors and project engineers responses.

Table 32: Comparison of the usefulness rating for capabilities and features in HeadLight

Ratings	Phase II Ratings [Inspectors]	Phase II Ratings [Project engineers]
1	Text observations	Timestamp capability
2	Photo observations	Video observations
3	Weather observations	Photo observations
4	Video observations	Text observations
5	Priority flagging capability	Priority flagging capability

Capability and Feature Enhancement Suggestions

During the post pilot interviews, there was a set of capability and feature enhancements for HeadLight that was identified to further assist project inspectors, engineers, and management in their day to day activities. Suggestions include enhanced capabilities such as:

- Force account
- Daily quantity sheets
- Payment documentation
- Punchlists
- Weekly summary report output

- Dropdown selection lists for equipment and personnel
- Automatic plan sheet updates on devices
- Spreadsheet output of observations
- Additional dashboard information
- Station and offset automatically correlated to x-y
- Materials testing
    - Concrete testing for slump, air, temperature
    - Gradations
    - Proctors
    - Sampling frequency
- Measurements for quantities and dimensions
- Pile driving measurement capabilities
- Decibel meter capabilities
- Critical Path Method (CPM) scheduling information
- Lanyard for inspection units
- Photo stream capabilities for quick capture
- Contractor revisions and submittals

Overall Usefulness of HeadLight

Tables 33 through 38 and Figure 32 use the project inspector's responses to qualitatively assess the overall usefulness of HeadLight.

Table 33: Interview responses related to changes in how inspectors observed activities out in the field

Describe how using HeadLight has changed the way you observe activities out in the field. (Answered: 7 Skipped: 17)	
Responses	**Response**
HeadLight is more useful in capturing observations compared to the traditional process	6 out of 7
There is no change	1 out of 7
HeadLight is less useful in capturing observations compared to the traditional process	0 out of 7

Table 34: Summary of interview responses related to changes in how inspectors create inspection reports

Describe how using HeadLight has changed the way you create inspection reports. (Answered: 7 Skipped: 17)	
Responses	**Response**
HeadLight is more useful compared to the traditional process	6 out of 7
There is no change	1 out of 7
HeadLight is less useful compared to the traditional process	0 out of 7

Table 35: Interview responses related to inspectors' preference in using HeadLight to perform inspection tasks

If you could create and submit your entire inspection report in the field similar to your experience with HeadLight, would you prefer that to your previous method? (Answered: 20 Skipped: 4)	
Responses	**Response**
Yes	20 out of 20

Table 36: Summary of interview responses related to how HeadLight impacted the inspector's job performance

How much of an impact do you think HeadLight would have on your job performance? (Answered: 20 Skipped: 4)	
Responses	**Response**
Positive impact (saves time and cost)	20 out of 20
No impact	0 out of 20
Negative impact	0 out of 20

Table 37: Interview responses related to inspector's experience entering information in HeadLight

Describe your experience in entering information to create observations. (Answered: 20 Skipped: 4)	
Responses	**Response**
Positive experience	20 out of 20
Neither positive or negative experience	0 out of 20
Negative experience	0 out of 20

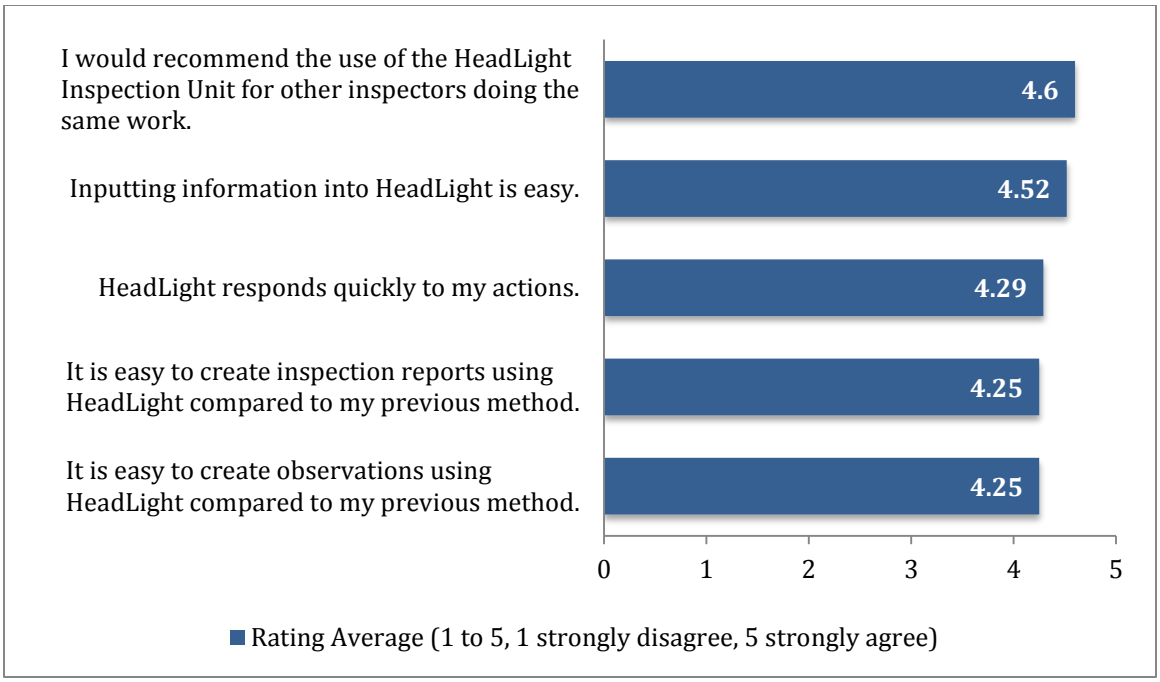


Figure 32: Summary of interview responses related to the overall usefulness of HeadLight

Table 38: Summary of interview responses related to inspector's preference for using an iPad on the jobsite to a laptop

Usefulness of Mobile Technology Question	
Question	**Yes**
I would prefer to have a tablet computer on the jobsite to a laptop for field use. (Answered: 24 Skipped: 0)	91.67%

Several inspectors also mentioned that they were satisfied and more motivated with their roles by having several different tools integrated into the HeadLight Inspection Units. The following statements from inspectors describe the impact HeadLight had on their inspection documentation process.

> *"Current process, I take notes throughout the day (conversations, observations…) on a scrap paper or the back of my hand. At the end of the day, I create a bigger picture note for my IDR. I often leave out small issues that were resolved out in the field. HeadLight allowed me to keep all notes in the IDR due to no effort creating the IDRs. I see that it's only a matter of time to link spec references to my report. Usually I make my IDRs when I'm not busy. Before, my priority was to finish payment docs before IDRs because my supervisor didn't read IDRs before. I was able to do my IDRs at the end of the day. I also even did it the next morning to see if it was capable of doing it later. It took less than ten seconds to create an IDR using HeadLight." – Project Inspector, WSDOT*

> *"Absolutely would prefer [HeadLight]. It will increase [my job performance]. More information is available. I can spend more time in the field. Wouldn't have*

to dedicate 30 minutes to 2 hours to recreate an IDR. State is going to save on overtime costs. Large portion of overtime is travel time or reports. All observations have to be collected in the field regardless of where you do the IDR. If you can do them in same location where you're collecting them, it increases the quality." – Project Inspector, WSDOT

"I typically don't make daily [inspection] reports, just weekly summaries. I ended up making daily [inspection] reports with HeadLight everyday." – Project Inspector, MnDOT

"[In reference to HeadLight] Groundbreaking for us. Now I feel better about doing my job. I don't have to go back to the office and type this [report] up, then come back out [to the field] in 20 minutes." – Project Inspector, TxDOT

A complete list of interview quotes organized by key metrics is included in Appendix G.

Safety

Table 39 and Figure 33 uses the project inspector's responses to assess any safety concerns with using HeadLight out in the field.

Table 39: Summary of interview responses related to safety concerns using the HeadLight system

Describe any safety concerns while using HeadLight and the Inspector's Tool Kit out in the field. (Answered: 23 Skipped: 1)	
Responses	**Response %**
None	52.17%
Need to pay attention to your surroundings when using the device	47.83%

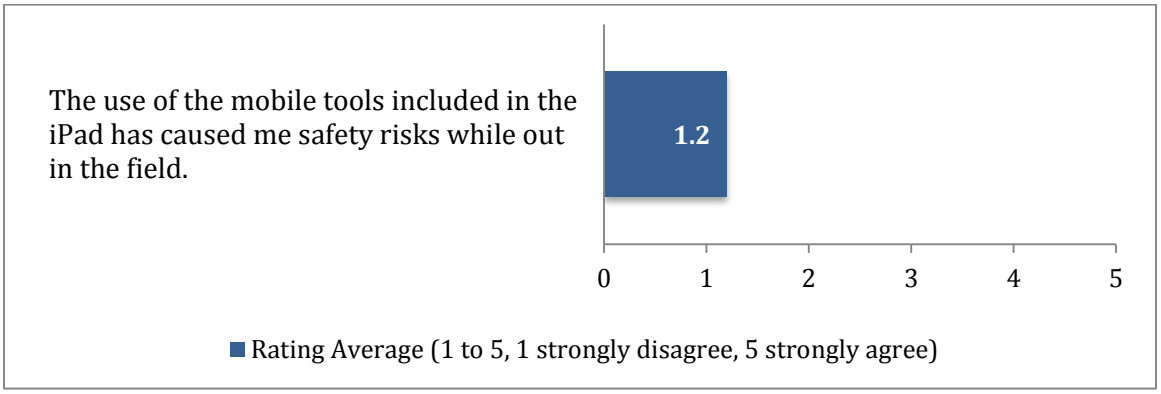


Figure 33: Summary of interview responses related to safety risks encountered during the pilot program

In examining the response to the safety concern shown in the table above, participants felt that the use of the mobile device posed no additional safety risks than are already present on the job site using current practices. Supporting this

result, an inspector was quoted as stating, *"I suppose you can get caught up in looking at the screens. As long as you find a good spot [on the jobsite] to enter in information, it's safe. No different than carrying a set of plans."*

Data Searchability

Table 40 uses the project engineer's and management's responses to qualitatively assess the overall usefulness of the search feature in HeadLight, which allowed them to recall information from reports.

Table 40: Summary of project inspector responses related to searchability

Describe your experience using the search function in HeadLight. (Answered: 11 Skipped: 0)	
Responses	**Response**
It was useful	11 out of 11
It was not useful	0 out of 11

Some additional participant's thoughts on data searchability include:

> *"Now in [current agency system], there's no search function. Not at all. Just have to remember by date [to search for content]. It's very important to have a good search [function]. [The] need to search happens often, 50% of the time" – Project Manager, TxDOT*

> *"Finding information in [current system] is very tough for claims situation. For example, a project, with a big claim, $500,000 claim. This project had several project managers, then had a temporary person, then someone else to close the project. The book keeper retired. [It was] very hard to have continuous information and would try to fish for information in [current system]. If we had HeadLight and could do a key word search, would have been so much easier." – Project Engineer, TxDOT*

A complete list of interview quotes organized by key metrics is included in Appendix G.

Conclusions

To tie the results and discoveries gathered in Phase II, key conclusions were made for each key measures and discoveries. The findings from Phase II include the following:

Finding 1: Inspectors using the HeadLight Inspection Unit significantly increased their productivity without increasing their work hours. Completing inspection reports, reduced travel time, and searching for information using the HeadLight Inspection Unit provided an average overall time savings of 1.78 hours per day per inspector.

Finding 2: Inspectors using the HeadLight Inspection Units collected and shared 2.75 times more inspection information while increasing the composition of valuable inspection information retained by the agencies.

Finding 3: Proper software tools on the mobile device are critical to achieve the productivity, quality, and availability benefits of mobile technology. The software integration of key hardware tools within the HeadLight Inspection Unit allowed inspectors to include and integrate a larger variety of observation types into their inspection reports. In particular, there were significant increases in photo, video, and weather observations provided directly in inspection reports, which contributed to more complete project records.

Finding 4: The automated inclusion of time and location metadata with every observation within HeadLight provides a complete observation record that can be recalled in the future by location or time.

Finding 5: Compared to traditional agency practice where project engineers and management personnel referred to inspection reports as their primary source of inspection documentation, HeadLight improved the timeliness of inspection information availability to project engineers and management by enabling real-time access to inspection information collected throughout the day on each active jobsite.

Finding 6: Learning to use mobile technology was not a barrier to adoption. On average, project inspectors were comfortable with using the HeadLight Inspection Unit in 2.7 days.

Finding 7: Designing mobile technology features and capabilities specifically for the job functions within project inspection was a critical factor in having successful adoption of mobile technology.

Finding 8: Existing tablet use within the agency limited to the traditional process provided negligible productivity, quality, and availability benefits in the field. Without the proper software, tablets were used much like a laptop in the traditional process.

Finding 9: Project inspectors using the HeadLight Inspection Units found the system useful as it incorporated specific sets of tools to support inspectors with their daily inspection tasks. 100% of the project inspectors prefer to use the HeadLight Inspection Units over their traditional inspection process.

Finding 10: The use of mobile technology in the field posed no significant safety hazards when compared to current practices. No project inspectors involved in the pilot program experienced any safety incidents due to the use of the mobile device.

Productivity

Using the HeadLight mobile technology specifically for inspection reports, agencies in this study achieved an average time savings of 1.78 hours per inspector per day. The time savings in Phase II were measured from performing tasks such as

documentation and administrative duties performed in the field as well as reduced travel. Analysis of this result indicated that an overall productivity gain of 22% was observed from using HeadLight to create daily inspection reports.

The scope of this research examined the impact of mobile technology on the daily inspection documentation responsibility of project inspectors. Based on the productivity gains for the daily inspection report, including other aspects of the inspector's daily responsibilities such as issuing pay notes and documenting force account and change order work will result in additional productivity gains to closer match the projected outcome of 31% made in the Phase I report.

Productivity Gain Benefits

As discussed previously, the added productivity from the pilot solution was translated to an average overall time savings of almost one day a week per inspector. The following example examines how time can translate to quantifiable productivity increases for the agencies considering deploying mobile technology.

The value of the productivity gains shown for each agency under this study was substantial as shown in Table 41. If all three agencies were to transition to full deployments of effective mobile technologies similar to HeadLight, it would provide a productivity boost worth $27 million. The average hourly pay rate was derived by obtaining the project inspector's salary from 2013 including additional compensation for benefits and vacation days. The average hourly pay rate is based on a standard 8-hour workday. The calculations and assumptions used to determine the average hourly pay rates is included in Appendix H.

Table 41: The value of the productivity gains resulting from the use of the HeadLight Inspection Unit

Agency	Average Hourly Pay Rate [$]	Productivity Gain per Day per Inspector [hours]	Estimated Number of Inspectors	Total Agency Productivity Gain [$]
WSDOT	$46.94[1]	2.07	397	$10,029,400
MnDOT	$39.16[2]	1.67	250	$4,250,600
TxDOT	$28.69[3]	1.60	1,092	$13,034,500
All Agencies	**-**	**-**	**1,739**	**$27,314,500**

The outcome of increased inspector productivity can also be seen as an increase in the capacity of DOT workforces without requiring additional staff. Figure 34 shows a graphic representation that compares the current inspector workforce to the increase in equivalent workforce as a result of using mobile tools for all agencies. WSDOT's workforce of 397 project inspectors can perform like a workforce of 518 inspectors, effectively increasing their capacity by 121 inspectors. MnDOT's

[1] WSDOT salaries obtained from http://fiscal.wa.gov/Salaries.aspx
[2] MnDOT salaries obtained from http://extra.twincities.com/car/salaries/default.aspx
[3] TxDOT salaries obtained from http://salaries.texastribune.org/

workforce of 250 project inspectors can perform like a workforce of 311 inspectors, effectively increasing their capacity by 61 inspectors. TxDOT's workforce of 1,092 inspectors can perform like a workforce of 1,350 inspectors, effectively increasing their capacity by 258 inspectors. This research did not attempt to quantify the productivity increase for project engineers and management that used HeadLight, although several project engineers and management shared that they recognized productivity increase through the interviews. Including the productivity increase from project engineers and management can potentially increase the effective workforce gain even further.

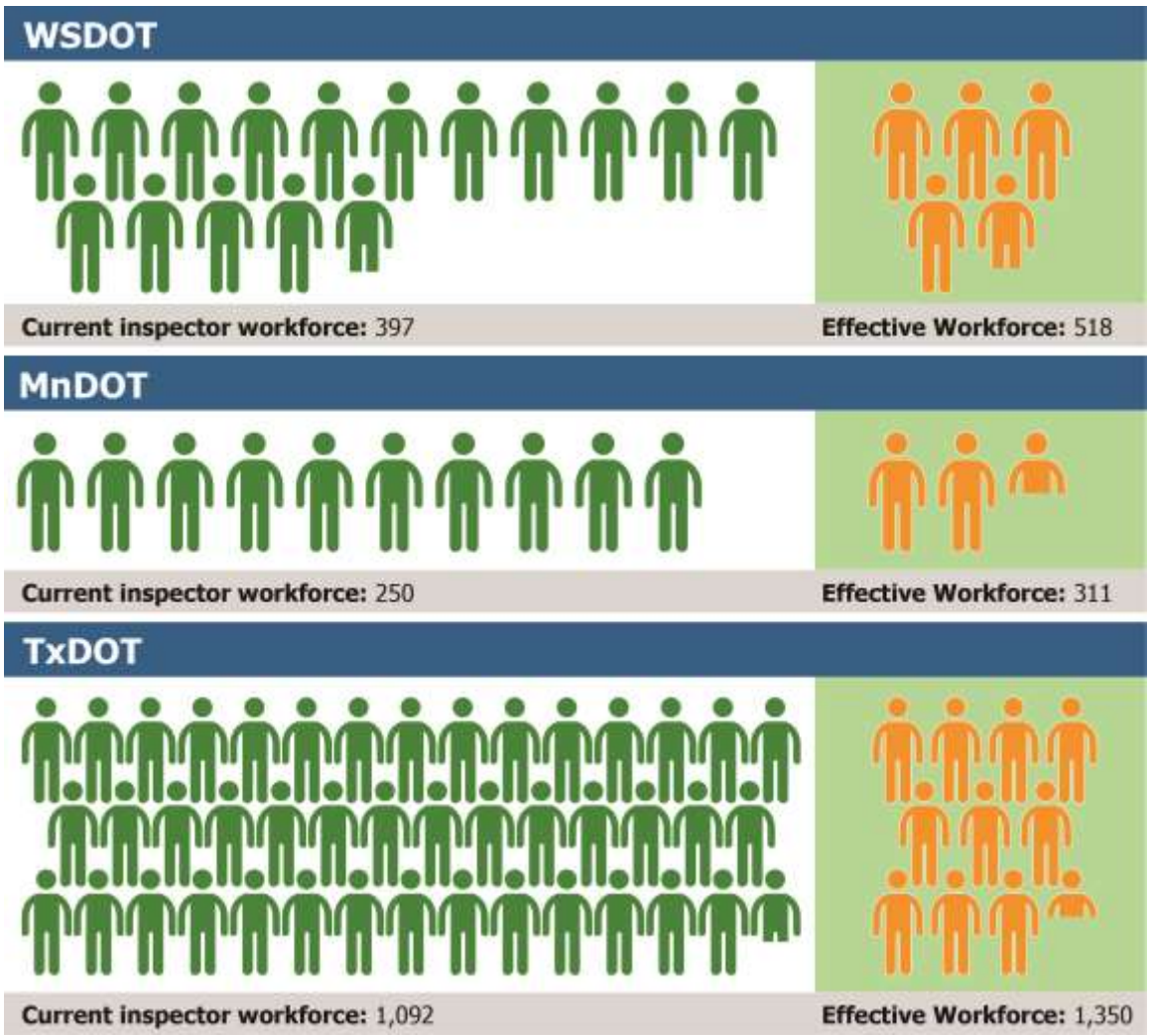


Figure 34: Increase in equivalent workforce resulting from the use of mobile technology (each person represents 25 inspectors)

Data Quality

There were several characteristics of data quality that were improved when inspectors used the HeadLight Inspection Units to collect inspection information. The following sections describe the data quality improvements in terms of the amount of observations collected, the composition of observation entries, and the completeness of each individual inspection observation.

Amount of Observations

Inspectors using the HeadLight Inspection Units collected and shared 2.75 times more inspection information while increasing the composition of valuable inspection information retained by the agencies. During the pilot, a total of 7,105 inspection observations were created throughout all three agencies.

Inspection reports created prior to the pilot were examined to determine that on average, an inspector collected 7 inspection observations per day. Analysis of the HeadLight results indicated that an inspector using the HeadLight Inspection Unit collected an average of 18 inspection observations per day.

This finding was validated as 82% of the inspectors and 100% of the project engineers and management personnel responded that the daily reports generated by inspectors using the HeadLight Inspection Units produced more information compared to the daily inspection reports generated using traditional agency practice.

Integration of Many Observation Types

The software integration of inspection types and hardware capabilities within the HeadLight Inspection Unit eliminated the transcription and duplication process involved in creating inspection reports. Additionally, inspectors no longer had to carry separate devices to take inspection photos and videos and eliminated the need for inspectors to manually upload images and videos to their computers or a shared network drive.

The automated generation of daily reports help ensure that all information captured as inspection observations are transferred over to the daily inspection reports. These features specifically designed for the inspection process helped eliminate many steps in the inspection tasks and simplified the method in collecting and sharing inspection information.

Examination of the observations collected per day per inspector using the HeadLight Inspection Unit showed a larger variety of observation types compared to observations collected using traditional agency practice. Increase in the use of photo observation was a trend observed throughout all agencies. The results of the composition analysis of the HeadLight inspection observations indicated that on average, photo observations accounted for 33% of the observation collected on a typical day. This is a significant improvement as analysis of the inspection reports created prior to the pilot indicated that photo observations were rarely included directly into the reports.

Completeness of Daily Inspection Reports

Inspectors using the HeadLight Inspection Units were able to improve the completeness of the data as HeadLight automatically captured accurate date, time, and location of each observation entry. The results of the metadata analysis indicated that the traditional process for each agency had significant limitations in

data completeness and consistency. HeadLight's ability to include metadata automatically without user intervention allowed each observation gathered to have a 100% complete set of location and time data.

The consistency of the inspection information improved in two ways for inspectors using the HeadLight Inspection Unit. Automated inclusion of inspection information eliminated the potential for inspectors to record incorrect information. The HeadLight Inspection Unit also eliminated the need to duplicate information from one source to another as it automatically generated daily inspection reports from collected observations. These factors contributed to improved consistency of the inspection reports. Further improvements in consistency can be achieved by adding a best practice component to the training deployment as well as best-practices reference guides included within the inspector's toolkit.

Benefits from improved completeness and consistency of inspection information include:

- Agencies can collect and retain higher quality inspection data by tracking the metadata for every inspection observation
- The consistency in inspection processes used by HeadLight reduces the potential to introduce error in the inspection data
- Able to use more accurate and robust data sources for claims and dispute situations

Data Availability

The availability of the inspection data captured using HeadLight Inspection Units significantly improved the timeliness of the availability of the inspection observations as well as the accessibility of inspection information.

Timeliness of Inspection Information Availability

HeadLight improved the timeliness of inspection information availability by enabling project engineers and management personnel to access real-time inspection observations collected throughout the day on each active jobsite. In addition, the timing of report submissions using HeadLight was improved over the traditional process.

Project engineers and management personnel identified inspection reports as their primary source of inspection documentation using the traditional process. The time of availability for inspection reports created prior to the pilot were inconsistent, depending on how busy the inspector is at the end of the day. In some cases, project engineers shared that it can take anywhere from 2 to 3 days to 2 to 3 weeks to obtain the reports. Additionally, when specific project-related information was needed immediately, project engineers and management personnel commonly called an inspector onsite or visited the site themselves. Retrieving the inspector's notebook typically took time as it was needed by the inspector performing tasks out in the field or due to some of the content being hard to read. A WSDOT project

engineer was quoted as saying, "*If there is a specific issue, I will check all of the IDRs for it. It was more useful to read through observations [from HeadLight] rather than the IDRs.*"

The HeadLight Web Client provided inspection observations directly to project engineers and management personnel. Inspectors using the HeadLight Inspection Units collected inspection observations similar to how they would collect inspection information in their field notebooks. The key difference in these two processes is the timely availability of inspection observations collected using the HeadLight System. Observations collected using the HeadLight System are synchronized to the HeadLight Web Service, enabling users of the HeadLight Web Client to view inspection observations in real-time.

Accessibility of Inspection Information

HeadLight automatically integrated and stored all inspection information in a central repository and improved the accessibility and searchability of the information within each agency. The information stored in a central repository remains secure, allowing agencies to retain all the information even in cases when the HeadLight Inspection Unit is lost or damaged.

Examination of the traditional agency practice indicated that information from the inspector's field inspection notebook, photos and other media, and inspection reports were all stored in different locations. The field notebooks were typically in the inspector's possession, photos and other media were typically shared via email or through a shared network drive, and inspection reports were accessible in the agency's document management system.

Overall, the benefits of having improved inspection information availability for agency personnel include the following:

- Sharing inspection observations through HeadLight helped the project inspectors communicate the progress of work and any issues brought up in real-time directly from the field
- Real-time inspection observations increased project engineer and management knowledge of activities performed out in the field and helped resolve field issues reducing the need to leave the project office
- Directly integrating photos and videos into the observation feed and daily inspection reports greatly increased the use of photos and videos and decreased the need to share media through email correspondence and through shared network drives
- Every inspection observation and daily report was stored in one centrally accessible repository, which improved the timeliness of availability and accessibility of all the inspection information
- Agencies no longer have to worry about losing inspection observation since all information is stored in the central repository vs. losing field notebook or laptops that are not backed up

- The information stored in a central repository can be searchable and retrievable years after the completion of the project

Data Availability Across the Agency

A key component to collecting project inspection data and information during the construction phase is that this same data and information can be leveraged by other divisions within a transportation agency for their respective functions as well. For example, a project inspection observation may photo document a drainage asset and its placement. That observation will be automatically time and location stamped, can be correlated to the bid item, and its prefab inspection information can be tied in as well through the QR code functionality. This would be very useful information for asset management, environmental, and maintenance divisions to leverage for their respective functions. Tools like this, if applied properly, can enable the "collect once, use many" strategy that has the potential to benefit additional transportation agency divisions beyond construction in their respective functions throughout the lifecycle of the infrastructure assets the agency owns and provides for the traveling public.

Additional Characteristics Observed

The following section discusses the findings from the additional characteristics observed during the study.

Learnability and Support

Providing a well-designed system, proper training, and technical support had a significant impact on the adoption and acceptance of the HeadLight Inspection Units during the pilot research. The results indicated that the vast majority of the project inspectors were able to learn and become comfortable using the HeadLight Inspection Unit quickly, within an average of 2.7 days. Designing the application to be straight-forward helped project inspectors of various existing experience with tablets, learn and use HeadLight as well as feel comfortable with its use.

Usefulness of the HeadLight Capabilities and Features

Designing mobile features and capabilities specifically for project inspection job functions was an important factor in the adoption of the HeadLight system. Inspectors rated text observations, photo observations, video observations, and priority flagging capabilities as the most highly useful features which correlated to the usage of those features during the pilot.

While the capability and feature ratings from project engineers included similar features and capabilities, they were ranked slightly different compared to the ratings from inspectors. The rankings provided by project engineers suggest that project engineers gave higher usefulness ratings for capabilities and observations that helped them provide a more robust portrayal of the activities performed on site.

Overall Usefulness of HeadLight

Project inspectors using the HeadLight Inspection Units found the system extremely useful as it incorporated specific set of tools to support inspectors with their daily inspection tasks. The results found that the HeadLight Inspection Units were more useful in collecting inspection observations and creating inspection reports compared to the traditional process. Overall, 100% of the inspectors prefer using the HeadLight Inspection Unit to their traditional inspection process. While some inspectors were using tablets or laptop computers prior to the pilot program for inspection tasks out in the field, the usefulness was extremely limited due to poor software and connectivity issues. This resulted in poor utilization of the tablet computers. In order to realize the full potential of using mobile technology for project inspection tasks, a system must be designed to encapsulate the various processes involved in project inspection.

Inspectors also strongly supported the agency adoption of the HeadLight system. When inspectors were asked to describe the impact that HeadLight had on their job performance, all inspectors responded that it would have a positive impact on their job performance. The common impacts mentioned in the interviews include time savings for the inspector and cost savings for the agency.

Safety

The use of the mobile device did not increase or decrease the existing safety risks or hazards to participants. No inspectors participating in the pilot program encountered a safety risk due to the use of the HeadLight Mobile Client, nor indicated a perceived increase in safety risk due to the use of a tablet computer. About half of the participants indicated the importance of paying attention to your surroundings, as there could be a potential of becoming unaware of the activities performed nearby. This result was similar for both the current process and that using a mobile device so therefore no additional safety risk was identified.

Data Searchability

Providing a search function capable of searching through the entire central repository is critical to providing project engineers and management an easy and timely method for searching through inspection data, especially when issues such as claims and disputes arise. All project engineers and management participants indicated that the search function provided in HeadLight Inspection Units and the Web Client were very helpful. There is also the benefit of having continuous and consistent source of information as all inspection information is stored in a central repository. Having information stored in a central repository allows any staff with security permission to retrieve project information at any time, even years after the completion of the project. The current document management systems used by some agencies do not have the capability to search through inspection information using key terms. A project engineer at TxDOT was quoted stating, "[I] *can't live without finding the information for a particular date [on Web Client]. So much easier in HeadLight. In [our current system] it will take hours and headache to find information."*

Recommendations

Some recommendations for agencies to consider in deploying mobile technology as well as additional areas of research include:

- **Include remaining inspection job functions in mobile technology system** to realize full potential of productivity, quality, and availability gains. Significant gains were observed from implementing mobile technology designed to assist inspectors with a portion of their work involving the documentation of inspection information and generating construction reports. Further benefits can be evaluated by expanding the function of mobile technology to encompass the entire aspect of project inspection. Participants of the interviews requested the following features and capabilities to be added on to the HeadLight system:
    - Ability to document force account items
    - Ability to issue pay notes
    - Ability to document change order items
    - Ability to document daily work quantities
- **Provide proper investment in training and support resources for broader deployments at agencies.** Training and support were identified as critical to achieving the measureable outcomes described in this study. Participants in this study varied in their familiarity and experience with mobile technology in order to best represent the expected conditions in a broader deployment and both the training and support element provided were identified as critical success factors.
- **Consider other field personnel responsibilities where mobile technology may provide similar benefit.** In addition to inspection, numerous participants identified other field personnel that could greatly benefit from using mobile technology including materials testing and environmental roles.
- **Examine the additional value mobile technology provides in improving agency decision making.** Further investigate how improving the completeness and consistency of inspection data affects real-time decisions made by project engineers and other office personnel. In addition, measure impacts of having information available and accessible for long-term decision making processes as well as claims abatement.
- **Examine the impact mobile technology has on job satisfaction and performance.** During the research several participants noted that using HeadLight improved their job satisfaction and performance. An investigation into how much of an impact it made on individual job performance could further support broader use of mobile technology within the organization.
- **Examine the potential productivity savings that mobile technology can provide for project engineers and management.** It was recognized through the participant interviews that project engineers and management that used the HeadLight system experienced increase in their productivity.

Further investigate how HeadLight impacts the productivity of project engineers and management using the system.

References

Pavia Systems, Inc. *Mobile Tools for Project Inspection*: *An investigation into existing business processes and areas for improvement using mobile technology* (2013).

Texas Department of Transportation. *Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges* (2004).
<http://ftp.dot.state.tx.us/pub/txdot- info/des/specs/specbook.pdf>

Washington State Department of Transportation. *Construction Manual* (August 2013).
<http://www.wsdot.wa.gov/publications/manuals/fulltext/M41-01/Construction.pdf>

Washington State Department of Transportation. *Construction Training Guide for Local Agencies* (January 2012).
<http://www.wsdot.wa.gov/NR/rdonlyres/FA224595-83C8-4AE1-BBFB-EAC553DF34F5/0/CTGuide.pdf>

Washington State Department of Transportation. *Standard Specifications for Road, Bridge, and Municipal Construction* (2012).
<http://www.wsdot.wa.gov/publications/manuals/fulltext/M41-10/SS2012.pdf>

Minnesota Department of Transportation. *Standard Specifications for Construction* (2014).
<http://www.dot.state.mn.us/pre-letting/spec/2014/2014-Std-Spec-for-Construction.pdf>

Lifeproof. *iPad Air Case – nüüd*, digital image, viewed November 2014.
<http://www.lifeproof.com/shop/us_en/ipad-air/ipad-air-nuud-case/?color=Black+%2F+Black>

Washington State Department of Transportation. *Inspection Daily Reports* (76 completed reports)

Minnesota Department of Transportation. *Weekly Construction Reports* (28 completed reports)

Texas Department of Transportation. *Daily Inspection Reports* (60 completed reports)

Washington State Department of Transportation. *WSDOT Project Bid Tabulations*. Accessed January 2015.
<http://www.wsdot.wa.gov/biz/contaa/BIDTAB/>

Minnesota Department of Transportation. *Mn/DOT-Bid Letting.* Accessed January 2015.
<http://www.dot.state.mn.us/bidlet/>

Texas Department of Transportation. *Letting and Bids*. Accessed January 2015.
<http://www.txdot.gov/business/letting-bids.html>

Washington State Fiscal Information. *Salaries-state employee salaries by calendar year*. Accessed November 2014.
<http://fiscal.wa.gov/Salaries.aspx>

St. Paul Pioneer Press. *Minnesota Public Salaries*. Accessed November 2014.
<http://extra.twincities.com/car/salaries/default.aspx>

The Texas Tribune. *Government Salaries Explorer*. Accessed November 2014.
<http://salaries.texastribune.org/>

Appendix A – Five C's of Good Report Writing (WSDOT 2012)

Five C's of Good Report Writing

- **Clear** – Being clear refers to both handwriting and meaning. Messy handwriting is unprofessional. Take the time to write neatly. Written material is useless if it cannot be read and understood.

  Being clear in meaning is just as essential. Whatever is written has to be clear, even to people not involved with the project. It can become a habit to write a kind of shorthand that project personnel understand, but others may not. Other personnel, including auditors, may have to review your documents, months or even years after the project is complete. What may be clear to project personnel now, may be unclear to an auditor at a later date.

- **Concise** – Being concise means using the minimum number of words to get the maximum amount of meaning. The rule is, write enough to be clear, but not any more than is necessary. Record the facts and keep your opinions out of the project diary.

- **Correct** – Being correct means having your facts straight and using the right forms. Using the wrong forms, or making errors, gives the appearance of sloppiness and can cause big problems in arbitrations or litigation proceedings.
- **Complete** – Being complete means including everything necessary to be clear. To be complete, the entry should contain four criteria:

  1. **Activity** – A description of the activity, including location.
  2. **Testing** – Any testing done or the acceptance criteria that was used.
  3. **Results** – The results of any testing.
  4. **Action Taken** – Any action that may have been taken.

  Another aspect of being complete is referencing other types of available project documentation. Be sure to mention any photographs, videotapes, contract documents, materials documentation, or anything else that would relate to your entry.

- **Concurrent** – Contract documentation should be completed concurrent with the construction activity. Extensive facts, figures, and conversations are hard to remember. Write them down as soon as possible. If it is not practical to write everything down immediately, then take abbreviated notes. Waiting until the end of the day to write everything down may cause you to forget important details.

Appendix B – Benchmark Observation Guide

Benchmark Observation Guide

Basic Information

- Inspector name
- Project location
- Date
- Shift start time
- Shift end time
- Travel time and distance from field to office
- Typical time of day when inspection reports are created/filled out
- Does he/she have spec and plans with them?
- Does he/she have a camera with them?

Inspection Observation Method

- How are inspection observations made? In field notebook?
- Is he/she using any mobile device/tools?
- What kinds of observations are made?
- How long does it take to record observations?
- How many observations are in typically included in an inspection report?

Creating Inspection Reports

- Are inspection reports created out in the field or the office?
- Is there a prepopulated worksheet or is everything made from scratch?
- What are the basic processes in creating an inspection report?
- How are attachments like photos included in the inspection report?
- On an average month, what percentages of inspection reports are submitted within 24 hours?
    - Out of the inspection reports not submitted within 24 hours, when are they typically submitted? (2 days, 3 days, 1 week later?)

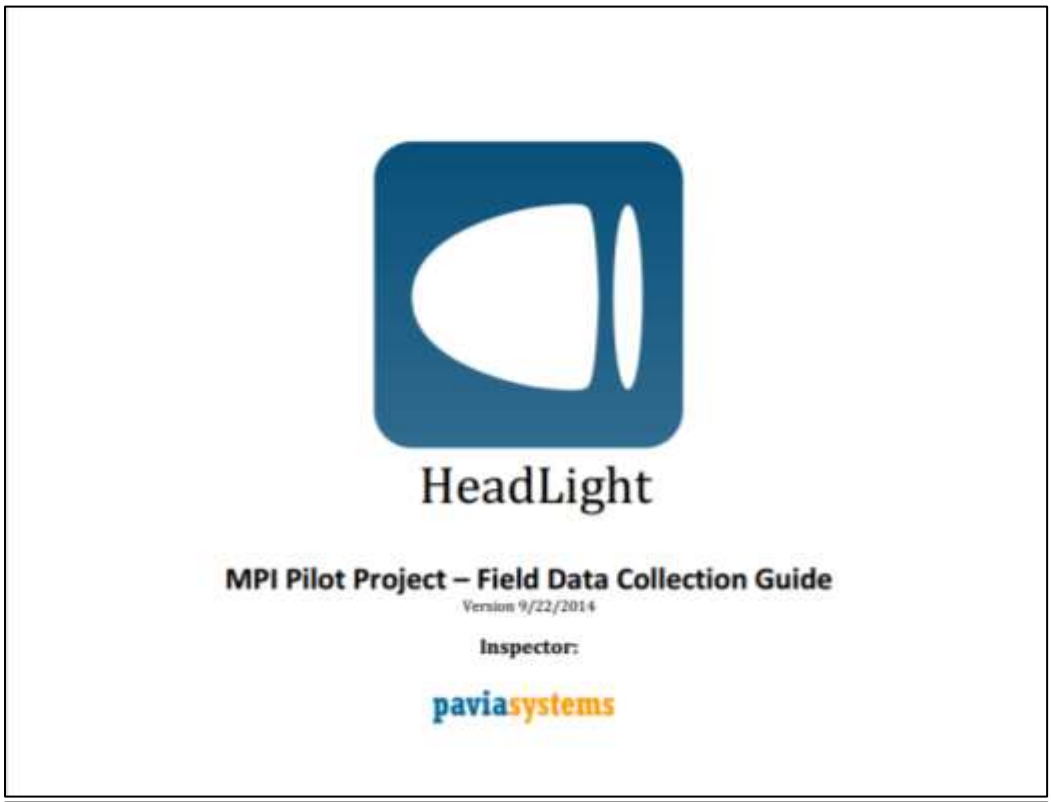
Searching for project and agency specific information

- How often does the inspector search for contents in the plans, specs, or other references?
- On average, how long does it take to look this information up?
- How is the information acquired? By hard copies, electronically on tablet device, etc.?

Other Observations

- Memorable quotes?
- Any questions or comments?

Appendix C – Field Guide



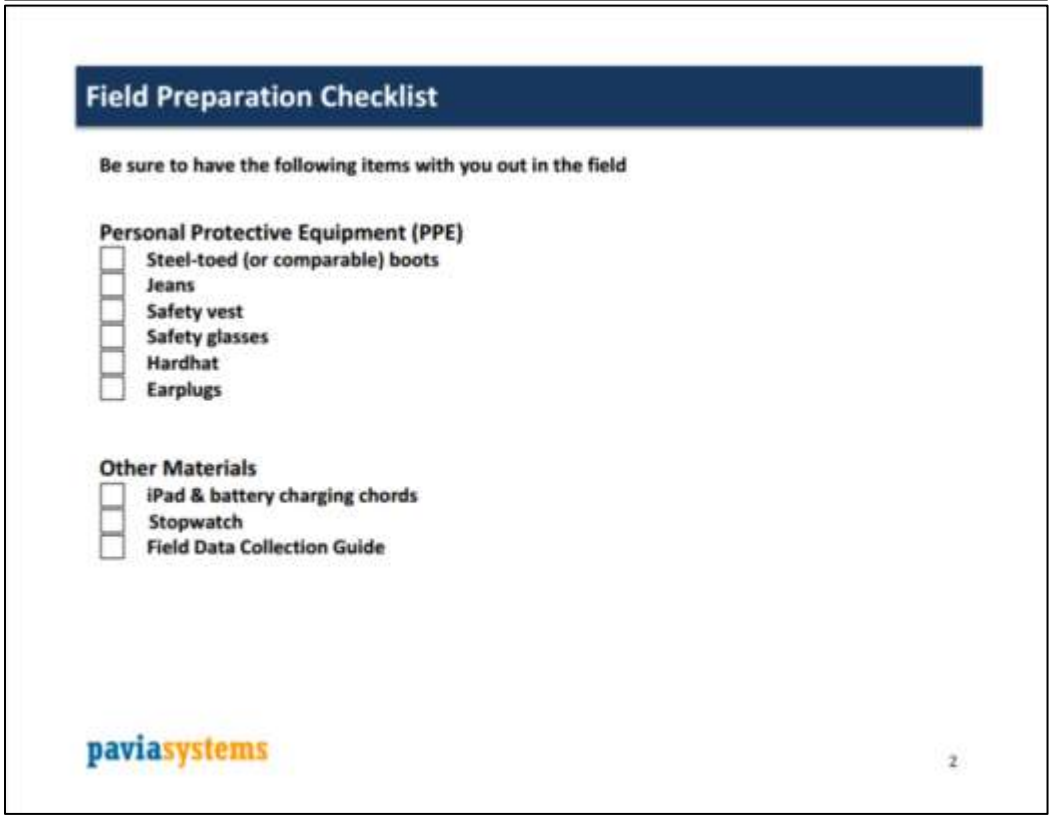
HeadLight

MPI Pilot Project – Field Data Collection Guide

Version 9/22/2014

Inspector:

paviasystems



Field Preparation Checklist

Be sure to have the following items with you out in the field

Personal Protective Equipment (PPE)

- ☐ Steel-toed (or comparable) boots
- ☐ Jeans
- ☐ Safety vest
- ☐ Safety glasses
- ☐ Hardhat
- ☐ Earplugs

Other Materials

- ☐ iPad & battery charging chords
- ☐ Stopwatch
- ☐ Field Data Collection Guide

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2

The First Week – Help & Support

During the first week, we want to make sure that field inspectors are getting familiar with HeadLight. This week will mostly be spent answering questions and providing support for the inspectors.

We will collect inspector and project related information as well as some basic "over-the-shoulder" observations on how the inspectors are using HeadLight and the Tool Kit. Please use the following form to collect the information.

Inspector & Project Information

Inspector Name:	Project Name:
Inspector's tentative schedule for the next month:	
Site Parking Instructions:	

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The First Week – Help & Support

Pavia research diary log – Use the form below to summarize each visit.

Initial	Date	Summary

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The First Week – Help & Support

Initial Observations and things to look for

Is the inspector using anything other than an iPad or HeadLight to record observations?
Are observations created for the correct project?
What kinds of observations are most often used?
How are observations created? Any usual processes involved?
Are time-by-time diary entries created using one text observation for each entry?
Are IDRs created at the end of the shift?
Are equipment observations made for each individual equipment/machinery?
Any frustrations encountered so far?

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Weeks 2 through 3 – Data Collection

1) Measure how long it takes to create observations using a stopwatch. Try to get 16 measurements per week (Create 4 observation types, 4 times each)

Observation	Date	Obsv. Type	Time (sec)	Notes
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				

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Weeks 2 through 3 – Data Collection

2) Measure how long it takes to create IDRs using a stopwatch. Try to get 4 measurements per week.

*If this measurement happens mid-shift, delete the IDR after the observation to avoid duplicates

IDR	Date	Time (sec)	Notes
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

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Weeks 2 through 3 – Data Collection

3) Measure how long it takes to search for content in Dropbox using stopwatch. Try to get 2 measurements per week.

*If inspector has previously searched for something in Dropbox, have them reenact those steps

Measurements	Date	Search topic	Time (min)	Notes
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

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Weeks 2 through 3 – Data Collection

4) Verbal questions - How much time is being spent in the field versus the field office?
***Can be interpreted by percentage of their time.**

Measurement	Date	Percentage of time spent in field	Reason to return to office
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

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Weeks 2 through 3 – Data Collection

5) Verbal question - What type of documents have been accessed in Dropbox so far? Try to get 2 measurements per week.

Measurement	Date	Document type/title
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

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Week 4 – Benchmarks and Post Pilot Interview

Week 4 will capture the inspector's typical process for recording observations and how they use that information to create daily reports and other important documents and reports. The following questions can help create benchmark notes for each inspector.

Observation Method

- How are observations made? Do they use a field notebook, camera, etc.?
- Is he/she using any mobile device/tools to help record observations?
- What type of obsevations are made?
- How long does it take to record a typical observation?

Daily Report Method

- How many observations are typically included in the daily report?
- What kind of format (.xlsx, pdf, etc.) is the report in?
- What are the process invovled in creating these reports?
- How are attachements like photos included in these reports?
- How long does it take to create the reports?
- When are these reports being made?

The post pilot interview questions can be found in our Dropbox account.

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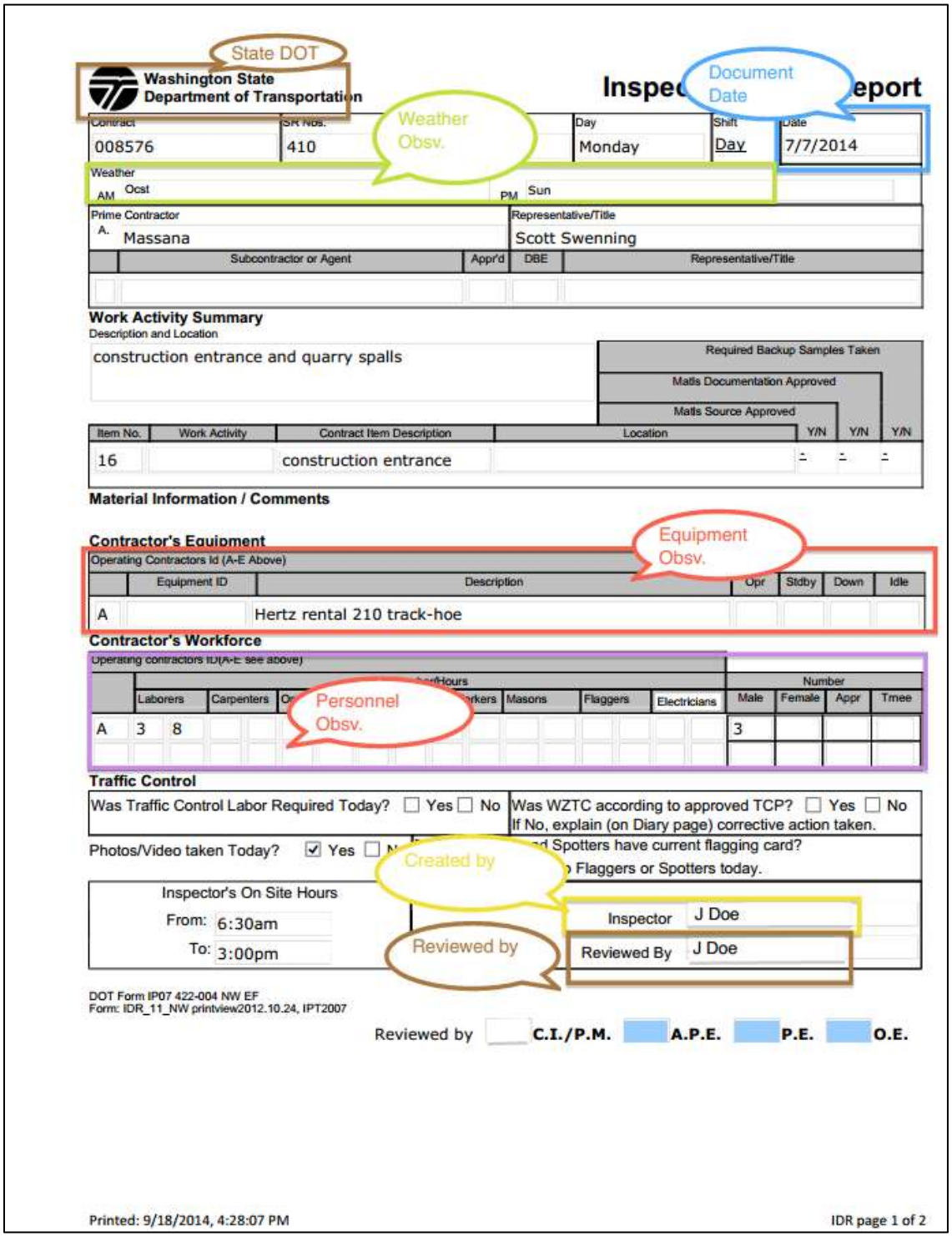
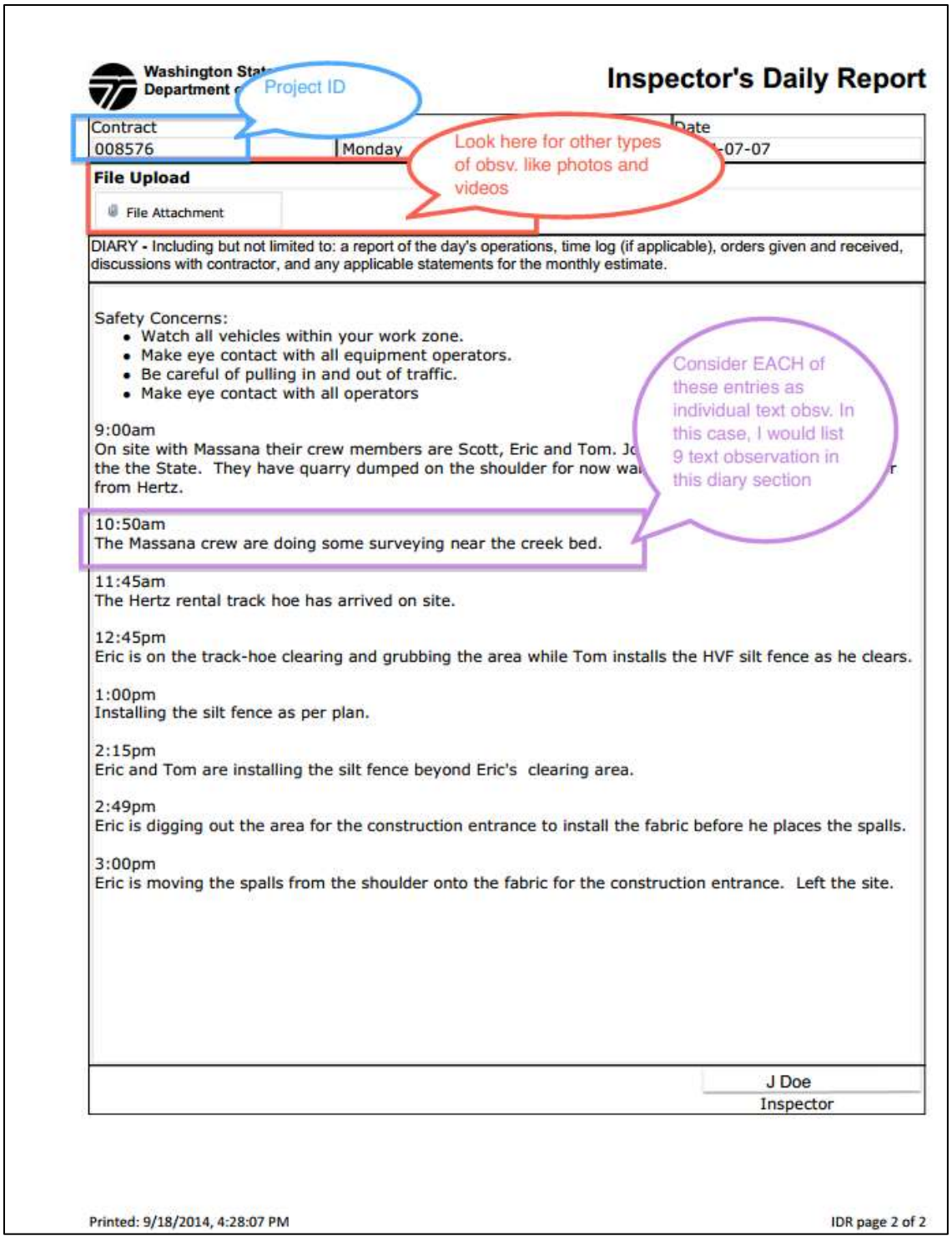
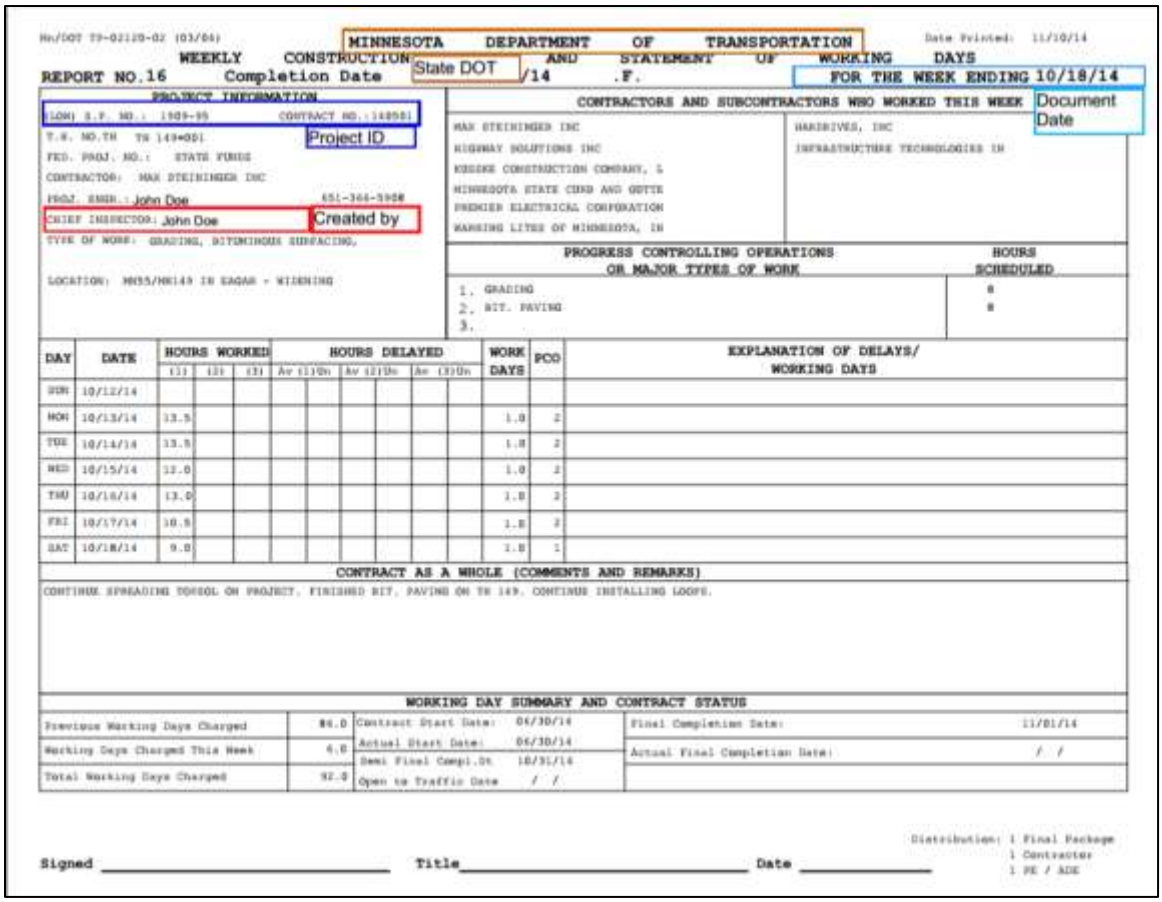
Appendix D – Baseline Inspection Report Assessment Guidelines

WSDOT Baseline Inspection Report Assessment Guide




Washington Sta
Department
Project ID
Inspector's Daily Report
Contract
008576
Monday
Date
-07-07
Look here for other types of obsv. like photos and videos
File Upload
File Attachment
DIARY - Including but not limited to: a report of the day's operations, time log (if applicable), orders given and received, discussions with contractor, and any applicable statements for the monthly estimate.
Safety Concerns:
Watch all vehicles within your work zone.
Make eye contact with all equipment operators.
Be careful of pulling in and out of traffic.
Make eye contact with all operators
9:00am
On site with Massana their crew members are Scott, Eric and Tom. Jo
the the State. They have quarry dumped on the shoulder for now wa
from Hertz.
Consider EACH of these entries as individual text obsv. In this case, I would list 9 text observation in this diary section
10:50am
The Massana crew are doing some surveying near the creek bed.
11:45am
The Hertz rental track hoe has arrived on site.
12:45pm
Eric is on the track-hoe clearing and grubbing the area while Tom installs the HVF silt fence as he clears.
1:00pm
Installing the silt fence as per plan.
2:15pm
Eric and Tom are installing the silt fence beyond Eric's clearing area.
2:49pm
Eric is digging out the area for the construction entrance to install the fabric before he places the spalls.
3:00pm
Eric is moving the spalls from the shoulder onto the fabric for the construction entrance. Left the site.
J Doe
Inspector
Printed: 9/18/2014, 4:28:07 PM
IDR page 2 of 2

MnDOT Baseline Inspection Report Assessment Guide



Mn/DOT TP-02129-02 (03/06) MINNESOTA DEPARTMENT OF TRANSPORTATION Date Printed: 11/10/14

WEEKLY CONSTRUCTION AND STATEMENT OF WORKING DAYS

REPORT NO.16 Completion Date State DOT /14 .F. FOR THE WEEK ENDING 10/18/14

PROJECT INFORMATION

(LOW) S.P. NO.: 1909-95 CONTRACT NO.: 148581

T.H. NO.TH TH 149=001 Project ID

FED. PROJ. NO.: STATE FUNDS

CONTRACTOR: MAX STEININGER INC

PROJ. ENGR.: John Doe 651-366-5908

CHIEF INSPECTOR: John Doe Created by

TYPE OF WORK: GRADING, BITUMINOUS SURFACING,

LOCATION: MN55/MN149 IN EAGAN - WIDENING

CONTRACTORS AND SUBCONTRACTORS WHO WORKED THIS WEEK Document Date

MAX STEININGER INC
HIGHWAY SOLUTIONS INC
KEEGAN CONSTRUCTION COMPANY, L
MINNESOTA STATE CORD AND GUTTE
PREMIER ELECTRICAL CORPORATION
WARNING LITES OF MINNESOTA, IN
HARDRIVES, INC
INFRASTRUCTURE TECHNOLOGIES IN

PROGRESS CONTROLLING OPERATIONS OR MAJOR TYPES OF WORK	HOURS SCHEDULED
1. GRADING	8
2. BIT. PAVING	8
3.	

DAY	DATE	HOURS WORKED (1)	(2)	(3)	HOURS DELAYED Av (1)On	Av (2)On	Av (3)On	WORK DAYS	PCD	EXPLANATION OF DELAYS/ WORKING DAYS
SUN	10/12/14									
MON	10/13/14	13.5						1.0	2	
TUE	10/14/14	13.5						1.0	2	
WED	10/15/14	12.0						1.0	2	
THU	10/16/14	13.0						1.0	2	
FRI	10/17/14	10.5						1.0	2	
SAT	10/18/14	9.0						1.0	1	

CONTRACT AS A WHOLE (COMMENTS AND REMARKS)

CONTINUE SPREADING TOPSOIL ON PROJECT. FINISHED BIT. PAVING ON TH 149. CONTINUE INSTALLING LOOPS.

WORKING DAY SUMMARY AND CONTRACT STATUS

Previous Working Days Charged	86.0	Contract Start Date:	06/30/14	Final Completion Date:	11/01/14
Working Days Charged This Week	6.0	Actual Start Date:	06/30/14	Actual Final Completion Date:	/ /
Total Working Days Charged	92.0	Semi Final Compl.Dt	10/31/14		
		Open to Traffic Date	/ /		

Distribution: 1 Final Package
1 Contractor
1 PE / ADE

Signed _____ Title _____ Date _____

WEEKLY CONSTRUCTION DIARY AND STATEMENT OF WORKING DAYS Date Printed: 11/18/14

REPORT NO. 16 FOR THE WEEK ENDING 10/18/14

DAILY REMARKS AND COMMENTS

Sunday 10/12/14

Monday 10/13/14

MAX STEININGER- SPREADING TOPSOIL ALONG TH 149.
HARDRIVES- MILLING AND PAVING ON NB/SB TH149.
WARNING LITES-TRAFFIC SWITCHES FOR MILLING AND PAVING OPERATION.
PREMIER ELECTRIC- WORKING ON SIGNAL SYSTEM D.
KUSSKE CONST.- WATERMAIN WORK ON O'NEILL.
Weather - High: 57 Low: 50 Conditions: Cloudy

Weather Observation

Consider EACH of these entries as individual text obsv. For Tuesday, I would list 5 text observation in this diary section

Tuesday 10/14/14

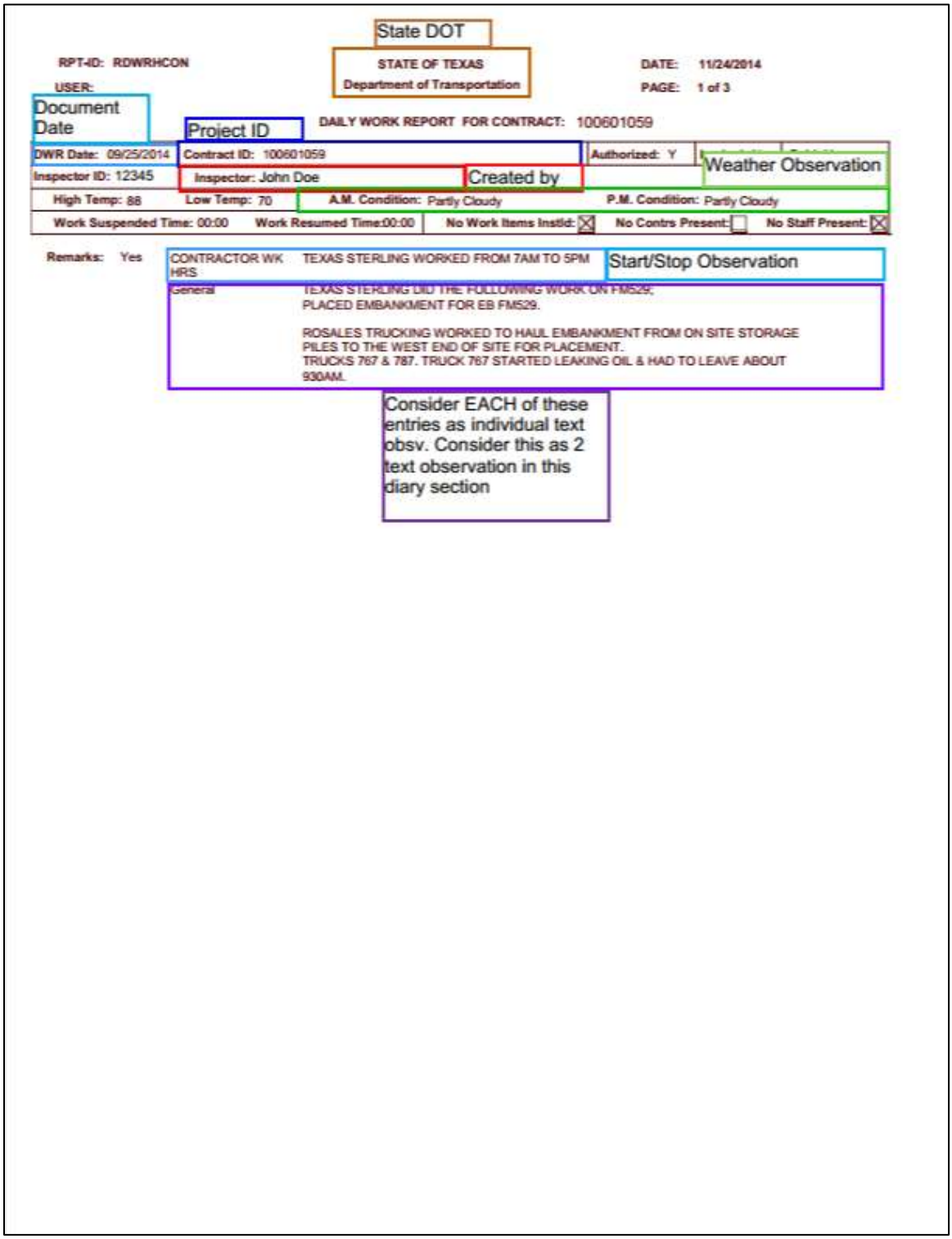
MAX STEININGER- SPREADING TOPSOIL ALONG TH 149.
HARDRIVES- MILLING AND PAVING ON NB/SB TH149.
WARNING LITES-TRAFFIC SWITCHES FOR MILLING AND PAVING OPERATION. INSTALLING SIGN POSTS FOR PERMANENT SIGNS.
PREMIER ELECTRIC- WORKING ON SIGNAL SYSTEM E.
KUSSKE CONST.- INSTALLING BEE HIVES ON TH 55 BY LONE OAK ROAD. INSTALLED DITCH BLOCK BY HOLIDAY LANE.
Weather - High: 65 Low: 47 Conditions: Partly Cloudy

Wednesday 10/15/14

MAX STEININGER- GRADING DITCH IN MEDIAN OF TH 55 BY LONE OAK ROAD. MISC. CLEANUP.
HARDRIVES- PAVING NB AND SB TH 149 FROM LONE OAK PARKWAY TO I494.
HIGHWAY SOLUTIONS- INSTALLING POLY PREFORM ARROWS ON TH 149/55.
WARNING LITES- TRAFFIC SWITCHES FOR BIT. PAVING. INSTALLED GUARDRAIL ON EB TH 55 FORM COMMERS DR. TO LONE OAK ROAD. INSTALLING PERMANENT SIGNS.
MN STATE C&G- POURED CURB AND GUTTER ON O'NEIL CUL-DE-SAC. POURED MEDIAN ISLAND ON TH 55.
PREMIER ELECTRIC- WORKING ON INSTALLING LOOPS ON TH 149.
Weather - High: 66 Low: 38 Conditions: Sunny

LOW S.P. NUMBER: 1909-95 CONTRACT: 140501

TxDOT Baseline Inspection Report Assessment Guide



RPT-ID: RDWRHCON | STATE OF TEXAS | DATE: 11/24/2014

USER: | Department of Transportation | PAGE: 2 of 3

DAILY WORK REPORT FOR CONTRACT: 100601059

Contractor Information

Contractor ID: 06958 Contractor Name: TEXAS STERLING CONSTRUCTION CO. Hrs Worked: 60.000

Nbr of Supervisors: Nbr Of Workers: 12

Variable Labor:	Personnel Title	Qty	Hrs.Worked
	SUPERVISOR	1	10.000
	SKILLED	3	10.000
	UNSKILLED	2	10.000

Count each role as 1 personnel observation. In this example, there are 3 personnel observations.

Equipment:	Description	Qty	Qty Used	Hrs. Used
	BLADE 12FT	1	1	6.000
	BACKHOE	1	1	1.000
	BULLDOZER 8FT	1	1	8.000
	FLAT WHEEL ROLLER	1	1	2.000
	LOADER	1	1	1.000
	SHEEPSFOOT DOZER	1	1	2.000
	TRACKHOE	1	1	9.000

Count each equipment as 1 observation. In this example, there are 8 equipment observations.

RPT-ID: RDWRHCON | STATE OF TEXAS | DATE: 11/24/2014

USER: | Department of Transportation | PAGE: 3 of 3

DAILY WORK REPORT FOR CONTRACT: 100601059

¾ TON PICKUP	1	1	10.000

Contractor ID: 20773 Contractor Name: ROSALES TRUCKING Hrs

Nbr of Supervisors: Nbr Of Workers: 4

Variable Labor:	Personnel Title	Qty	Hrs.Worked
	SKILLED	2	10.000

Count each role as 1 personnel observation. In this example, there is 1 personnel observations.

Equipment:	Description	Qty	Qty Used	Hrs. Used
	HAUL TRUCK 12 CY	2	2	6.250

TRUCK 767 = 2.5 HOURS
TRUCK 787 = 10.0 HOURS
TOTAL = 12.5 HOURS

12.5/2=6.25 HOURS AVERAGE.

Count each equipment as 1 observation. In this example, there is 1 equipment observations.

Appendix E – HeadLight Training Presentation Outlines

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phone: 206.428.3094 fax: 206.428.7114
website: www.paviasystems.com

iPad 101 Training Outline

1. Device Basics
    a. Case
        i. Drop proof & water resistance.
        ii. Gaskets cover the edge of the screen to create a water-tight seal. The iPad screen is exposed with no protective screen sticker.
        iii. Case comes with strap for ease-of-use.
        iv. The button and input covers must be closed for the iPad to be water resistant.
    b. iPad
        i. Display
            1. 9.7-inch LED backlit display with fingerprint-resistant coating on screen.
        ii. Camera
            1. 1.2 MP front camera, 5 MP back camera. Records 1080p HD videos. Use the camera on the back for higher quality images and videos.
        iii. External Buttons
            1. On/Off or Sleep/wake.
            2. Silent/Screen rotation lock.
            3. Volume up & down.
            4. Home.
        iv. Connectors & Input/output
            1. Microphone located on top-center of iPad.
            2. 3.5 mm stereo headphone minijack located on top-left of iPad.
            3. Lightening connector (for charging and syncing) located on bottom-center of iPad.
            4. Built-in speaker located on bottom of iPad.
        v. Support contact and information is placed on the back of the iPad
            1. Each device has its own serial number.
        vi. Power & Battery
            1. 42.5-watt-hour rechargeable lithium-polymer battery.
            2. 9 hours use on cellular network, 10 hours on Wi-Fi.
            3. Charge using power adapter or plug in to computer. Charge iPad everyday.

2. Account Information
    a. Unlocking iPad
        i. Unlock iPad using 4-digit passcode: 1234

b. Apple ID
    i. All pilot program users will have their own Apple ID and password.
    ii. Apple ID account allows iPad users to access the App Store to download apps.
c. Headlight Account
    i. All pilot program users will have their own Headlight account ID and password.
    ii. Users need to log in to access the Headlight app and website.

3. Using your iPad
    a. Turning the device on
        i. Hold down the on/off button until the Apple logo appears on the center of the screen.
        ii. Enter the four-digit code to unlock the iPad.
    b. Getting familiar with the home screen
        i. Top of the screen shows data/Wi-Fi connection, time, and battery life.
        ii. Dots on the bottom of the screen indicate the number of home screens available.
        iii. Swipe up from the bottom of the screen to access the control center. From here, you can easily adjust volume and brightness. You may find it useful to increase the brightness when viewing the iPad in daylight.
    c. Connecting to a data network
        i. Cellular data connection has already been configures on the iPads.
        ii. Go to Settings and turn on cellular data. Once connected, the data provider's name will be shown on the upper left area of the screen.
    d. Apps
        i. Similar to clicking the buttons on a computer mouse, touch or tap the app icon to open apps.
        ii. While in app, press the home button to return back to the home screen. This will not close the app, it will be running in the background.
        iii. Double tap the home button to see all running apps. While in this mode, swipe up to close the app.
    e. Common gestures
        i. Zoom in and out of image or website by "Pinching".
        ii. Double-tapping an image or website to zoom in.
        iii. "Tap and hold" an image or a word to copy it. "Press and hold" an empty field to paste copied content.
    f. Keyboard
        i. The keyboard will appear anytime the user taps a text box.
        ii. Tap on ".?123" to show numbers and symbols.
        iii. Tap on the "keyboard" symbol to hide the keyboard.
        iv. Split keyboard to use "thumb-only" keyboard.
        v. Tap on the microphone symbol to use voice recognition.

g. Tips and Tricks
   i. Screenshots by pressing the on/off button and the home button together. Picture can be found under photos.
   ii. When typing, double tapping the space button will add a period and a space so you can start a new sentence.
   iii. To use the "thumb friendly" keyboard, place both thumbs on each side of the keyboard and spread both thumbs away from each other. The keyboard should now be split towards both edges of the screen. Swipe the keyboards together to return it back to the original layout.

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phone: 206.428.3094 fax: 206.428.7114
website: www.paviasystems.com

HeadLight Training Outline

1. HeadLight Overview
    a. Key elements of the app
        i. Observations
        ii. Documents
        iii. Dashboard
    b. Inspector's Tool Kit - Dropbox
    c. Training Exercise
        i. Create/edit/delete observations
        ii. Create/edit/delete IDRs
        iii. Search/screenshot plans and specs
2. Why Headlight?
    a. Deigned to make project inspection and documentation easier for field personnel
        i. Easy way to collect information
        ii. Great way to share information
        iii. Easy and quick way to create field documentation
        iv. Easy way to access resources like plans and specs
        v. Do all of this anywhere onsite
3. Key Elements of the app
    a. Getting Started
        i. Access and login to headlight
            1. HeadLight app is optimized for landscape view only
            2. Username and password = first initial and last name
    b. Navigation menu
        i. Specify the project
        ii. Choose between dashboard, observations, and documents
        iii. Current username
        iv. Sync Information
    c. Observations
        i. Summary view - existing observations shown sorted by most recent entry on the left side
        ii. Summary view - existing observations filtered by type and date on the right side
        iii. Creating new observations (demo photo observation)
            1. Tap the "+" button on top
            2. Select observation type
                a. Buttons up top: delete, flag, observation title, and save.
                b. 13 types of observations available

c. Every observation will automatically be tagged with the following data:
    i. Time and date, GPS location (decimal degrees) & Station /offset, & add signature
3. Add basic information
    a. Priority flag
    b. Rename observation
    c. Notes & descriptions
    d. Modify date & time (will display current date & time)
    e. Modify location information (will display current location)
    f. Signature
4. Tap the check icon on upper right corner to save observation

iv. Discuss how to use each of the observation types
1. Video
2. Audio
3. Density
4. Text
5. Equipment
    a. Komatsu 400 Excavator – 1 hr opr
    b. TMA – 4 hr opr
    c. Broom #B-14 – 1 hr opr, 1 hr idle
6. Personnel
    a. Contractor A Laborer x 5; 50 hrs
    b. Contractor A Foreman x 1; 10 hrs
    c. Contractor B Laborer x 3; 3 hrs
    d. Contractor B Operator x2; 2 hrs
    e. Contractor B Foreman x2; 2 hrs
7. QR Scan
    a. Scan demo paint can
8. QR Create
    a. Create QR code for cantilever sign structure
    b. Description can include bid item # and approved for shipment information
9. Temp
    a. Material temperature for HMA – 273˚
    b. Description can include ambient temp 67.2˚and hopper temp 295˚
10. Weather
    a. Include weather observation for AM and PM
11. Start/Stop
    a. Contractor crew time hours
12. Materials
    a. Calculate CSBC quantity and insert into descriptions

v. Viewing observations

1. Tap on existing observations to see more information
2. A new side-screen will show the observation and any associated data
3. Tap on "left-arrow" to go back to the observation main menu OR...
4. Tap on the trash can icon to delete this observation OR...
5. Tap on the pencil icon to edit this observation

vi. Editing observations
1. When viewing an observation, tap the pencil icon
   a. To cancel editing, tap on the trash can icon and select "cancel edit"
2. Modify the observation
3. Tap on the check icon to save changes

vii. Deleting Observations
1. When viewing an observation, tap on the trash can icon
2. A warning pop-up window will appear to verify this action
3. Tap "delete" to remove this observation

d. Documents
i. Summary view - Existing documents and its observation contents shown on the left side
ii. Summary view - Existing documents filtered by date on the right side
iii. Creating new IDRs
1. Tap the "+" button on top
   a. Tap the trash icon to cancel creating an IDR
2. Select the IDR date
3. Select the observations to be included in the IDR
4. Select priority level if needed
5. Tap on the save icon when finished

iv. Viewing Documents
1. Tap on a existing IDR to see more information
2. A new side-screen will show the populated IDR form, map showing the location of each observation included in the IDR, and the observations themselves
3. Tap on "left-arrow" to go back to the documents main menu OR...
4. Tap on the trash can icon to delete this IDR OR...
5. Tap on the pencil icon to edit this IDR

v. Editing Documents
1. When viewing an IDR, tap the pencil icon
   a. To cancel editing, tap on the trash can icon and select "cancel edit"
2. Modify the IDR
3. Tap on the check icon to save changes

vi. Deleting Documents
1. When viewing an IDR, tap on the trash can icon

2. A warning pop-up window will appear to verify this action
3. Tap "delete" to remove this observation

e. Dashboard
   i. "Home screen"
   ii. Project specific information
      1. Document approval notification
      2. Weather – at project location
      3. Interactive Map
         a. Tap on the satellite icon on the upper left corner of the map to switch to satellite view.

4. Inspector Tool Kit
   a. Access the inspector tool kit using the Dropbox app
   b. You do not need to be connected to data or Wi-Fi to access documents in Dropbox
   c. Included many reference documents including project plans, special provisions, & standard plans/specs

Appendix F – Post-Pilot Interview Questions

Field Personnel Interview Guide

Background

1) How long have you been in the inspector role?
2) How long have you been creating DWRs in Site Manager? How long have been creating these reports using the most current method?
3) How long did it take you to become comfortable with creating Daily and Weekly construction Reports using the current process?
4) Do you own a tablet computer? Have you used one before the pilot program?
5) How experienced are you in using tablets and smartphones. (1 = not experienced, 5 = extremely experienced)
6) Did your experience with other mobile services or products make it easier to operate the HeadLight application and the inspector's tool kit. (1 = strongly disagree, 5 = strongly agree)
7) In a typical week, how often do you have to look up information in the project plan, specs, and other project references out in the field?
    a. How do you look up this information (hard copy, electronic, etc.)?
    b. How long does it typically take to look up information?

Learnability

8) Did you get used to using the HeadLight app?
9) How long did it take until you were comfortable?
10) After you were comfortable, did you want to give it up?
11) Describe your experience learning how to use HeadLight and the Inspector's Tool Kit.
12) It was easy to learn to use the HeadLight application. (1 = strongly disagree, 5 = strongly agree)

Usability

13) On a scale of 1 to 5 (1=not useful, 5 = extremely useful), rate the following features: (Bold items were referenced in the Phase 1 report)
    a. **Photo observations with annotations integrated with notes.**
    b. **Metadata**
        i. **Timestamp**
        ii. **Location tag/Map View**
        iii. **e-signature**
        iv. **Priority flag**
    c. **Equipment observation**
    d. **Personnel observation**
    e. **Weather observation**
    f. **QR create/QR scan observation**
    g. Video observation
    h. Audio observation
    i. Density observation
    j. Text observation

k. Temperature observation
l. Start/Stop observation
m. Material observation

14) It is easy to create observations using HeadLight compared to my previous method. (1 = strongly disagree, 5 = strongly agree) Please explain some differences with specific features, such as including photos to IDRs.
15) It is easy to create Daily and Weekly Construction Reports using HeadLight compared to my previous method. (1 = strongly disagree, 5 = strongly agree) Please explain the differences.

Efficiency

16) Describe the impact of using HeadLight when compared to the previous method for the following:
    a. Creating observations
    b. Creating Daily and Weekly Construction Reports
    c. Searching for information in plans, specs, and other resources
    d. Performing calculations
17) I can complete my work tasks quickly by using HeadLight and the inspector's tool kit compared to my previous method. (1 = strongly disagree, 5 = strongly agree)
18) The HeadLight app responds quickly to my actions. (1 = strongly disagree, 5 = strongly agree)

Effectiveness

19) Describe your experience in entering information to create observations.
20) Describe your experience in viewing the information entered into HeadLight.
21) HeadLight and the Inspector's Tool Kit enables quick and effective performance of work tasks. (1 = strongly disagree, 5 = strongly agree)
22) Do you feel you were able to collect more information, the same amount of information, or less information in the field using the pilot system vs. your previous method? Please explain.

Information Sharing

23) Did your supervisor/PE look at your HeadLight observations from the office? If yes, was it helpful to be able to share field information directly with them through HeadLight? Tell us about the particular situation where it helped.

User Satisfaction

24) Describe how you feel about HeadLight's user interface.
25) If you could create and submit your Daily and Weekly Construction Reports in the field similar to your experience in the pilot program, would you prefer that to your previous method? How much of an impact do you think this would have on your job performance?

26) I would recommend the use of HeadLight and the Inspector's Tool Kit for other inspectors doing the same work. (1 = strongly disagree, 5 = strongly agree)
27) What was your favorite feature of HeadLight?
28) What was your least favorite feature of HeadLight?

Factors Related to Mobile Work Context

29) Inputting information into HeadLight is easy. (1 = strongly disagree, 5 = strongly agree)
30) Did the environment of the jobsite impact your use of the iPad and HeadLight?
    a. Sunshine makes the use of iPad and HeadLight difficult. (1 = strongly disagree, 5 = strongly agree)
    b. Darkness makes the use of iPad and HeadLight difficult. (1 = strongly disagree, 5 = strongly agree)
    c. Dust and dirt makes the use of iPad and HeadLight difficult. (1 = strongly disagree, 5 = strongly agree)
    d. Noise makes the use of iPad and HeadLight difficult. (1 = strongly disagree, 5 = strongly agree)
    e. Outside temperature makes the use of iPad and HeadLight difficult. (1 = strongly disagree, 5 = strongly agree)
31) Making observations and Construction Reports available to my supervisor/management is easy. (1 = strongly disagree, 5 = strongly agree)

Safety

32) Describe any safety concerns while using HeadLight and the Inspector's Tool Kit out in the field?
33) The use of the mobile tools included in the iPad has caused me safety risks while on the move. (1 = strongly disagree, 5 = strongly agree)

Support

34) Did you seek help from our support staff or the support call center? (Yes/No) ******If no, skip to next section***
35) Describe your experience in receiving support from the support staff.
36) I always know who to ask for help if I have problems performing work tasks with HeadLight and the Inspector's Tool Kit. (1 = strongly disagree, 5 = strongly agree)
37) The help information given by the support call center and staff is useful. (1 = strongly disagree, 5 = strongly agree)

Impacts on Mobile Work Productivity

38) Using HeadLight and the Inspector's Tool Kit on the iPad in my job reduces travelling from and to the office during the workday. (1 = strongly disagree, 5 = strongly agree)
39) Using HeadLight and the Inspector's Tool Kit on the iPad helps me complete my work tasks quickly. (1 = strongly disagree, 5 = strongly agree)

Baseline Comparison

40) I would prefer to have an iPad on the jobsite to a laptop for field use. (Yes/No)
41) If HeadLight was tied in fully to TxDOT's process, for example where bid items were automatically available and output formats were exactly tied to TxDOT forms for Daily Reports, Pay Items, Force Account, etc., how beneficial would these capabilities be for your job? (1 = not beneficial, 5 = extremely beneficial)
42) HeadLight was a pilot to aid in field data collection for your job. After spending several weeks with it, what are the features you can't live without? What are the features you'd like to see? And looking to your whole job of ensuring proper documentation of the job, what do you feel are the most important additional capabilities that should be incorporated next to eliminate the need for you to return to the office?
43) Is there anything else about the pilot experience that you feel is important to share with us?

Office Personnel Interview Guide

Background

1) How long have you been in your current role (chief inspector, APE, PE, etc.)?
2) How often did you use HeadLight to access observations and Daily Reports?
3) What was your main reason for using the system?

Learnability

4) Describe your experience learning how to use HeadLight web service.
5) How easy was it to learn to use the HeadLight web service. (1 = not easy, 5 = extremely easy)

Usability

6) Describe how using the HeadLight web service changed the way you access observation activities out in the field.
7) Describe how using the HeadLight web service changed the way you review Daily/Weekly Construction Reports.
8) On a scale of 1 to 5 (1=not useful, 5 = extremely useful), rate the following features that can be included in Daily/Weekly Construction Reports: (Bold items were referenced in the Phase 1 report)
    a. **Photo observations with annotations integrated with notes.**
    b. **Metadata**
        i. **Timestamp**
        ii. **Location tag/Map View**
        iii. **e-signature**
        iv. **Priority flag**
    c. **Equipment observation**
    d. **Personnel observation**
    e. **Weather observation**
    f. **QR create/QR scan observation**
    g. Video observation
    h. Audio observation
    i. Density observation
    j. Text observation
    k. Temperature observation
    l. Start/Stop observation
    m. Material observation
9) How easy is it to navigate the HeadLight web service. (1 = not easy, 5 = very easy)
10) How easy is it to review Daily/Weekly Construction Reports using the HeadLight web service. (1 = not easy, 5 = very easy)

Efficiency

11) How beneficial is it for you to have information provided and accessible throughout the day on each active jobsite? (1 = not beneficial, 5 = extremely beneficial) Please describe why.
12) Describe changes in your productivity in reviewing Daily Reports.
13) How quickly can you complete your task by using the HeadLight web service? (1 = not quickly, 5 = very quickly)
14) Were Daily Reports available for review in a more timely manner using the HeadLight system compared to the previous method? Please explain. (If yes, what was the impact of having information available in real-time?)

Effectiveness

15) Describe your experience in reviewing observations and Daily/Weekly Construction Reports using the HeadLight web service.
16) Do you feel that the Daily Construction Reports created by HeadLight capture more information, the same amount of information, or less information compared to the previous method?

User Satisfaction

17) Describe how you feel about the HeadLight web service's user interface.
18) Would you prefer to review Daily Construction Reports using the HeadLight web service compared to the previous method? If yes, how much of an impact would the HeadLight web service have on your job performance?
19) What was your favorite feature on the HeadLight web service?
20) What was your least favorite feature on the HeadLight web service?
21) Would you recommend the use of HeadLight and the web service for others doing the same work? (1 = not recommend, 5 = strongly recommend)

Searching & Reporting

22) Describe how useful it would be to incorporate a search function to enable searches for specific information?
23) What type of reports (trends across projects, etc.) would you like to generate from the information collected by HeadLight?

Support

24) Did you seek help from our support staff or the support call center during the pilot program? (Yes/No) ******If no, skip to next section***
25) Describe your experience in receiving support from the support staff.
26) I always know who to ask for help if I have problems performing work tasks with the HeadLight web service. (1 = strongly disagree, 5 = strongly agree)
27) How useful was the help information given by the support call center and staff? (1 = not helpful, 5 = extremely helpful)

Impacts on Mobile Work Productivity

28) Did the use of the HeadLight web service in your job reduce travelling from and to the field during the workday. (1 = strongly disagree, 5 = strongly agree)

Baseline Comparison

29) I would prefer reviewing and approving documents, such as Daily/Weekly Construction Reports, using the HeadLight web service to other methods. (Yes/No)
30) If HeadLight system was tied in fully to TxDOT's process, for example where bid items were automatically available and output formats were exactly tied to TxDOT forms for Daily Reports, Pay Items, Force Account, etc., how beneficial would these capabilities be for your job? (1 = not beneficial, 5 = extremely beneficial)
31) HeadLight was a pilot to aid in field data collection for your job. After spending several weeks with it, what are the features you can't live without? What are the features you'd like to see? And looking to your whole job of ensuring proper documentation of the job, what do you feel are the most important additional capabilities that should be incorporated into HeadLight?
32) What other areas for your project office could HeadLight help? (i.e. Pay Notes, Force Account, etc.)
33) Is there anything else about the pilot experience that you feel is important to share with us?

Appendix G – Interview Quote List

Quotes Related to Productivity

"When I normally do it, I have to carry my rain-write notebook. I have to look at the time and correlate it to my observations. Then I have to get on my computer and change the weather, date, BI, personnel, etc. Then you get to the [diary portion] IDR. You have to look at your notes, remember what you did out in the field, and then type it all up. With HeadLight, all you have to do is select the observations and sync. That's it and you're done. Now I'm two days behind, I won't be able to get to my IDRs until next week. I probably will lose some content for those two days. I have good notes but you don't always remember everything. When you do it on the spot, it flows better and the information is fresh." – Project Inspector, WSDOT

"Absolutely, it will increase my job performance. More information would be available, and I can spend more time out in the field. State will save on overtime cost because a large portion of our over time is travel time or reports. Being able to do it in the field increases the quality of the IDR." – Project Inspector, WSDOT

In reference to using HeadLight compared to the traditional inspection process - *"Yes, it would be huge. Right now I'm two weeks behind on four different jobs. If I had HeadLight, it would be all caught up."- Project Inspector, MnDOT*

"The program is very user friendly. It makes my life a lot easier out in the field, not having to go back to the office to produce daily and weekly diaries. The more time out in the field, the better for us." – Project Inspector, MnDOT

"If inspectors can create WCR using HeadLight, it would be submitted sooner or on time." – Project Engineer, MnDOT

In reference to how much time savings HeadLight would save for inspectors - *"A few hours a day. Just sitting down to write a DWR at the end of the day. When [I] was an inspector, [I] didn't want to connect laptop inside the truck, so [I] wrote the required information, don't go into much [in] detail as it's at the end of the day, you want to go home. But with HeadLight, just take a picture, and it becomes a part of your observations. It's much easier." – Project Engineer, TxDOT*

In reference to how much time savings HeadLight could save a Project Manager - *"It would save a few hours daily, because they have to review and authorize DWRs, review calculations." – Project Engineer, TxDOT*

"[With HeadLight] I can resolve issues right away, vs. waiting 2-3 days." – Project Engineer, TxDOT

[Reviewing Daily Reports] How much time did it save? "At least 2-3 hours per day." – Project Engineer, TxDOT

"I was shocked being able to see my inspectors do so much." – Project Engineer, TxDOT

"Everything you do in your program saves me time, I don't know what else there is to save." – Project Engineer, TxDOT

"In this case of using HeadLight, I can't tell you how much more time efficient it is. I can do my job a lot easier without having to run back and forth, when you take gas, drive time, it's costing the tax payer." – Project Inspector, TxDOT

"It saved me from having to duplicate information to [current system]. It saved time for me. Pictures say a whole lot so having them in my IDR tells a better story." – Project Inspector, TxDOT

"Taking pictures on one operation, and observing another one somewhere else was easy. It was easy to be able to take photos quickly. It saved half of my time by using this app." – Project Inspector, TxDOT

"[HeadLight] saved about 75%of my typical IDR process." – Project Inspector, TxDOT

In reference to time saved by using HeadLight - *"Yes, it would save me an hour a day." – Project Inspector, TxDOT*

"[HeadLight] saved me about 20 minutes of travel a day. My project is 8 miles long so it can be a hassle to go back to the field office." – Project Inspector, TxDOT

"Before, when we were out in the field and you have to pay for something and put something in, you have to leave the crew and go back in to put it in the computer, then go back out and watch the guys. With HeadLight, you can just stay right there, do what you need to do while you're there on site" – Project Inspector, TxDOT

"If you lag by 1 DWR, the next day, you're gonna have to catch up, which is difficult. HeadLight completely takes the worry out" – Project Inspector, TxDOT

"Total time savings in a day, 2 hours a day. Then can spend that time watching your crew instead of other unnecessary activities" – Project Inspector, TxDOT

"Don't have to go to the office for anything with HeadLight." – Project Inspector, TxDOT

"Save time because you're not on the computer putting it all in. [HeadLight] is a lot faster." – Project Inspector, TxDOT

Quotes Related to Data Quality

"I was able to collect more information. Especially useful if I had 6 different activities going on at the same time. I can capture it, observe it, and I didn't have to remember everything going on. I can move on to the next activity." – Project Inspector, WSDOT

"More information through observation was created. It was a much more comprehensive diary report. There is significant amount of savings with HeadLight. I could have saved half-million [dollars] on a current claim with this tool." – Project Engineer, WSDOT

"Managing and recording what's happening is so much easier with HeadLight than writing stuff in the notebook." – Project Engineer, WSDOT

"[Information is] very accurate as far as what would go in his daily [using HeadLight]. The information I've seen from the daily reports via HeadLight has more information than the hand written daily reports." – Project Engineer, MnDOT

"HeadLight reports are more complete." – Project Inspector, TxDOT

"There is value in having that information turned in on time. [Specific project] is a high profile project. I need to see this every day." – Project Engineer, TxDOT

"Carrying that big old Dell thing is a pain in the ass, it really is. It keeps me from wanting to do my job more efficiently, takes forever to do something. With HeadLight, I get going [doing a DWR], and I get a call, I can just take it with me." – Project Inspector, TxDOT

"I absolutely loved it. You get your inspectors that don't write out as much detail, but those inspectors do a lot of photo observations, when you pair their short little writing with the photo observation, you get a good idea of what's going on. Williams brothers laying down base at frontage road from station x to y. Is it first lift of second left? Take a look at the picture, can tell just by the depth." – Project Engineer, TxDOT

"Site Manager you get inaccurate stationing. And you don't even know if the inspector left the office that day. HeadLight shows you where they were, where work was taking place, gives you an accurate x-y, which can convert to stationing." – Project Engineer, TxDOT

"Using the HeadLight system…you'll get more information because it's so easy to get the information into their daily report." – Project Inspector, TxDOT

"Easier to collect the information [in HeadLight], then you tend to get more observations made." – Project Inspector, TxDOT
"I think you could get a lot more comprehensive DWRs out of [HeadLight]" – Project Inspector, TxDOT

"You're gonna collect more than you can do on the laptop. Everything's right there, camera, video, voice, signature, anything you need to highlight, it's all right there." – Project Inspector, TxDOT

"I used the app to get locations to see where everyone was at, could see what parts of the job were being covered, and I knew what parts of the job I needed to inspect when driving the jobsite." – Project Engineer, TxDOT

Quotes Related to Data Availability

"I must be able to address issues in real time. This is very important. It helps to be able to stay in the office. Project sites could be very far away. Currently, phone calls are the way issues are communicated. Visiting sites can take away half the day, having real time info saves this much time. This real time info does not just stop at my desk, it could be available to a specialist in Olympia [HQ] on bridge design. Instantly pass information to the person who needs to make a structural decision."– Project Engineer, WSDOT

"I typically don't make Daily reports, just weekly summaries. I ended up making daily reports with headlight every day." – Project Inspector, MnDOT

"The real-time diary information is valuable to everyone, not just the engineers" – Project Inspector, MnDOT

When asked, how timely were HeadLight inspection reports submitted - *"[I currently] get them every 2 to 3 weeks. HeadLight would help with timeliness. Can do it in the field. If they're busy one week, they sometimes don't even come in the office." – Project Engineer, MnDOT*

"Can be on top of the project even when you're not there" – Project Engineer, TxDOT

"[HeadLight] can just show me the problem, I can figure it out from here, and can send back solution" vs. receiving an email, "it will be 2 days and then I'll have to go to the field to look at it. Or I have to go into the field right away. I can figure it out here" – Project Engineer, TxDOT

"Now driving through the 3 projects 6 times to see everything. With HeadLight just have to drive through it twice, once on the frontage road, once on the main lines. Also, can show video proof if contractor is out of spec." – Project Engineer, TxDOT

"Keeps you informed on what's going on in the field at all times." – Project Engineer, TxDOT

"Saves a ton of time. With [current system], inspectors don't input observation until end of day. Guys using headlight it pops up immediately. I know what's going on exactly to the minute. I know at that point what's going on, vs. finding out a day late after the damage has already been done." – Project Engineer, TxDOT

Are HeadLight DWRs submitted more timely compared to the traditional process? - *"By far. Easily a day. Inspectors don't put stuff in till end of the day. [I] can go a whole week without getting DWRs from guys, then get all at once. Whereas with HeadLight you see it every half of the day." – Project Engineer, TxDOT*

In reference to information stored in a central repository - *"Having it all in 1 place is significantly beneficial because everyone who needs it has access to it right there." – Project Engineer, TxDOT*

"I like that it's secure for you. Someone else can't get on it." – Project Inspector, TxDOT

Quotes Related to Learnability and Support

"After the [training presentation], it was very easy to use HeadLight." – Project Inspector, WSDOT

"I've seen a lot in my time here (technology-wise). Pavia's presentation is the best so far and this product is something that I hope MnDOT adopts. The presenters from previous presentations [implementation of new technology], similar to HeadLight's orientation presentation, would get hung up when we ask construction related questions. Questions were answered in [the orientation] presentations and during the pilot program. It was great to have people involved that understood our tasks and processes. I was very impressed with the speed of the application as well. I hope the speed stays the same if MnDOT adopts this application." – Project Inspector, MnDOT

"This has been a very positive experience. It's easy to use. Given more time, I might have been able to use more of the other observation type to include them in my daily activities." – Project Inspector, MnDOT

"I didn't have to hunt around to figure out how to enter something, it was very easy" – Project Engineer, TxDOT

When asked how do you feel about the web service interface - *"Heck, the easiest way to explain it is I'm gonna be upset that we're not gonna have it to use throughout the entirety of the project." – Project Engineer, TxDOT*

"I was pretty comfortable with [HeadLight] after the first day. I don't even know if it took the whole day." – Project Inspector, TxDOT

"I was comfortable with [HeadLight] the day after the presentation. I was comfortable with taking pictures and videos. I was able to read emails and all the next day." – Project Inspector, TxDOT

"I liked [HeadLight], I was pleasantly surprised, I'm not really a computer person." – Project Inspector, TxDOT

"[Roadway] cracking, goes right along the lines of where there was moisture before. I couldn't for the life of me find that spot, and if I had HeadLight, that picture would have been easy to find." – Project Inspector, TxDOT

In reference to comparing the inspection process between HeadLight and the traditional method - *"Easier on HeadLight, you're right out in the field, don't have to leave to go back in. They have little brown book, now I don't have to write in there, put it in HeadLight and you're done." – Project Inspector, TxDOT*

"I really thought this was going to be confusing at first. [Coworker] said, from the way I see it, this is a lot easier than what we're doing right now. I said, [coworker] are you trying to dump something on me. [After the pilot program] I said you're gonna have to fight me to get this back." – Project Inspector, TxDOT

"Overall for me, [HeadLight] was easy, I like the features that were put in here, it was awesome. Easy to take with you. It's pretty" – Project Inspector, TxDOT

Quotes Related to Usefulness of the HeadLight Capabilities and Features

"Can't live without the instant availability of photo observations." – Project Inspector, WSDOT

In reference to observations taken using HeadLight - *"[The information collected by HeadLight] is objective. Our eyes are never going to be the same when we measure." – Project Inspector, TxDOT*

"Some of the pictures look like you're there on the job." – Project Engineer, TxDOT

Regarding the location stamping – *"We had an issue with a frontage road not draining, went out and got the picture before it rained, then took the picture of after, how much rain came, and how much drained." – Project Engineer, TxDOT*

In reference to QR create and scan capabilities in HeadLight - *"Samples that sent into district lab months ago, that they still don't' have results. Can find out when they picked it up, scanned it into your system. Could easily save weeks if you had that kind of tracking." – Project Engineer, TxDOT*

"Absolutely love the functionality of it, the metadata the pictures, the amount of information you are able to get in in such a short amount of time." – Project Engineer, TxDOT

"I'd just as soon keep that (points to HeadLight Inspection Unit). [Before] I would get contractor to take pictures, print 'em out, then give 'em to my book keeper. With that thing, I could take a picture and email 'em to my book keeper." – Project Inspector, TxDOT

"When the pilot first started, I would only take a photo of an activity once. I would not take pictures of the same activity being performed at a different location because I thought it looked the same (redundant, same activity just in a different location). But after talking to [a HeadLight Support Staff], he pointed out that taking photos shows progress of work so I started to take more photos and videos." – Project Inspector, TxDOT

In reference to the Inspector's Tool Kit - *"I'm lovin' being able to scroll through the plans" – Project Inspector, TxDOT*

"No, I didn't want to give it up. I wanted to give up that laptop. By me going out in the field, taking pictures, adding things. I was loving that, being able to go back and clone, then modify things." – Project Inspector, TxDOT

"Camera, taking the pictures, signature all of that comes in handy. Without it, it takes the fun away" – Project Inspector, TxDOT

In reference to looking at plans and specs using HeadLight - *"Hard copies are good, but the iPad is a lot faster, then boom, it would bring it up right away. Limited space, and don't want to lean over to the passenger seat all day. You can enlarge it." – Project Inspector, TxDOT*

In reference to HeadLight's photo observations with annotations integrated with notes. – *"We were down to using our cell phones before, you start accumulating all that on your phone. I prefer this because it's Johnny on the spot. I liked that you could widen it up, then circle the detail area" – Project Inspector, TxDOT*

In reference to the capabilities of HeadLight - *"I like the whole aspect of it. It covers everything I'm doing out there. It's right there at your fingertips." – Project Inspector, TxDOT*

"I check my email every day now. All in one, this is great man, I love it." – Project Inspector, TxDOT

"[I] hardly took any pictures at all [before]. [With HeadLight], every day. All day long, morning afternoon, tracking progress. Pictures speak 1000 words, I could just add on the bottom his notes." – Project Inspector, TxDOT

Quotes Related to Overall Usefulness of HeadLight

"Yes, more content, more efficient. I like the way it would organize things. Getting in to my advanced age, the less I have to remember the better." – Project Inspector, WSDOT

"Managing and recording what's happening is so much easier with HeadLight than writing stuff in the field notebook." – Project Engineer, WSDOT

"I would absolutely want to keep it [HeadLight Inspection Unit]. This thing was with me all the time, it was nice." – Project Inspector, MnDOT

"I think we need to proceed with the use of this program. This is the way to go for the future." – Project Inspector, MnDOT

"Showed us the light, and now you're taking it away!" – Project Engineer, TxDOT

"My employees enjoyed what they were doing." – Project Engineer, TxDOT

"Allows me to make decisions from wherever I am." – Project Engineer, TxDOT

"HeadLight will help me in claims." – Project Engineer, TxDOT

"I was probably more opposed to it vs. 80% of the people. What y'all have done is phenomenal. It's made my life so much easier." - Project Inspector, TxDOT

[Do you want to give HeadLight up?] "Hell No, you can quote me on that." – Project Inspector, TxDOT

"Groundbreaking for us. Now I feel better about doing my job. I don't have to go back to the office and type this up, then come back out here in 20 minutes." – Project Inspector, TxDOT

"Barricade inspection will save a lot of people a lot of headaches. Save state and contractors a bunch of liability for accidents due to traffic control." – Project Engineer, TxDOT

In reference to HeadLight - *"I was really impressed." – Project Inspector, TxDOT*

"Can I keep it!? Actually I lost it… (joke) If TxDOT decides to go with the device and the HeadLight app, I would support the use of Headlight." – Project Inspector, TxDOT

"I'd say my work ethic would shoot to the sky. The laptop wastes a lot of time." – Project Inspector, TxDOT

"I like the layout that you have on [HeadLight]. [It's] simple to read, if you need to go to another section, it's right there." – Project Inspector, TxDOT

"I don't want to part with it, that's the honest truth." – Project Inspector, TxDOT

"I'm gonna miss this bad boy [referring to HeadLight]. For me, being new, it's been very convenient and very helpful." – Project Inspector, TxDOT

Quotes Related to Safety

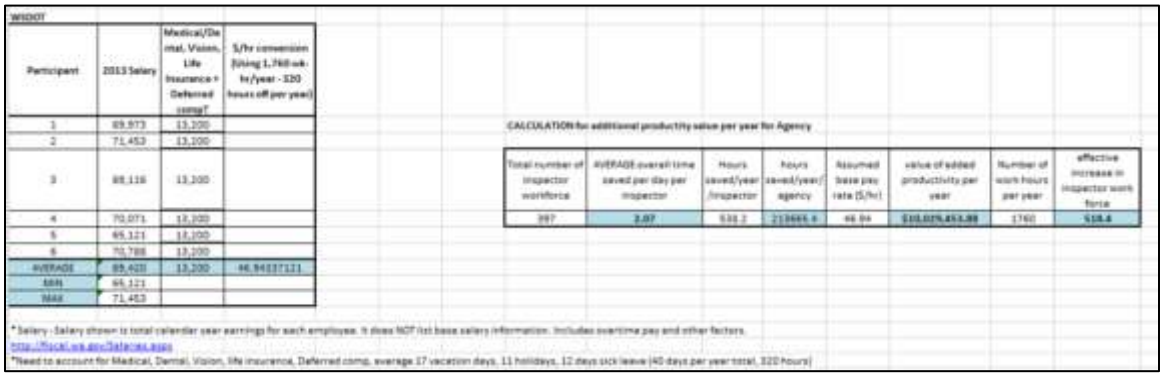
"[I] strapped it to [my] wrist and climbed [the] ladder. No issues." – Project Inspector, MnDOT
"I suppose you can get caught up in looking at the screens. As long as you find a good spot [on the jobsite] to enter in information, it's safe. No different than carrying a set of plans." – Project Inspector, MnDOT

Quotes Related to Data Searchability

"If we had HeadLight and could do a key word search, would have been so much easier." – Project Engineer, TxDOT

"Now in [current agency system], there's no search function. Not at all. Just have to remember by date [to search for content]. It's very important to have a good search [function]. [The] need to search happens often, 50% of the time" – Project Manager, TxDOT
"Project, with a big claim, $500,000 claim. They had to go back. This project had several project managers, then had a temporary person, then someone else to close the project, book keeper retired. Just to find information for that claim. (That's why contractor took advantage). Very hard to have continuous information and would try to fish for information in site manager." – Project Engineer, TxDOT

Appendix H – Pay Rate Calculations



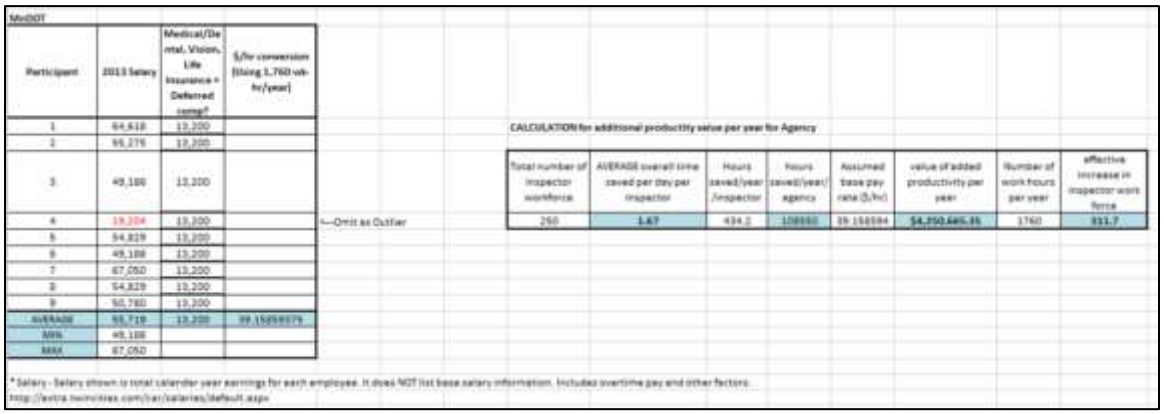
WSDOT

Participant	2013 Salary	Medical/Dental, Vision, Life Insurance + Deferred comp?	$/hr conversion (Using 1,760 wk-hr/year - 320 hours off per year)
1	69,973	13,200	
2	71,453	13,200	
3	88,116	13,200	
4	70,071	13,200	
5	95,121	13,200	
6	70,786	13,200	
AVERAGE	89,420	13,200	46.94337121
MIN	95,121		
MAX	71,453		

CALCULATION for additional productivity value per year for Agency

Total number of inspector workforce	AVERAGE overall time saved per day per inspector	Hours saved/year /inspector	Hours saved/year/ agency	Assumed base pay rate ($/hr)	value of added productivity per year	Number of work hours per year	effective increase in inspector work force
397	2.07	538.2	213665.4	46.94	$10,029,453.88	1760	518.4

* Salary - Salary shown is total calendar year earnings for each employee. It does NOT list base salary information. Includes overtime pay and other factors.
http://fiscal.wa.gov/Salaries.aspx
*Need to account for Medical, Dental, Vision, life insurance, Deferred comp, average 17 vacation days, 11 holidays, 12 days sick leave (40 days per year total, 320 hours)



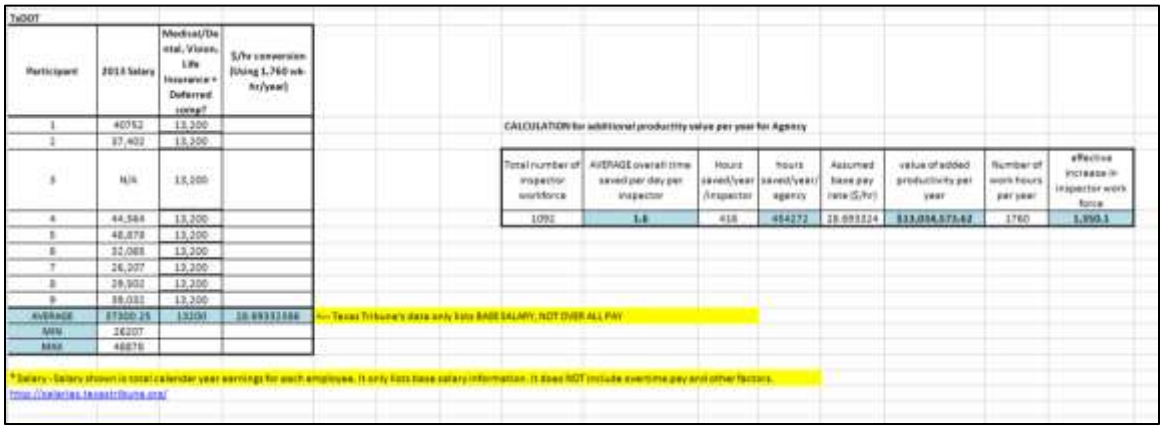
MnDOT

Participant	2013 Salary	Medical/Dental, Vision, Life Insurance + Deferred comp?	$/hr conversion (Using 1,760 wk-hr/year)	
1	64,618	13,200		
2	96,276	13,200		
3	49,188	13,200		
4	19,204	13,200		<--Omit as Outlier
5	54,829	13,200		
6	49,188	13,200		
7	67,050	13,200		
8	54,829	13,200		
9	50,780	13,200		
AVERAGE	55,719	13,200	39.15894375	
MIN	49,188			
MAX	67,050			

CALCULATION for additional productivity value per year for Agency

Total number of inspector workforce	AVERAGE overall time saved per day per inspector	Hours saved/year /inspector	Hours saved/year/ agency	Assumed base pay rate ($/hr)	value of added productivity per year	Number of work hours per year	effective increase in inspector work force
250	1.67	434.2	108550	39.158894	$4,250,665.35	1760	311.7

* Salary - Salary shown is total calendar year earnings for each employee. It does NOT list base salary information. Includes overtime pay and other factors.
http://extra.twincities.com/bar/salaries/default.aspx



TxDOT

Participant	2013 Salary	Medical/Dental, Vision, Life Insurance + Deferred comp?	$/hr conversion (Using 1,760 wk-hr/year)	
1	40762	13,200		
2	87,402	13,200		
3	N/A	13,200		
4	44,564	13,200		
5	48,878	13,200		
6	32,068	13,200		
7	26,207	13,200		
8	28,902	13,200		
9	38,032	13,200		
AVERAGE	37500.25	13200	38.69331084	<-- Texas Tribune's data only lists BASE SALARY, NOT OVER ALL PAY
MIN	26207			
MAX	48878			

CALCULATION for additional productivity value per year for Agency

Total number of inspector workforce	AVERAGE overall time saved per day per inspector	Hours saved/year /inspector	Hours saved/year/ agency	Assumed base pay rate ($/hr)	value of added productivity per year	Number of work hours per year	effective increase in inspector work force
1092	1.6	416	454272	38.693324	$33,004,573.62	1760	1,390.1

* Salary - Salary shown is total calendar year earnings for each employee. It only lists base salary information. It does NOT include overtime pay and other factors.
http://salaries.texastribune.org/