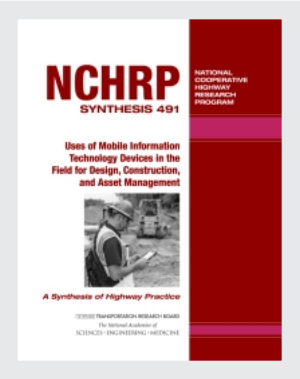

Uses of Mobile Information Technology Devices in the Field for Design, Construction, and Asset Management

DETAILS

113 pages | 8.5 x 11 | PAPERBACK

ISBN 978-0-309-43822-3 | DOI 10.17226/23410

AUTHORS

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NCHRP
SYNTHESIS 491

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Uses of Mobile Information Technology Devices in the Field for Design, Construction, and Asset Management

A Synthesis of Highway Practice

TRB TRANSPORTATION RESEARCH BOARD
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Subscriber Categories
Construction • Data and Information Technology • Design • Highways

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2016
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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NCHRP SYNTHESIS 491

Project 20-05 (Topic 46-06)
ISSN 0547-5570
ISBN 978-0-309-27212-4
Library of Congress Control No. 2015959625

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are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

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Cover figure: Image from the January 9, 2015, FHWA Innovation Implementation EDC Newsletter. *Source:* https://www.fhwa.dot.gov/innovation/everydaycounts/edcnews/01092015.cfm.

FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Tanya Zwahlen
Consultant
Transportation
Research Board

This report documents the state-of-the-practice and state-of-the-art applications of state transportation agencies related to their use of mobile information technology (IT) devices in the field for the areas of design, construction, and asset management. Mobile IT devices such as laptop computers, mini-laptop computers, handheld multifunctional data collectors, tablets, and smartphones play a critical role in bringing the transportation industry into digital platforms.

The synthesis was developed through a literature review and surveys to gather information from end users and IT professionals at state transportation agencies.

Gabriel B. Dadi, Roy E. Sturgill, Jr., and Xi Wang, University of Kentucky Research Foundation, Lexington, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

USE OF MOBILE INFORMATION TECHNOLOGY DEVICES IN THE FIELD FOR DESIGN, CONSTRUCTION, AND ASSET MANAGEMENT

SUMMARY

In this study, a survey synthesizes the state-of-the-practice and state-of-the-art applications of state transportation agencies (STAs) related to their use of mobile information technology (IT) devices in the field for the areas of design, construction, and asset management. Mobile IT devices are defined as laptop computers, mini-laptop computers, handheld multifunctional data collectors, tablets, and smartphones. They play a critical role in the e-construction, civil integrated management (CIM), and Every Day Counts (EDC) initiatives to bring the transportation industry into more digital platforms. Surveys were conducted to gather information from select end users and IT professionals at STAs. One hundred survey responses were received from various STA divisions in 42 states. The respondent mix can be seen in Figure 1.

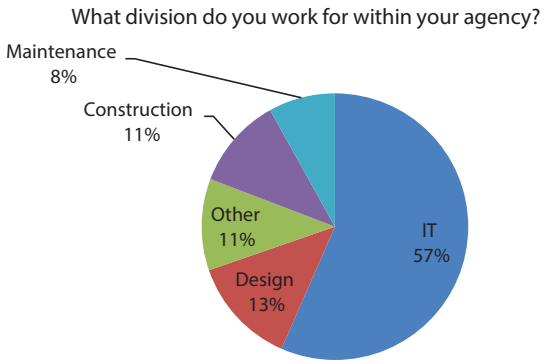

FIGURE 1 Summary of respondent mix within agencies.

The responses were used to classify the STAs in terms of their level of technology adoption. The majority of STAs that responded use mobile IT devices; however, most believe they are low-level adopters (Figures 2 and 3). STAs of varying levels were identified for a more thorough evaluation, and follow-up case studies were conducted to enrich the survey responses and gather details regarding mobile IT use.

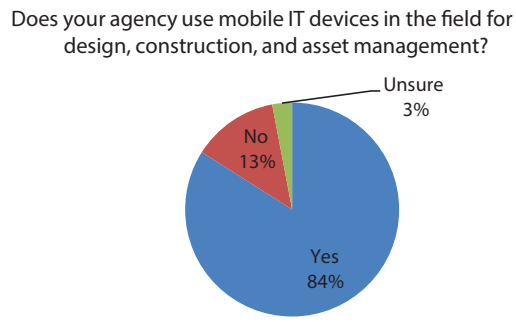

FIGURE 2 Summary of agency mobile IT use in the field.

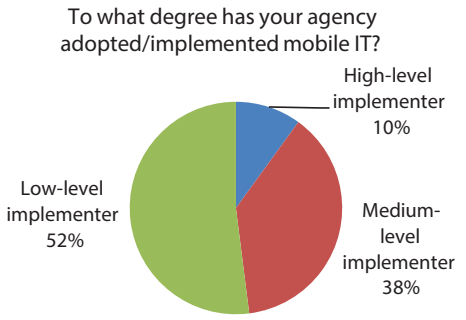

FIGURE 3 Summary of agency adoption level.

The objectives of this synthesis study are to identify—

- Processes for identifying, selecting, and evaluating mobile IT uses
- Potential mobile IT field uses in design, construction, and asset management
- Procedures for application development, integration, and optimization
- Potential benefits of adopting mobile IT in design, construction, and asset management
- Challenges and issues associated with mobile IT use in design, construction, and asset management
- Strategies for successful implementation of mobile IT use in design, construction, and asset management
- Strategies for managing the data collected by mobile IT devices
- Advances and emerging technologies to consider for mobile IT use in design, construction, and asset management.

The following are highlights of the findings of this synthesis:

- Processes for identifying, selecting, and evaluating mobile IT uses
  - STAs vary in their flexibility to procure mobile IT devices, from an annual purchasing contract to being able to open-purchase devices. Agency IT groups vary in their involvement, from being in complete control of the solution procurement to offering various levels of support or even no support at all for the solution. The approach identified as optimal is for the end user to work collaboratively with the IT business unit to select a device and solution that will meet the needs of the end user; adapt it to the security, connectivity, and compatibility of the agency's systems; and ensure that there is a favorable cost-to-benefit ratio.
- Potential mobile IT field uses in design, construction, and asset management
  - Communication, photo and video capturing, and information referencing all save time by reducing the need for travel. Other basic functions of many of the mobile IT devices are beneficial as well. More details on specific uses are highlighted in chapter five.
- Procedures for application development, integration, and optimization
  - STAs use three basic types of applications: those customized for the agency, whether developed in-house or by a consultant; out-of-the-box solutions in which the agency has adapted its process to the application; and out-of-the-box solutions modified for the agency's process. The findings of the case studies suggest that the technology industry has not focused on the transportation industry's needs in application development.
- Potential benefits of adopting mobile IT in design, construction, and asset management
  - By far the most frequently identified benefit of mobile IT devices was time savings. The use of these devices reduces travel time to access resources, limits construction delays while seeking direction or approval of changes, and (assuming application and device connectivity) enables immediate data entry.

  - Another identified benefit is the quality of data captured. GPS locations are more accurate than using landmarks or some other means in lieu of surveying, and entering information once instead of transcribing notes maintains information quality.
- Challenges and issues associated with mobile IT use in design, construction, and asset management
  - The most significant reported challenge to mobile IT use was service availability. Each state interviewed commented on areas of low or unavailable cellular coverage. Some have been able to compensate by using devices or applications that operate when they are disconnected and synchronize with systems once service is restored.
  - Another challenge has been personnel resistance to using mobile IT devices. Training focused on the devices, their uses, and the associated benefits may help alleviate these issues.
  - Table 1 lists the greatest challenges from both the IT and end user perspectives. IT professionals are concerned about maintaining and supporting the devices and their applications. Users are more concerned about cost-effectiveness, connectivity, and poor/ineffective applications.

TABLE 1
RANKING OF MOBILE IT CHALLENGES

Challenges	IT Overall Rank	End User Overall Rank
Connectivity issues (loss of cell signal)	1	2
Device maintenance and user support	2	3
Application maintenance and support	3	6
Cost-effectiveness	4	1
Poor/ineffective applications	5	4
Interoperability issues (software incompatibility)	6	7
Lack of security of collected data	7	14
Poor durability/lack of ruggedness	8	8
Electronic signatures/approval	9	13
Quality of collected data	10	11
End user resistance	11	10
Training requirements	12	9
Battery life	13	12
Deploying devices to employees	14	5
Other	15	15

- Strategies for successful implementation of mobile IT use in design, construction, and asset management
  - A key strategy for the successful implementation of mobile IT devices in design, construction, or asset management involves close coordination between the end user and the IT provider or solution manager. The case study findings suggest that if these two subject matter experts collaborate, they can create a strong solution that produces tangible benefits and is easy to implement and use.
  - Trials and follow-up lead to successful implementation. Trials should be carefully coordinated between IT and end users to identify pitfalls and determine resolutions. Follow-up efforts by IT are necessary after programmatic implementation of a new solution.

  - Once a solution is determined, training should specifically illustrate the ease of use and the benefits to the end user. The case studies suggest that use of the device must be illustrated in a manner that is understandable and relevant to all technology skill levels. Multiple levels of training may be necessary.
- Strategies for managing the data collected by mobile IT devices
  - The most frequent strategy is to collect and share data with the other stakeholders on a project; however, sometimes the individual collector retains the data.
- Advances and emerging technologies to consider for mobile IT use in design, construction, and asset management. As mobile technologies advance, more tools will become available to end users.
  - The ability to capture and develop 3D models using photogrammetry or mobile light detection and ranging (LiDAR) is becoming more readily available.
  - Increasing accuracy in GPS functional devices improves location services for surveying grade capabilities.
  - Increasing cellular coverage and network speeds open doors to more applications and faster data sharing. Video conferencing from the field is already possible and could become standard.

STAs use mobile IT devices in many ways, including to increase production and to create and access remote information. Mobile IT devices are emerging, improving, and offering a multitude of benefits at a relatively low cost. They have become an integral part of daily life but have yet to be incorporated into full use by transportation agencies. Research could investigate emerging technologies and provide guidance to STAs regarding best practices; uses; and strategies for selection, function, implementation, and integration into the transportation industry. Development of a formal methodology to identify the costs and benefits of mobile IT devices could stimulate widespread adoption. This area is dynamic and will continue to change as technologies such as unmanned aerial vehicles (UAVs) and mobile LiDAR advance.

CHAPTER ONE

INTRODUCTION

Mobile information technology (IT) devices offer an avenue for state transportation agencies (STAs) to increase efficiency, data richness, and communication. These devices offer a host of benefits over traditional methods of data capture and reporting. Mobile IT devices are an integral part of everyday life, but the transportation industry has only scratched the surface of their potential benefits. This chapter offers an overview of the subject of using mobile IT devices in the field for design, construction, and asset management. Background information is provided, including definitions and terminology applicable to the field.

BACKGROUND

Increasingly, STAs seek to increase productivity in response to infrastructure demands while simultaneously facing staffing concerns. This situation presents some very significant challenges, and technology can help manage these issues. One rapidly advancing area of technology support is mobile IT devices, specifically their field applications. Highway administrators, engineers, designers, technicians, and contractors have access to an increasing variety of advanced and powerful data tools (*1*). These technologies can help STAs increase productivity to maintain or improve their current level of service. Cost savings can be realized by using the devices to share data throughout the agency and among partners. For instance, Michigan DOT estimated annual cost savings of $12 million just from reduced use of paper, postage, envelopes, and storage (*2*). Transportation projects require that a large amount of data be collected, processed, and shared among various people in different divisions; mobile IT is adept at serving these functions.

The complicated nature of transportation projects requires physically dispersed participants—such as contractors, designers, workers, suppliers and customers—to cooperate and communicate for successful project delivery (*3*). However, as Aziz et al. stated, "Collaboration needs of site-based staff and other mobile workers are not well addressed" (*4*). In this context, mobile technology could have a significant influence on improving the efficiency of collaborative project processes. Currently, IT is used to exchange drawings, pictures, schedules, documents, and other workflow-related information (*5*). Although some researchers have reported that rapid technological improvements in mobile devices did not significantly improve project efficiency (*6*), many STAs that are experiencing staff reductions have compensated by deploying more advanced technologies, especially mobile IT devices, to ensure that the existing service capability will not change. These mobile IT applications can be found throughout the agencies.

For example, using mobile IT applications in the construction area improves the infrastructure, applications, communications, and processes of the organizations (*7*). The devices can improve communication on jobsites by enabling people to easily share data and pictures. They can also keep project participants connected in the field and updated with the latest project information and workflow. In some of the case studies, data were updated in accounting systems so that the overall performance of the agency, as well as the progress of each project, could be viewed at any time. Mobile applications can be easily integrated with agency operation systems, such as payroll. Using smartphones, tablets, and other mobile devices, team members can view images and other information onsite and communicate with the office and with participants in other divisions. They can review documents and images, share updates with project team members, and manage tasks and issues related to the project. Mobile IT can also assist with the coordination of multiple projects in an agency.

STAs benefit from the use of mobile IT devices and applications such as tablets, software technologies, and application software, with their powerful functional capabilities and continuous innovations. These devices are providing agencies with efficient ways to communicate, obtain feedback, complete inspections, and digitally sign documents. They help the STAs move toward a paperless environment, manage activities in multiple projects, and access a wide array of data for better decision making. Mobile IT helps convert downtime into productive time and allows individuals to access enterprise data that provide up-to-date information and business insights.

Mobile IT can increase opportunities, information sharing, and efficiency on a wide variety of projects and can facilitate cooperation among different divisions in an STA. However, if it is not effectively implemented, its value will not be realized. Application of a new technology requires the transportation agency to examine all

potential costs (e.g., equipment purchase, accessories, training, connectivity, and maintenance) and benefits (*1*). The introduction of a new technology into any agency also carries a certain amount of risk; thus, it is important to identify potential challenges and obstacles in order to pass through the adoption phase smoothly. In a recent survey of STAs, only 10% had conducted a cost-benefit analysis of their technology use (*8*).

Transportation agencies face certain typical challenges in deploying mobile IT devices and related applications. First, the new devices might not be introduced independently. They might come with corresponding systems, including a variety of mechanical and computer components, that necessitate technical expertise and special training to ensure the effective use of the devices. Texas DOT has managed this training through an extensive YouTube page that hosts videos that show employees how to use new technology. Second, STAs typically benefit from the continuous innovation and updating of IT; however, technologies change fast and agencies must keep pace with upgrades to ensure that they maintain their current level of services. This might mean more investment and involvement. Ensuring the effective use of mobile IT can sometimes be a challenge; for example, unsupervised use of mobile devices at a construction site for data collection and interdivision communication can lead to unintended and unproductive outcomes. Device and data security also could be an issue. And finally, acceptance of and adaptability to new technology often varies among individuals on the basis of age, education, and experience. Agencies can face resistance to change or adoption when they try to deploy a new technology (*9*).

Mobile IT is a feasible alternative in communication, reporting, and logistics, but opinions differ regarding its use in practice. Mobile IT applications can fully reflect their value when they are used in daily operations, but they may not offer sufficient strategic solutions for the core business because their capabilities are not fully utilized. Until STAs and their employees are able to exploit a wide range of functions and applications, they will not benefit from the potential value of these devices in projects and operations (*10*).

LITERATURE REVIEWED AND STUDY SIGNIFICANCE

Several recent studies suggest opportunities and potential applications of mobile IT devices for field use at STAs, and some attempt to summarize the applications under way at various STAs. This section summarizes the most relevant findings and their alignment with this synthesis, especially regarding field use of mobile IT in design, construction, and asset management, along with the practices of technology acquisition, integration with existing systems, and implementation. Table 2 summarizes surveys similar to that conducted for this synthesis and reports their key findings.

TABLE 2
SUMMARY OF PREVIOUS MOBILE IT SURVEYS

Date	Study	Number of Responses	Key Findings
April 2011	PennDOT Construction IT Survey (*11*)	17	• Few states using or considering mobile devices • Those using devices are using personal digital assistants
December 2012	AASHTO 2012 Fall IT Survey (*12*)	27	• Variety of levels of mobile IT adoption and application development • Most respondents rely on commercially available solutions • Most allow personal devices to access agency data
November 2013	WisDOT Usage of Mobile IT Devices for State DOT Field Operation Synthesis Report (*13*)	75	• Most use mobile devices for inspection activities in construction and asset management • Mobile devices are replacing digital cameras and recording devices but not ready to replace laptop computers • Cost, data security, and lack of mobile applications are the biggest deterrents

In response to STA studies of the use of mobile IT devices, several national initiatives seek to push the industry forward into a more digital world. The FHWA developed an implementation plan in January 2015 to promote innovation in the transportation industry through the third phase of the Every Day Counts initiative (EDC-3) (*14*). This phase focuses on e-construction, which seeks to reduce hard copy documentation in transportation construction projects. Through research and outreach activities, EDC-3 identifies, promotes, and publishes the benefits of e-construction activities (*14*). The lead states in this effort have undertaken major steps toward a paperless environment. Many of them claim to be over 90% paperless, using a variety of software, including SiteManager, Citrix, Blue Beam, ESRI, and ProjectWise (*15*). Mobile IT devices are a critical component of the move toward paperless field practices.

It is clear that technology and applications are rapidly advancing, although some barriers are present in national adoption. This synthesis documents the move toward standardization of mobile IT practices for design, construction, and asset management uses. Additionally, the study highlights the most significant barriers to standardized adoption in an effort to push the state of the practice toward the state of the art.

SYNTHESIS OBJECTIVE

This synthesis study gathered state-of-the-practice information regarding the current and potential uses of hand-

held mobile IT devices by field staff at STAs in the areas of design, construction, and asset management. Collection of field-sourced data can and should be streamlined for ease of use, ease of transfer, ease of organization, and, ultimately, ease of analysis. In this project, mobile IT devices are defined as agency-issued laptop computers, mini-laptop computers, handheld multifunctional data collectors, tablets, and smartphones. Historically (and in many cases currently), field data have been collected as written records and photographs. Although these methods are efficient enough for collection, the transfer and use of the data incur inefficiencies and degradation of data quality, and lack the rich data collection abilities of current technologies. Many STAs have been investing in technology trials to streamline these procedures, with both successes and failures. The purpose of this synthesis is to summarize current practices, uses, and selection and adoption techniques so that a broader agency forum can benefit from a previously blazed trail. Specifically, the synthesis will collect the following information:

1. Current transportation agency uses of mobile IT in the field for design, construction, and asset management
2. Cross-functional (i.e., design, construction, and asset management) use of mobile IT devices
3. Array of devices used and their associated platforms, interfaces, connectivity, compatibility, etc.
4. Array of application types used and their associated protocols, source coding, deployment, and development
5. Sources of applications, development, and optimization
6. Cross-sector use of applications; that is, adapting applications and technologies from other industries
7. STA collaboration on application development or mobile IT use
8. Existing standards or specifications for application development within the transportation sector
9. Adoption and implementation barriers, challenges, and strategies for success
10. Direct efficiencies incurred through mobile IT use
11. Costs and benefits of STA use of mobile IT devices
12. Selection procedures and strategies for STA selection, evaluation, and adoption of mobile IT devices
13. Formal division policies on the use of mobile IT devices for STAs.

KEY DEFINITIONS

This section defines the terminology used throughout the report. The goal is to explain the scope of the technologies considered as well as the scope of the applications and uses of the devices. These definitions are presented in two categories: those dealing with mobile IT technology and potential use areas within the STA.

In this project, *mobile IT devices* are defined as laptop computers, mini-laptop computers, handheld multifunctional data collectors, tablets, and smartphones. These are typically agency-issued devices. *Mobile applications* are computer programs designed to run on smartphones, tablets, laptops, and other mobile devices to accomplish a subset of functions or data capture.

It is important to understand STA field functions and needs in the areas of design, construction, and asset management. The following list includes a sampling of those functions and needs:

- Design
  - Locating physical and design features during field visits
  - Referencing 3D models, plans, specifications, and design guidance materials in the field
  - Photo and video capturing during site visits
  - Timely communication and decision making.
- Construction
  - Locating physical and design features during construction to resolve questions or create as-built plans
  - Referencing 3D models, plans, specifications, and construction guidance materials in the field
  - Recording work reports and quantities, identifying change orders and pay items
  - Conducting inspections, quality assurance, and oversight
  - Timely communication and decision making.
- Asset Management
  - Locating physical and transportation features during inventory
  - Recording condition report data for pavement, sign, or structure inventories
  - Timely communication and decision making.

STUDY APPROACH

An extensive literature review provides background material for the current state of research on mobile IT devices. This process assisted in the development of a survey to capture the state of practice within STAs.

A survey was designed under the guidance of the topic panel to gather input from professionals in design, construction, asset management, and information technology. Electronic survey

software was provided that enabled widespread dissemination. Once the survey had been created, an e-mail request with a link to the survey was sent to the AASHTO Standing Committee on Finance and Administration Subcommittee on Information Systems. This subcommittee works mainly in the IT area, but the e-mail requested that members forward the survey to others in the areas of design, construction, and asset management. The majority of respondents were from the IT sectors. This information can be seen in Appendix A.

Case studies were also performed to gather additional insights into the survey data. Because mobile IT devices are a relatively new technology for STAs, input was sought from various levels of implementation. Categorizing states into Everett Rogers' groups from his *Diffusion of Innovations* book, allowed a holistic view of types of devices and applications, uses, and performance evaluations (*16*). However, Rogers' categories were intended for individuals while this survey categorizes STAs, which are institutions. For the purposes of this report, the names of the categories have been modified to better fit the landscape of STAs. These categories and their respective market shares are innovators (2.5%), believers (13.5%), leading majority (34%), following majority (34%), and judicious (16%). People tend to resist change and new technology, so the innovators and leading edge categories include relatively few STAs. Believers consider themselves to be tech-savvy, but they wait until the initial bugs are eliminated. A large segment of the population jumps on board as the leading majority and then the following majority. Finally, the judicious tend to be more calculating and deliberate regarding their technology decisions. See Figure 4 for a graphical depiction of these groups.

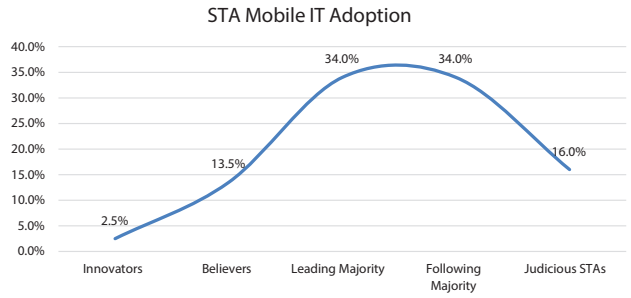

FIGURE 4 Categories of STA technology adoption [adapted from *Diffusion of Innovations* (*16*)].

An STA can diversify its efforts while relying on other STAs to take the lead in certain areas. For example, an STA might decide to have a basic program for mobile IT devices while investing significantly in light detection and ranging (LiDAR), automated machine guidance (AMG), or another aspect of technology. Thus, this STA might lag in the use of mobile IT devices but lead in another area.

To categorize states into one of the groups, two main survey responses were evaluated. Respondents were asked to list the types of mobile devices used in their agencies and what they were being used for. Numerical values were assigned to devices and uses that could be considered a high-level implementation, a medium-level implementation, and a low-level implementation, as seen in Tables 3 and 4. A score of 3 was given for high-level implementation, 2 for medium-level implementation, and 1 for low-level implementation. The scores are averaged and plotted in Figure 5.

TABLE 3
SCORING LEVELS FOR SURVEY RESULTS OF MOBILE IT DEVICES

Score	Mobile Devices
1 (Low)	Laptops, mini-laptops, smartphones
2 (Medium)	Tablets, digital cameras
3 (High)	Handheld multifunctional data collectors, GPS cameras, RFID readers, and laser rangefinders

TABLE 4
SCORING LEVELS FOR SURVEY RESULTS OF MOBILE IT USAGE

Score	Mobile IT Uses
1 (Low)	Access standards and manuals, e-mail, phone calls, text messages, etc.
2 (Medium)	View/edit plans, take photos, view 3D models, and record entries
3 (High)	Take/view geotag photos and videos, RFID scanning, GPS/GNSS coordinates, GIS viewing, and collecting spatial geometry

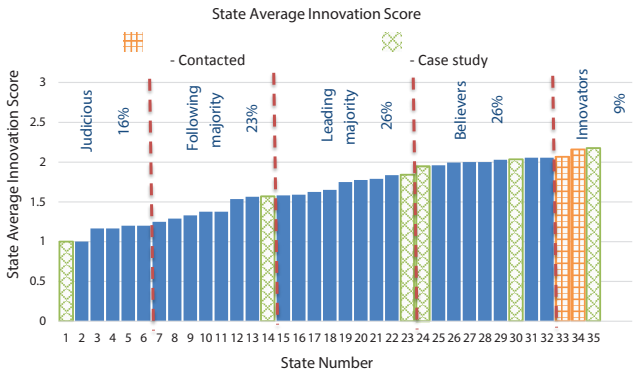

FIGURE 5 State average innovation score.

Eight states were contacted for assistance in the case studies; six agreed to participate. One state from each of the categories participated. Details of the case studies are outlined in chapter five.

SURVEY DEMOGRAPHICS

A nationwide survey was developed to capture critical information regarding the use of mobile IT in design, construction, and asset management. The survey was sent out to members of the AASHTO Standing Committee on Finance

and Administration Subcommittee on Information Systems. Recipients of the survey request were asked to forward the link to professionals in the design, construction, and asset management divisions of their STAs to capture their input. Figure 6 presents a map of the 42 states in which at least one person provided a survey response.

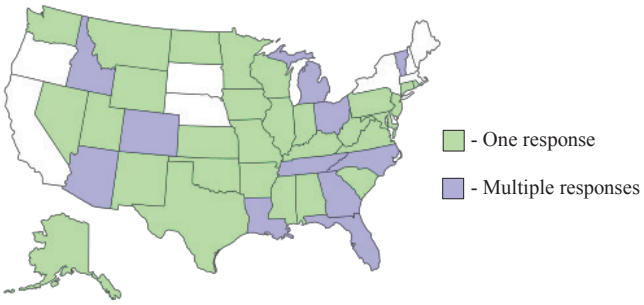

FIGURE 6 Map of states where at least one individual provided a survey response (shaded).

A multidivisional approach was taken to understand the gamut of mobile IT use in STAs; professionals in design, construction, IT, and maintenance were solicited for their participation in the survey. Although the majority of respondents were in IT, 43% were end users (see Figure 7). Certain questions in the survey allowed respondents to select multiple items; thus, many of the bar charts in this report will aggregate to an amount greater than 100%.

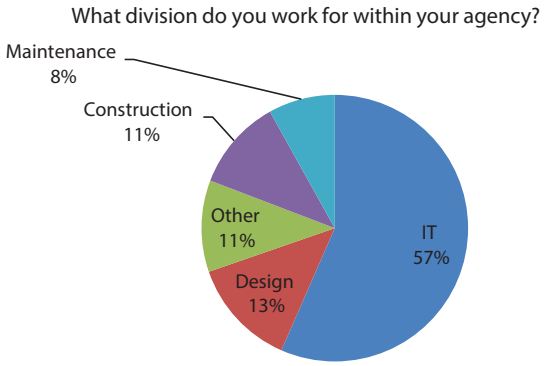

FIGURE 7 Survey respondents by DOT division.

The Transportation Research Board; the National Academies of Sciences, Engineering, and Medicine; and the sponsors of the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear only because they are considered to be essential to the subject.

CHAPTER TWO

MOBILE INFORMATION TECHNOLOGY DEVICES AND APPLICATIONS

SELECTION AND TYPES OF MOBILE DEVICES

For this project, mobile IT devices are defined as handheld technologies that can improve work tasks through a digital platform—devices such as smartphones, laptops, and tablets. Mobile or truck-mounted LiDAR and unmanned aerial vehicles (UAVs) are not considered because they are not handheld devices.

The types of mobile devices used at STAs are chosen by both IT departments and end users; 97% of survey respondents said that IT professionals are involved in the selection of devices, whereas 86% of end users are involved (Figure 8). The parties most affected by mobile IT decisions are the people who manage the purchasing, deployment, and maintenance of the devices (IT) and the ultimate end users in design, construction, and asset management. Many states involve all of those parties in choosing devices.

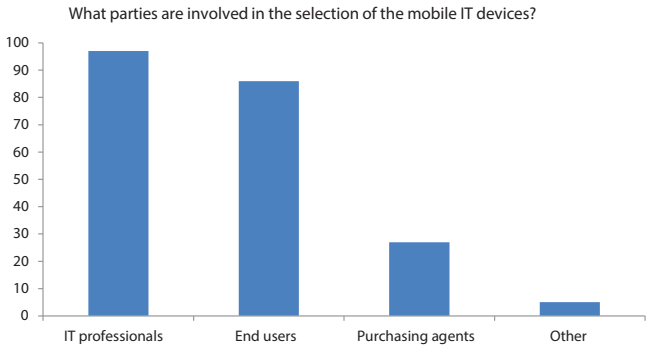

FIGURE 8 Parties involved in device selection.

The majority of STAs—although not all—issue smartphones and laptops to their employees (89% and 87%, respectively) (see Figure 9). In addition, more than 50% of respondents issue tablets, digital cameras, and handheld multifunctional data collectors such as Yumas, Nomads, and Junos by Trimble. A few STAs use laser rangefinders and radio frequency identification (RFID) readers. These results do not include personal devices that might be used for agency business. As was discovered during the case study interviews, some states expect their employees to use an agency smartphone, while others expect them to use personal devices but will pay for the monthly voice and data package.

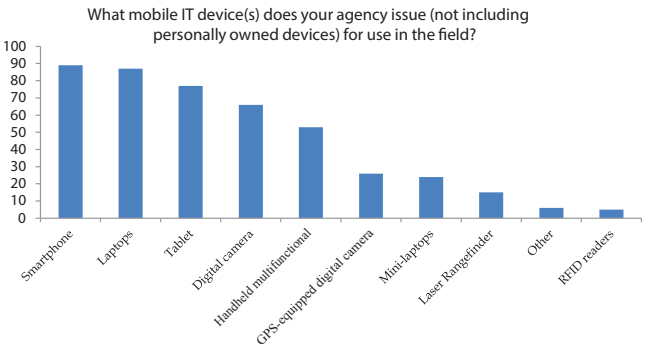

FIGURE 9 Types of mobile IT devices used by DOTs.

As anticipated, the majority of devices run an iOS (Apple) or Windows-based operating system (Figure 10). The newer versions of Windows designed for desktop (Windows 8) and mobile use (Windows RT) are not as common as the older Windows 7. Blackberry and Linux systems have all but fallen out of use in STAs.

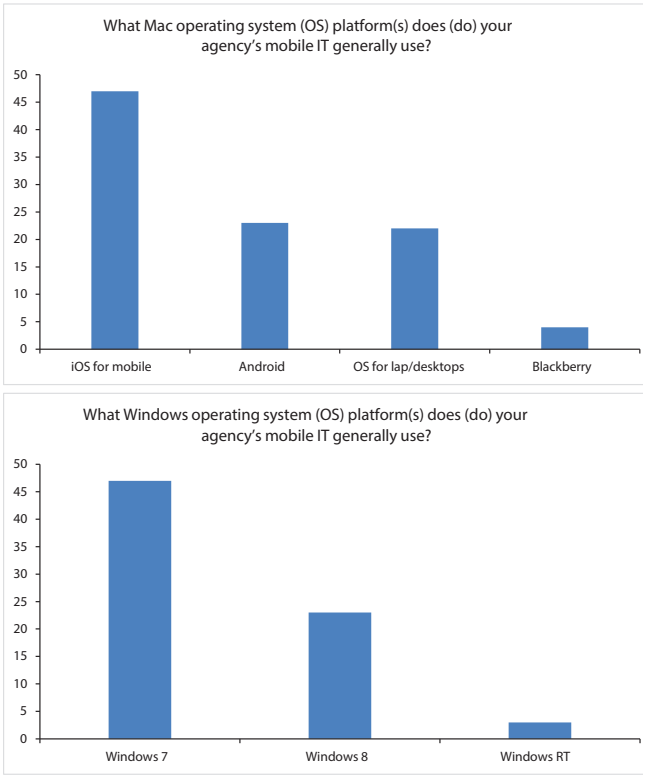

FIGURE 10 Device operating systems.

With a fairly even breakdown in Apple- and Microsoft-based products, various criteria can lead an STA to select one over the other. When the STAs were asked what criteria they considered for mobile IT, the primary consideration was cost, followed by security of data and ease of use (Table 5). They gave little consideration to the availability of applications for a device or operating system, perhaps because, across multiple platforms, few applications are specifically designed for the transportation industry. Using a device that is an agency standard weighed more heavily than other criteria.

TABLE 5
MOBILE IT DEVICE SELECTION CRITERIA CONSIDERATIONS BY DIVISION

Criteria	IT Overall Rank	End User Rank
Security of data	1	5
Cost	2	1
Ease of use	3	2
Agency standard	4	7
Interoperability	5	8
Durability	6	3
Operating system	7	4
Available native applications	8	6
Other	9	9

DEVICE AVAILABILITY AND USE

Once the mobile devices are selected and purchased, it is critical to make them available to the appropriate parties. Whether it is a project designer, an inspector in construction, or a maintenance worker in asset management, the end user must find value in the device, using it to assist with or replace a typical work function in an efficient manner. For STAs, the primary functions for mobile IT devices are to send and receive e-mails, make phone calls, and send text messages (Figure 11). Other primary functions are entering records and accessing standards. When it comes to advanced use of mobile IT devices, there is a lag in practice. Fewer than half of the respondents use mobile devices for GIS, RFID technology, or editing plans, which are in their infancy. The least-used function of mobile IT devices is viewing 3D models, although this might be a front-end issue (i.e., 3D models are not created in the project). Several states, including Wisconsin and Michigan, have significant ongoing e-construction efforts that emphasize viewing 3D models on mobile devices, but they are in their infancy. The lack of advanced use can be attributed to policies, procedures, or training, which are further discussed in chapter three.

Although many agencies use mobile IT devices, survey respondents said that distribution of the devices remains limited. The majority of survey respondents said that mobile IT device use on projects is between 0% and 25% within their divisions (design, construction, or asset management) and at the agency level (Figure 12). In chapter five, considerations for the use of mobile IT devices are examined; as expected, more complex and larger-scale projects are more likely than smaller and more routine projects to use mobile IT.

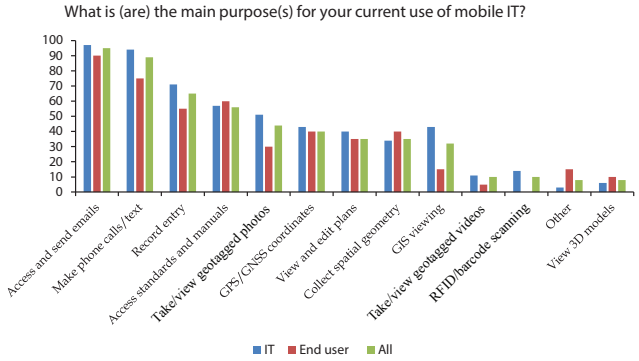

FIGURE 11 Uses of mobile IT devices.

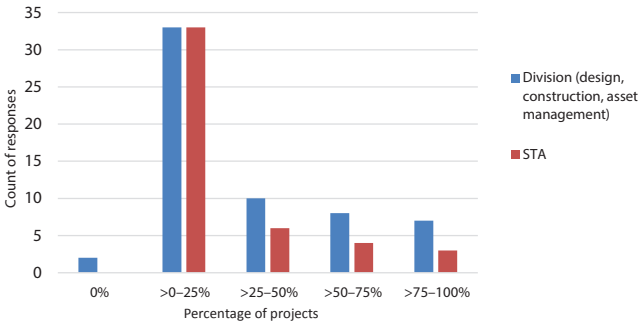

FIGURE 12 Perceived percentage of projects and functions using mobile IT devices.

APPLICATION DESIGN AND DEVELOPMENT

Most STAs rely on mobile IT devices to access e-mails and make phone calls, but numerous applications exist that can help agency employees in the field performance of tasks, even though few are specifically designed for the transportation industry.

Application use is varied and inconsistent. The most frequently used applications are the software suite from Microsoft Office, mobile SiteManager applications recently released from AASHTOWare, and in-house agency-developed applications (Figure 13). As mobile devices become more popular, a shift is expected toward cloud-based and web-based software such as Office 365. The development of commercially available and transportation-specific applications, along with standardizing of their use, could help with the adoption of mobile IT.

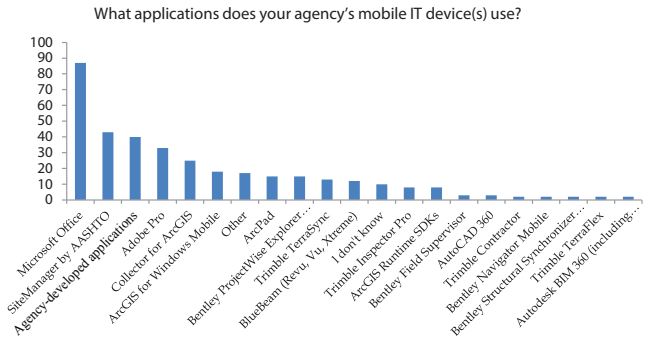

FIGURE 13 Most frequently used applications on mobile devices.

The large number of applications used can be attributed to the fact that most applications are purchased off the shelf or downloaded from an app store (Figure 14); typically, they are only partially applicable to and rarely specific to transportation. Android, Apple, and Windows application stores offer numerous engineering-related apps to help with calculations, reading standards and codes, and viewing design files. IT departments also create their own apps through fully in-house operations, consultants, a partnership of consultants and in-house input, or internal modification of an existing application.

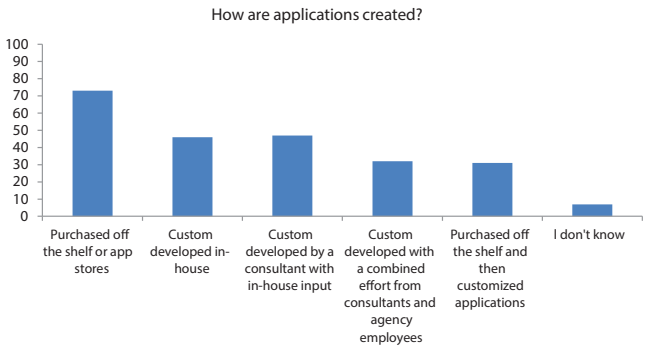

FIGURE 14 Application creation strategies.

Applications are part of the constantly evolving world of technology and frequently require updates to improve their performance and address bugs. Most STAs (76%) use their IT infrastructure to push updates of the applications to the devices (Figure 15). About 30% of respondents rely on the end user to update the applications in response to push notifications from the app store (Figure 15).

These applications are primarily web-based (90%) and require some kind of Internet connection to function properly and upload information (Figure 16). This is a problem in many states that have connectivity issues in rural areas. Some states have addressed the problem by using apps that can store data while they are in an unconnected state and then update once they obtain a cellular signal.

In the case studies, a few states mentioned that they have explored using software as a service (SaaS) or cloud-based systems. These services require trust in the server system for security, connectivity, and access needs, but they can be a cost-effective measure for certain products.

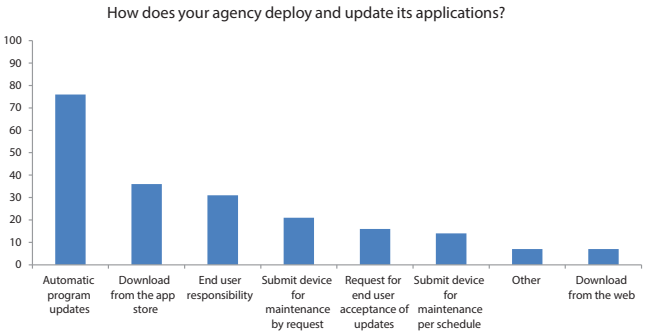

FIGURE 15 Application update strategies.

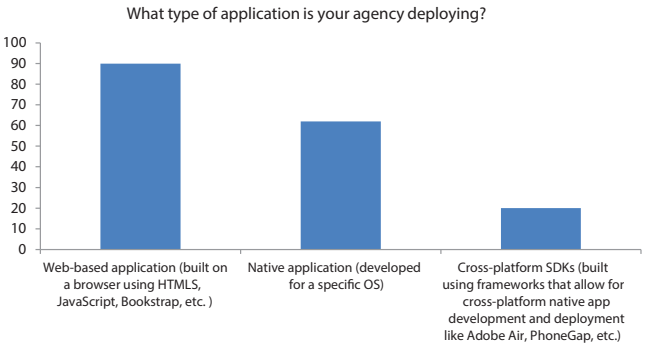

FIGURE 16 Types of application frameworks.

TYPES AND USES AMONG DIVISIONS

The majority of respondents, regardless of division, reported having experience with various forms of mobile IT devices; however, the types and uses differ. All respondents who self-identified as working in asset management had a laptop or smartphone; however, not all designers and construction employees did. Digital cameras were more likely to be provided in the design division to assist in planning and gathering general layout information for the design work.

In both the survey and the case studies, some designers suggested that more mobile IT could help with their job functions. No designers said their STAs are high-level implementers of mobile IT devices; 62% believe they are low-level implementers. Limited applications are available for designers. Some respondents in this area mentioned that an opportunity exists to develop more applications relevant to their fieldwork. Many respondents in construction and asset management rated their STAs as low-level implementers, although 17% and 20%, respectively, believe they are high-level implementers.

Construction appears to drive advanced use of mobile devices, using them primarily for digital and paperless record entry and documentation. According to the survey

responses, the most frequent mobile IT use in design and asset management is to make phone calls and to send and receive e-mails and text messages.

Construction division employees are more likely than those in design or asset management to see the value of mobile IT. Responding construction employees rate their perceived return on investment (ROI) positively: 80% believe the ROI is greater than 50%. On the other hand, 17% and 20% of design and asset management employees, respectively, believe that a negative ROI is associated with mobile devices. The difference in perceptions probably corresponds to construction employees' more frequent exposure to the devices and the fact that more apps are designed for their use.

CHAPTER THREE

AGENCY POLICIES FOR MOBILE INFORMATION TECHNOLOGY USE

MOBILE INFORMATION TECHNOLOGY DEVICE IMPLEMENTATION AND PERCEPTIONS

When it comes to technology, the engineering and construction industries have a plethora of options to investigate. However, industrywide adoption of a particular technology usually requires that a business case be made for it and that technology decisions are based on solid evidence.

This phenomenon is apparent in the survey of state transportation agencies' (STAs') use of mobile IT devices, where potential practice far exceeded current practice. Although 84% of the states (42 states) provided at least one response to the survey, only 10% believe they are high-level implementers (see Figures 17 and 18). Market penetration exists but, at least perceptually, much more remains to be gained from mobile IT device use.

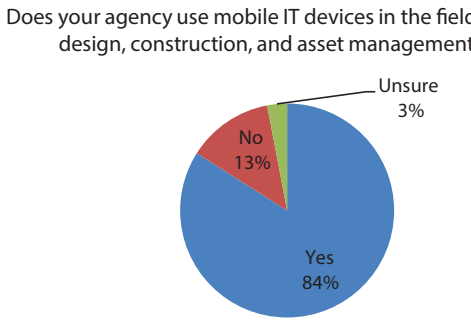

FIGURE 17 Agency use of mobile IT devices.

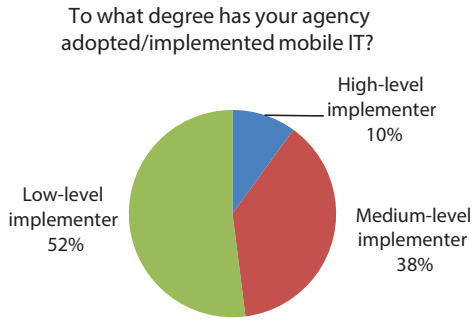

FIGURE 18 DOTs' perception of mobile IT implementation.

To assist in the implementation process, some STAs work with others to develop strategies and policies, and to deploy the devices. When IT respondents were asked if they collaborate with other STAs, 53% said no, 41% said yes, and 6% were unsure. End users were much less certain: 50% were unsure, 28% said their agency did not collaborate with other STAs, and 22% believed they did. As STAs advance in their mobile IT device use, perhaps they will be more receptive to collaborating with other states.

DEPLOYMENT AND TRAINING STRATEGIES

Agency policies for deploying the devices and training the end users are critical to the success of technology implementation. Issues such as standardization of devices, how an individual obtains one, who is responsible for updating the devices and applications, and how end users are trained to effectively use them can set the agency on a path toward a mobile workforce.

Current practices show mixed results in these areas. A majority of agencies do standardize mobile IT devices across their multiple business platforms (Figure 19), especially according to their IT staff. However, the majority have only an informal process to deploy the devices: a "give and go" strategy (Figure 20). Thirty percent to 40% of STAs use some project-specific and software-specific deployment strategies, but they are not consistently applied across all divisions and projects. STAs identified the need for an effective training program for mobile IT devices, and can seek assistance from agencies such as the Associated General Contractors of America that have local chapters that can assist in training employees.

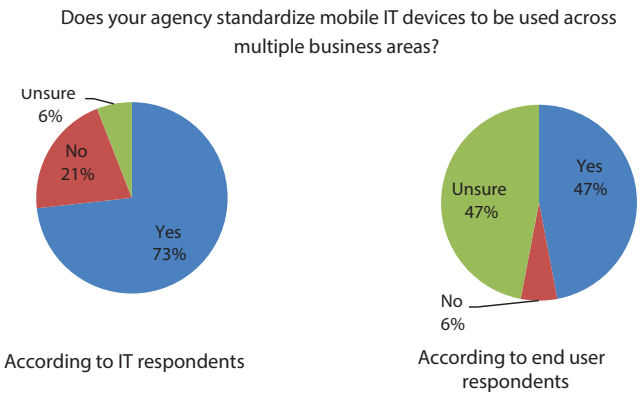

FIGURE 19 Agency standardization of mobile IT devices.

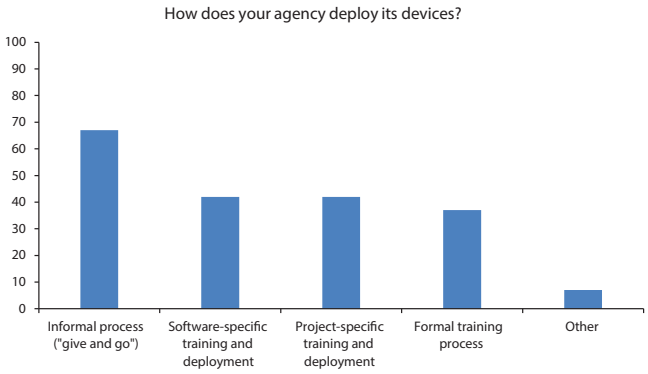

FIGURE 20 Agency deployment strategies.

Although standardization and deployment strategies exist in various forms for STAs, the number of employees who receive a device is relatively low. Whether within their division or throughout the agency, the majority of survey respondents said that fewer than a quarter of their employees are provided with a mobile device (Figure 21).

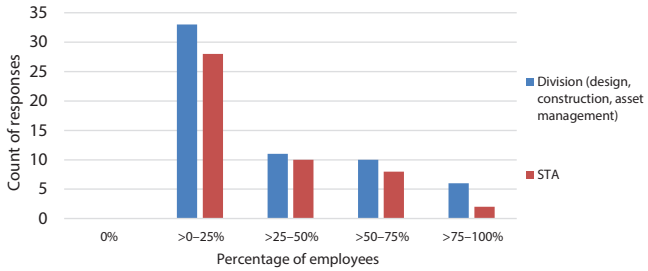

FIGURE 21 Percentage of STA employees provided mobile devices.

Once devices are deployed to the appropriate employees, training is the next critical step. Because the types and uses of devices vary across agencies, it is no surprise that the amount of training varies as well. Slightly more than 50% of respondents provide a brief overview of the device's functionality; while one in five do not provide any training whatsoever for their users (Figure 22). This is because many STAs use only cellphones or smartphones as their mobile IT devices and assume that users do not need any specific training on those devices.

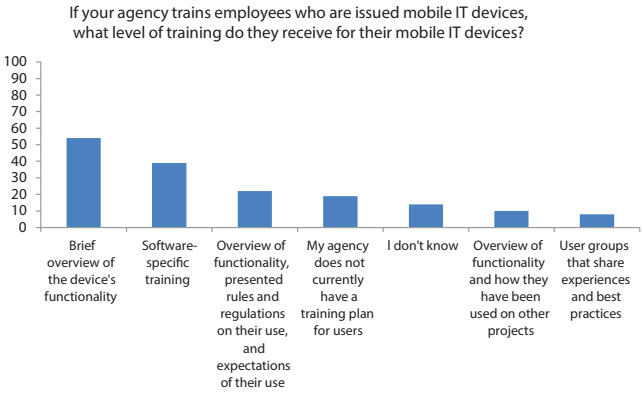

FIGURE 22 Training strategies.

There is little consistency across STAs when it comes to dealing with data collected from mobile IT devices. The most frequently employed strategy is to sync the data to land-based servers (60%); however, 24% of STAs have begun to use cloud-based servers for data storage (Figure 23). States also vary in how they share the data: 42% share project data with other stakeholders, 35% keep the data within the agency, and 16% keep them with the individual data collector (Figure 23).

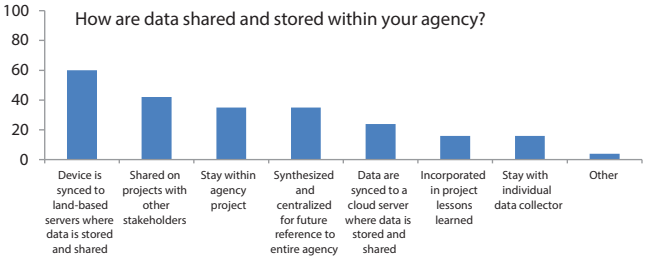

FIGURE 23 Data sharing strategies.

CHAPTER FOUR

PERFORMANCE EVALUATION AND OPTIMIZATION

PERCEPTIONS AND EVALUATION OF PERFORMANCE

Technologies are widely adopted only when they are easily used and cost-effective. In the case of mobile devices, IT departments see a higher value for the devices than end users do: 45% of IT departments and 32% of end users believe that the return on investment is greater than 50%, which is encouraging. However, 13% of those in IT departments and 15% of end users believe that mobile IT devices produce a negative ROI (Figure 24). The top three challenges reported by the state transportation agencies surveyed were connectivity issues, cost-effectiveness, and maintaining the devices. Support and poor/ineffective applications also were mentioned as challenges (Table 6).

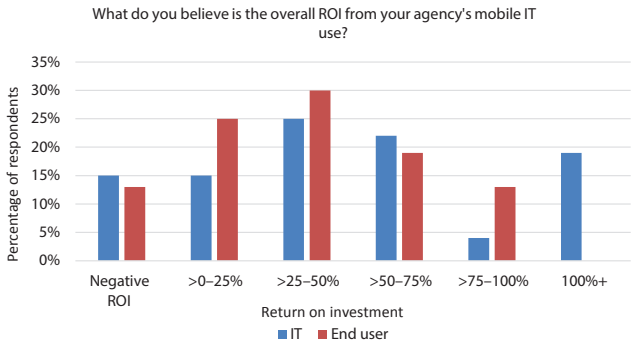

FIGURE 24 IT and end user perceptions of mobile IT device return on investment (ROI).

Performance evaluation and feedback help make the business case for mobile device use. The majority of STAs focus on cost-related issues. Efficiencies gained, device durability, and a cost-benefit analysis are frequently used metrics in evaluation. However, a formal cost-benefit analysis methodology does not exist across agencies. The cost of the devices can be determined by the purchase orders and maintenance services provided, but it is difficult to measure the benefit. Often, STAs quantify their benefit by time saved in reporting data from the field rather than traveling back to the truck, the jobsite trailer, or perhaps even the district office. This approach captures one benefit of mobile devices, but it misses other items, such as consistent access to e-mails and project plans. Those benefits are more difficult to quantify, as they occur randomly and the previous alternatives are often forgotten. End user approval is the second most often used metric in device selection, which shows that agencies understand the need to consider their consumers' opinions (Figure 25).

TABLE 6
MOST SIGNIFICANT CHALLENGES TO MOBILE IT USE

Challenges	IT Overall Rank	End User Overall Rank
Connectivity issues (loss of cell signal)	1	2
Device maintenance and user support	2	3
Application maintenance and support	3	6
Cost-effectiveness	4	1
Poor/ineffective applications	5	4
Interoperability issues (software incompatibility)	6	7
Lack of security of collected data	7	14
Poor durability/lack of ruggedness	8	8
Electronic signatures/approval	9	13
Quality of collected data	10	11
End user resistance	11	10
Training requirements	12	9
Battery life	13	12
Deploying devices to employees	14	5
Other	15	15

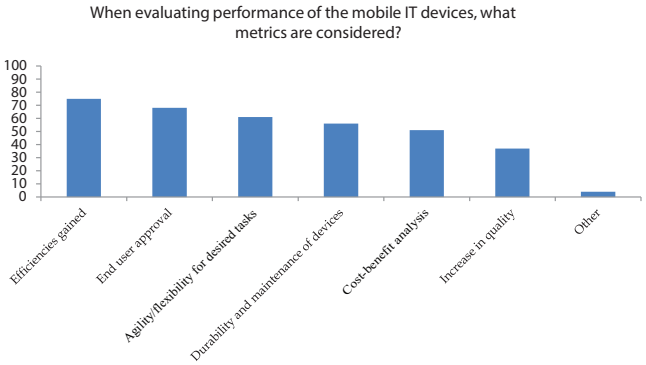

FIGURE 25 Metrics used in evaluating performance.

FUTURE OF MOBILE INFORMATION TECHNOLOGY

The use of mobile IT devices in the field increased in the past few years, and this trend promises to continue: 64%

of the STAs surveyed plan to expand their use of mobile IT devices, whereas only 2% believe they will not (Figure 26). Many of the STAs believe the landscape will change owing to more significant investments, more detailed policies, and more adjusted users. Although consultants have identified more advanced uses for the devices, the STAs are just skimming the surface, and they are aware of this.

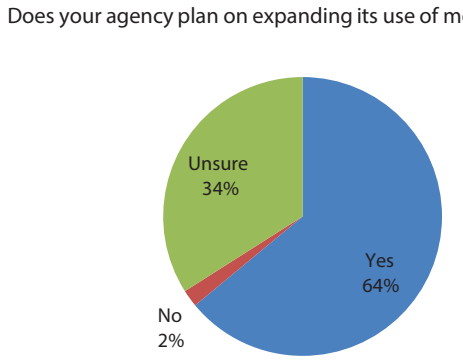

FIGURE 26 Future expansion of mobile IT devices.

Several initiatives are under way to expand usage. The ones most frequently mentioned are deploying additional devices and purchasing and investigating more progressive devices. Ongoing development of applications and documentation of uses are other considerations for expansion plans.

CHAPTER FIVE

MOBILE INFORMATION TECHNOLOGY USE CASE STUDIES

INTRODUCTION

Outside the use of surveys for data collection, some respondents were selected for interviews as case studies, to add richness and detail to the feedback garnered through the surveys. The selection process involved a systematic approach with the goal of collecting feedback from states at various adoption and implementation levels. Feedback from STAs at different levels provides a snapshot of implementation and use across the spectrum of adopters. The interviews covered the benefits, challenges, and approaches at different levels, which can help adopters plan for the next appropriate step rather than simply an end goal. This chapter summarizes the findings from the case studies and presents a detailed account of the information relayed during the interviews. The questions asked of each STA are included in Appendix E.

OVERVIEW

As noted earlier, STAs were chosen for case studies according to an adaptation of Everett Rogers' *Diffusion of Innovations* classifications (*12*). Table 7 shows the alignment of the study's adaptation index, with the STAs' self-assessments from the survey and a summary of notes from the case studies. The self-assessment score was the average of multiple survey responses, with 1 denoting a low-level implementer and 3 a high-level implementer. Although the index is not an exact match to the study assessment, there is some similarity, and the case study notes appear to support the study assessment score. This assessment is not presented as a judgment but is meant to illustrate what various levels of adoption might look like at an STA. With this knowledge, an STA can understand its own adoption level and set goals for the future.

DETAILS

The following are summaries of interview responses according to the objectives of the case studies. The initial interview questions focused on the objective findings of the survey; follow-up questions sought to garner more detail on the uses of mobile IT at a particular STA. Some respondents were able to provide more detail than others, but in all instances useful information was provided because of the willingness and generosity of the participants.

North Carolina

The North Carolina Department of Transportation (NCDOT) responses to the survey indicated that the agency was a high-level (one response) or medium-level implementer (one response); however, further analysis using the logic applied in this synthesis identified the agency as an innovator. With the goal of gleaning details of mobile IT use at this adoption level, all innovator states were contacted with a request for an interview. NCDOT generously agreed to be interviewed for this case study.

Mobile Device Selection

NCDOT began a handheld device program for highway maintenance functions in the late 2000s, only to have the program cut as a result of budget shortfalls. The program has recently been revived, and mobile IT devices have been implemented in other functions as well. NCDOT has users with smartphones and some with regular mobile phones. For the standard uses of phone calls, e-mail, and web access, NCDOT will either provide a smartphone (typically an Apple iPhone, based on the agency's ability to support these devices) or will allow users to use their own devices with a set monthly reimbursement. These programs are contingent on manager approval of need. NCDOT construction inspectors have also used Apple iPads and Microsoft Windows–based devices in the field, through integration with Microsoft SharePoint.

Procurement of devices for more innovative uses has been by bulk purchase. NCDOT uses specifications and standards to put a bulletin out for bid for these devices. The business units begin the process by requesting the devices, in coordination with IT staff for support. An IT project-level cost-benefit analysis is completed for the request, generating an ROI figure. This analysis is difficult, as the devices and prices might change in response to the bids submitted. Changing devices from procurement to procurement is another concern with the bulk contract purchase method.

Application Adaptation and Development

NCDOT's current focus is on the adaptation of web-based applications for compatibility with mobile IT screen sizes. Rather than recreate applications for the mobile environ-

ment, NCDOT begins with web-accessible applications and modifies them to conform to a mobile-sized screen. The agency uses two tools to help with this effort: Visual Studio to develop multiplatform products functional for Android, iOS, and Windows systems; and Xamarin, a cross-platform development tool that allows virtual views across multiple devices.

In-house development is just beginning and has typically been in native applications. NCDOT has relied on consultant, vendor, and in-house services for mobile application development and customization. One current project involves a vendor developing a mobile multimedia messaging service application for asset management.

Standards or Specifications on Applications, Hardware, or Support Systems

NCDOT adheres to the standards developed by the North Carolina state IT group. These standards apply to both mobile and nonmobile devices and applications, and the security must match the architecture of the enterprise system. This approach requires encryption of mobile devices, although iPhone users may request a waiver. NCDOT also allows employees to use their own devices, which can add complexities.

Policies and Procedures Related to Storing, Securing, and Sharing Data Collected by Mobile Devices

Again, NCDOT applies the same standards for storing, securing, and sharing data to mobile devices and nonmobile devices. There are no separate policies or procedures for mobile devices, although the area is beginning to attract attention. NCDOT is a creating a data management group to set standards in that area and is creating a data/communication classification system. The system will classify correspondence such as e-mail as classified, unclassified, or private, although the boundaries for these classifications are difficult to determine.

One specific application for data sharing from mobile tablets (specifically iPads) is Microsoft SharePlus. NCDOT invested in SharePlus to allow iPad users to collect data that could be integrated with the enterprise SharePoint system. SharePlus allows the user to work offline and synchronize data later, which is useful when connectivity is not available.

Challenges Experienced Using Mobile IT Devices

NCDOT noted several challenges it has faced. The biggest one was overcoming a paper-based culture; for example, convincing construction managers to trust a mobile device over their tried-and-true field notebooks for documentation. NCDOT used a 20-device (iPad) pilot effort to troubleshoot and field questions. The pilot enabled the rollout team to be more successful when it issued 1,000 devices.

NCDOT has also dealt with multiple device types. The use of a bulk purchasing system has led to different devices being procured from one purchase to the next. This system causes many issues: IT support for multiple devices, varying updating needs, and training on different devices for the same application. Purchasing rules would have to be modified to resolve this issue.

Some platform-specific challenges have also surfaced, such as versioning issues between Windows 7 and 8, updating applications with compatibility across platforms, and dealing with the security aspects of pushing updates for some devices (e.g., Apple allows only one contact point for sending updates to the app store).

The final challenge involved questions about the costs of purchasing mobile devices and the data plans required to serve them. This challenge was easy to resolve by demonstrating that the time savings in driving alone more than covered these costs.

Benefits Experienced Using Mobile IT Devices

More than any other benefit, NCDOT has seen savings in time and money, especially with the use of iPads in construction management. Personnel can carry manuals and specifications electronically and update them easily using SharePoint, which saves on printing costs. Another savings has been in the monitoring or documentation of personnel, materials, and equipment. For example, in the past, timesheets were transported from field locations and entered into an enterprise system. Mobile IT has allowed these processes to be automated.

NCDOT embraces the efficiencies of mobile IT and provides users with the tools and accessories to increase these efficiencies. The agency maintains a list of approved accessories users may request, such as cases and Bluetooth keyboards. NCDOT views many of these mobile devices (such as iPads) as commodities; rather than purchasing more expensive tablets and laptops, it purchases low-cost devices that meet specifications and allows field use to test their ruggedness.

Specific Uses of Mobile IT

NCDOT uses mobile IT to access and use many of its legacy web-accessible applications; hence, the current focus on screen compatibility of these systems. One such system is HiCAMs. This construction management system was developed nearly a decade ago in-house and is web-accessible through Citrix. The system tracks construction quantities, materials management, pay records, and similar construction management documentation. Field staff use mobile devices (iPads) to input information into this system when connectivity is available. SharePlus allows them to connect to the SharePoint server for access or entry of project information, inspector field notebooks, plans, photos, real-time access to material test results, and countless

other specifications and manuals. SharePlus allows them to work with or without connectivity; if the latter, it synchronizes information once the connection is restored. NCDOT is also piloting the use of RFID tags and readers for cost-effectiveness in materials and later asset management.

In asset management, NCDOT recently invested in a large number of tablets for a vendor-developed multimedia messaging system. With GPS-enabled devices, staff can track operations, equipment, and personnel; the information is automatically entered into enterprise systems at the end of each day. The GPS feature also allows for quicker location times, as coordinates are much more accurate than the previously used mile points.

Other business units of NCDOT are also embracing mobile technology. Design has begun to use mobile applications for total stations in surveying, and the ferry services are allowing reservations through mobile technology. All in all, NCDOT views mobile technology as an important tool for increasing the efficiency of personnel and providing the public with the services it expects.

Ohio

The Ohio Department of Transportation (ODOT) rated itself as a medium-level (three responses) or low-level implementer (one response). Further analysis established the agency as a mobile IT believer. ODOT is one of two mobile IT believers that generously agreed to be interviewed for this case study.

Mobile Device Selection

ODOT's device selection process begins with the users. Typically, the potential user researches multiple devices and the administrator or manager makes a request after seeing the need and value of the proposal. The IT section makes the final determination on the basis of interoperability and security. There is usually no formal cost-benefit analysis, but ODOT uses trials to justify the purchases.

ODOT typically issues devices to staff members, although some have been able to use personal devices with restrictions owing to security concerns. ODOT is using devices such mobile phones, smartphones (iPhones), tablets, and mini-laptops. Many are Microsoft Windows–based for interoperation and consistency with other systems, although Android devices are also in use. The need for a smartphone and data services is assessed by managers.

Application Adaptation and Development

ODOT determines adaption and development on the basis of the needs and goals of the IT project. Applications are off the shelf, adapted off the shelf, vendor developed, and in-house developed. One of the most interesting aspects of ODOT is its developer-engineers. The agency is fortunate to have two engineers with interests and capabilities in mobile application development. Without careful communication and coordination between developer and user group, IT-developed applications can vary from end user expectations. When end users develop the applications themselves, they are more likely to be specific to user needs and directly integrated with existing procedures. But although there are numerous benefits to having end user developers, this combination of skills is rare in STAs, and such a skill set cannot be easily maintained with changing technology and the ongoing need to develop secure applications.

Standards or Specifications on Applications, Hardware, or Support Systems

ODOT does not have specific standards and specifications for mobile applications, hardware, or support systems, although many nonmobile specifications apply. The agency attempts to work through mobile solutions with its IT section. The IT section has a council that evaluates ideas and builds consistency in devices and cross-applications among business units.

Policies and Procedures Related to Storing, Securing, and Sharing Data Collected by Mobile Devices

Security, especially with personal mobile devices, is a major concern for ODOT. Personal devices have been limited to access of e-mail and web-based materials; they are not used for data entry or to store project files. ODOT does not have specific mobile policies and procedures, but there is overlap with the policies for nonmobile technology. The agency also has concerns about inconsistent storage locations and naming conventions; it is undertaking a major effort in standardization and enterprise architecture.

Challenges Experienced Using Mobile IT Devices

ODOT noted that one of its major challenges is dealing with connectivity issues in rural areas, as many of the mobile applications rely on decent broadband or cellular service. Also noted was the amount of capital required to apply mobile technology to business processes. Although an FHWA grant for e-construction has helped, costs for devices, applications, and data services can be dramatic. Efficiencies have been hard to capture, but time savings versus mobile data costs clearly show a positive ROI.

Perhaps an even more significant challenge is overcoming the existing culture, specifically in construction. Field staff who were hired on the basis of their nontechnical skills have been asked to develop technical skills; in some cases, they are resistant. Technological abilities, resistance to change, security concerns, and uncertainty have all played a role in field staff's reluctance to embrace mobile technology in construction. The paradigm change from paper documentation to a paperless system is up against the inertia of the long-established, documentation-heavy process of construction management.

Benefits Experienced Using Mobile IT Devices

ODOT noted that a major benefit in mobile technology has been a reduction in the amount of erroneous data, not only in direct entry of information instead of risking transcription errors, but mainly in location information. With GPS tagging, ODOT has noticed much more accuracy in field locations of assets and less chance for error. An additional benefit is a reduction in redundant data; again, as a result of data directly entering the systems. Another benefit is the ability to enter data and access resources from the field rather than needing office connections, which builds efficiency and saves travel time. ODOT noted that it is not as mobile as it would like to be, but it is going in that direction.

Specific Uses of Mobile IT

ODOT is incorporating mobile IT heavily in construction management field use. Although the agency chose not to jump into the first iteration of web-based AASHTOWare products for construction management, it is using the mobility of AASHTOWare Field Manager. Additionally, it has in-house-developed applications for access to specifications and manuals that are helping it move toward paperless procedures. It reports field buy-in for features such as talk-to-text for writing reports and field notes, as well as videotelephony (Skype or FaceTime) for communication and resolution of field issues with office or offsite management.

Mobile IT use in the field has improved asset management: GPS tagging allows for fast and accurate identification, locations, and condition reporting. Another benefit is in the management of tower lighting: ODOT has a GIS-based system that allows it to remotely control lighting and to review maps that indicate their operation.

Kentucky

The Kentucky Transportation Cabinet (KYTC) rated itself as a medium-level (one response) or low-level implementer (one response). Further analysis established it as a mobile IT believer. KYTC is one of two believers that generously agreed to be interviewed for this case study.

Mobile Device Selection

KYTC device selection often begins with an end user business unit request to the IT group. The IT group assesses the technology and accuracy needs of the customer (as they refer to the end user) and suggests devices. The IT group always assumes that the device will operate disconnected in the field, because there is no failsafe when connections are not available. The IT group does a cost-benefit analysis for device selection. The group aims for cross-application of the same devices among business units, although end users' needs drive the final selection.

Currently, KYTC has about 1,500 mobile devices in use, primarily iOS types. High GPS accuracy needs are met with price contracts with Trimble devices using Microsoft Windows Mobile (often Junos). Tablets in use are Apple iPads, Dell Venues, Microsoft Surface Pros, and some Android-based devices. IT believes that Android is offering some better features and plans to replace Windows Mobile devices. With consumer-grade GPS chipsets approaching the accuracy of survey-grade chipsets, the IT group hopes to see more standardization. Apple iOS devices are much more in demand by users; they are easy to support and have a good lifecycle. Device use often starts with trials. The trial of six iPads resulted in 600 being distributed to users.

Application Adaptation and Development

The IT group also assists business unit customers with the application needs of their IT solution. Applications may be out of the box, adapted out of the box, vendor developed, or in-house developed; decisions are made by project leaders and the IT group on the basis of needs. Most applications involve adapting out-of-the-box solutions or using in-house consultant contractors, although some vendors and outside consultants are used. This activity is handled by the Application Development Branch or the SharePoint team—both units in the IT group. In some cases, the end users work directly with vendors for solutions (e.g., a business unit is currently working directly with Waze).

Some applications have been adapted from existing nonmobile systems or web-based tools. KYTC uses AASHTOWare and is in the process of moving to Web TrnsPort, which will use iOS devices. Other mobile devices access the systems via Virtual Proxy Network connections and Citrix.

Standards or Specifications on Applications, Hardware, or Support Systems

The KYTC IT group does not have official written standards for mobile hardware. Apple devices have become a de facto standard as the result of user demand. The group provides support for solutions and writes specifications on a project-by-project basis. The Application Development Branch does have some standards, but they are hard to maintain because technology changes so rapidly. The branch uses a code repository to build consistency for items developed in-house. Kentucky Commonwealth Office of Technology is working on more mobile-IT-friendly standards.

Policies and Procedures Related to Storing, Securing, and Sharing Data Collected by Mobile Devices

KYTC storage, security, and sharing of all data are managed by the Enterprise Data Management Branch within the IT group. A Microsoft SQL server is used to manage the data. No specific procedures are written for mobile devices, but nonmobile policies and procedures apply. Oracle and ESRI

ArcServer also house data. GIS applications developed in-house are stored and available through ArcServer; they are secure and protected by KYTC firewalls.

Challenges Experienced Using Mobile IT Devices

KYTC has faced several challenges in implementing mobile IT solutions in the field. As with most rural states, cellular service can be a problem. KYTC uses multiple cellular carriers to provide users with the most effective coverage for their respective areas.

KYTC also has faced challenges as a result of allowing the implementation of multiple devices. User demand for Apple products alleviates some of this problem, but incompatibility of iOS devices with some systems is a concern. In the future, the IT group expects consolidation of mobile operating systems and customer demand to resolve some of the issues. The IT group also hopes the interest in iOS devices continues, as the costs for these devices are easy to calculate with device and data plan charges. Other mobile devices incur additional, unexpected costs.

KYTC is moving past trials of several mobile IT projects and into widespread distribution and implementation of devices. Learning from trials and previous implementation, the IT group understands that interests and skill levels vary in the field. They provide end users with devices and training, and conduct field visits to ensure successful implementation and service. When so many devices are distributed, problems will arise in maintaining them. KYTC has addressed the issues of lost, broken, and stolen devices by developing a mobile device management plan to track problems, as well as a replacement policy.

Benefits Experienced Using Mobile IT Devices

KYTC is embracing the movement toward mobile devices. Employees want the devices and are using them in numerous applications, including e-mail, photography, videotelephony, and data entry. The devices make employees more responsive and enable real-time data collection. Employees save time in numerous ways with these devices, which makes KYTC more efficient. Data entered are available in real time and data richness is maintained, compared with the data loss inherent in end-of-the-day transcription.

Specific Uses of Mobile IT

KYTC is using mobile IT in the field for asset management, design, and construction. Asset management is using mobile IT devices to conduct its Maintenance Rating Program, sign inventories, and other asset inventories. Applications streamline processes, GPS device functionality provides locations quickly and accurately, and real-time access to data improves office efficiency. The Maintenance Rating Program application uses Trimble Junos to capture data; conditions are reported within 1 week instead of three, with fewer staff involved.

Design has attempted to enter into mobile fieldwork, but applications are lacking and the necessary conversions are cumbersome. This group has used Trimble Junos and the DataEast CarryMap application with multiple conversions from Bentley MicroStation files to allow specific projects to capture design field data when requested, but owing to the complexity, this has only been implemented a few times with assistance from the IT group.

Construction is implementing AASHTOWare Web TrnsPort. The integration with Citrix is allowing improved implementation of mobile devices and field data entry for construction management. This system requires iOS devices; construction field staff are using iPads for construction management functions and data entry. These devices also allow other opportunities, such as FaceTime to communicate and resolve field issues.

Vermont

The Vermont Agency of Transportation (VTrans) rated itself as a medium-level implementer (one response). Further analysis established the agency as a leading majority in mobile IT. VTrans generously agreed to be interviewed for this case study.

Mobile Device Selection

VTrans has a very informal mobile device selection process. In 2011, Tropical Storm Irene damaged or destroyed many roads and bridges. Immediate field IT and communication were required, and the popularity of Apple products drove the decision to purchase and implement iPads and iPhones. This was an effective solution, as many people were familiar with the devices and ready to use them. Currently, VTrans is beginning to move toward Microsoft Surface Pros so it can use Microsoft DirectAccess. Switching to Microsoft Office365 will eliminate the need for Citrix and the use of virtual proxy networks, and will build consistency among the hardware and applications used.

The VTrans IT group attempts to partner with end users for solutions. Currently, only state-issued devices have system access, and device allocation is typically assigned to a position. The job function determines which device and data services are provided.

Application Adaptation and Development

For data capturing, VTrans has relied on vendor-developed applications and support. The agency has also used AirWatch, Citrix, and virtual proxy network (VPN), as well

as Xen Mobile for file sharing and work within its network. Limited success and user dissatisfaction are motivating the move to Microsoft Office365. Vendors will supply and support these applications as well.

VTrans IT is developing its own reporting and mapping applications for mobile use, such as with ArcGIS. These reporting applications have involved 511 and other read-only interfaces.

Standards or Specifications on Applications, Hardware, or Support Systems

VTrans standards and specifications for mobile applications, hardware, and support systems are informal and largely controlled by the local business offices. The agency attempts to maintain device consistency by keeping staff on the same device types and providing devices on the basis of function. It also attempts to assign the device to a position so public contacts do not change.

VTrans is strategic in the devices and accessibility provided according to job functions. For example, owing to their job functions, managers in maintenance can request the ability for their phones to be able to provide a hot spot. Different levels of device and service combinations exist to match services with functions and at the same time mitigate costs.

Policies and Procedures Related to Storing, Securing, and Sharing Data Collected by Mobile Devices

Security concerns have led to a policy that only state-issued devices are supported for access to systems and data. Managing data through VPN connections mitigated risk, but there was a concern related to the Freedom of Information Act if personal devices were allowed. The VTrans IT group typically tries to serve the customer without creating any problems, and this was its solution: VTrans allows personal use of state-issued devices as long as performance is not impacted. This policy resulted in many staff members giving up their personal devices and embracing the state-issued devices. There was some concern about data costs, but an unintended benefit to the agency has been after-hours responsiveness of staff.

Challenges Experienced Using Mobile IT Devices

Vermont is a rural state with large areas that have no cellular service; thus, VTrans has not relied on mobile IT but has used it to supplement functions. Additionally, some instances of international roaming on the Canadian border have caused unexpected problems. In addition to connection issues, workforce use and training has presented challenges. With Tropical Storm Irene, there was no time for formal education and training; peer-to-peer training was found to be sufficient.

Some challenges have also presented themselves in updating devices. End users are responsible for updates, but they are not the administrators of their desktop devices. Depending on update requirements and operating systems, an update might require a coordinated effort between IT management and the end user.

A final challenge mentioned by VTrans was device inventory. Management of devices, especially when they are distributed during an emergency, is challenging. The focus is on repairing and opening roads and bridges rather than on tracking devices.

Benefits Experienced Using Mobile IT Devices

Mobile IT has offered many benefits to VTrans. The iPads and iPhones used during Tropical Storm Irene enabled services, communication, and coordination that would otherwise not have been possible. Instant picture sharing was especially vital during and after the storm. Efficiencies and savings are difficult to quantify, but some offices have been able to eliminate their landlines, and travel costs have clearly been reduced. Pooled data and minutes have helped mitigate plan costs.

Specific Uses of Mobile IT

VTrans uses mobile IT in field applications for construction and asset management. The InfoTech Mobile Inspector application is used to enter field data into SiteManager for construction management. Field staff are able to track materials, approvals, and change orders, and to enter pay items. This requires VPN and Citrix, which then allow access to other network resources.

Asset management users can request the ability for their iPhones to provide a hot spot. Using their iPads, they can provide daily reporting of staff, materials, and equipment from the field. Using ESRI ArcGIS Collector and GPS-enabled tablets, they can collect asset locations and conditions. They can also use ArcGIS to assist in managing winter weather events, including updating road conditions and 511.

Idaho

The Idaho Transportation Department (ITD) rated itself as a medium-level (three responses) or low-level implementer (three responses). Further analysis established the agency as a following majority. ITD generously agreed to be interviewed for this case study.

Mobile Device Selection

ITD does not have a specific process for mobile device selection. The agency relies on its wireless carrier, Verizon Wireless, to provide input and make suggestions for devices. On the basis of user needs and suggestions, ITD is using smart-

phones and tablets. Some of these devices use iOS, while others use Microsoft operating systems. The mobile IT program includes mostly state-issued devices, although a few personal devices have been allowed. MobileIron is used for security and privacy on personal devices.

Application Adaptation and Development

ITD uses mostly off-the-shelf applications and does not have in-house development capabilities. Most applications are web-based and not strictly mobile; rather, they are accessible by mobile devices through VPN connections. ITD is beginning to require vendors to provide applications with mobile capability. The agency has few applications meant for field use and is not at a level of maturity where it could demonstrate successes. Most uses are in trial stages, with anecdotal evidence of success.

Standards or Specifications on Applications, Hardware, or Support Systems

ITD is currently working on standards and specifications for mobile applications, hardware, and support systems. Central to this policy development is that only agency-issued devices will be granted connectivity, not personal devices.

Policies and Procedures Related to Storing, Securing, and Sharing Data Collected by Mobile Devices

Security of data and mobile device integration is a concern for ITD. It uses MobileIron to provide some security features, and VPN connections also mitigate risk. MobileIron requires a password for agency data access and can remotely clear data from missing devices. In terms of other mobile security and storage, ITD relies on the end user to back up information. Android device users are expected to use anti-malware software.

Challenges Experienced Using Mobile IT Devices

ITD noted that one significant challenge is allowing end users to choose between iOS and Android operating systems. This is a sensitive subject, as it is often a matter of preference. However, the fracturing of the open-sourced Android operating systems causes issues, and although iOS devices are more costly, ITD believes that their consistency and security offer substantial benefits. The agency's IT division would like to standardize the devices the agency purchases to build consistency within and across units.

Other challenges mentioned by ITD were that tablets are not a direct substitute for laptops and tablet users have been disappointed in the downgrade of performance. Like some other states, ITD faces the challenge of problematic cellular coverage. The final challenge mentioned, which is leading current policy development, is that the Freedom of Information Act causes discovery concerns under the previous practice of allowing people to use their own personal devices.

Benefits Experienced Using Mobile IT Devices

ITD has been impressed by the anecdotal successes of its pilot uses of mobile IT. The ability to maintain communication wirelessly when other systems go down ensures better service to the public. Mobile IT is building efficiency in field operations: staff are becoming more efficient in communications, issues are resolved more quickly, and reaction times to emergencies are decreasing. Where connectivity and wireless networking are available, data entry is further increasing project efficiency. These successes have occurred with staff using their own devices; ITD is now trying to provide agency devices and establish standard practices.

Specific Uses of Mobile IT

ITD is using mobile IT in construction and asset management in some trials and some standard applications. Maintenance staff are using phone conference call capabilities for quicker reaction times to emergencies. Truck-mounted devices and roadside automatic traffic recorders (ATRs) allow systems such as the 511 mobility index to be updated in near real time and make them available on GIS maps. Office maintenance managers can view this information and send help where it is needed by contacting workers on their mobile devices.

ITD construction is using mobile technology to resolve issues in real time, process and track change orders, and enter construction and materials data in SiteManager or ProjectWise. These applications require network access and a VPN connection, but the successes justify moving to more mobile-capable systems. Although it is just getting started in mobile IT use, ITD is already seeing improvements.

Wyoming

The Wyoming Department of Transportation (WyDOT) did not rate itself, but analysis of its responses established the agency as a judicious mobile IT user. WyDOT generously agreed to be interviewed for this case study.

Mobile Device Selection

WyDOT mobile device needs are driven by the agency's construction operations. It uses mini-laptop computers and web-based applications. Its construction management software is a solution by ExeVision called iPDweb. This system can operate when it is disconnected from the network and allows synchronization. WyDOT allows employees to use their own personal devices.

Application Adaptation and Development

WyDOT's main mobile IT application is vendor developed. ExeVision was originally used and customized for the Utah Department of Transportation, where WyDOT staff were

able to see a demonstration. With vendor-made modifications, WyDOT implemented this application.

Standards or Specifications on Applications, Hardware, or Support Systems

WyDOT has no specific mobile standards or specifications.

Policies and Procedures Related to Storing, Securing, and Sharing Data Collected by Mobile Devices

Security of data and mobile devices is dealt with by the WyDOT IT group, and the contract with ExeVision specifies security, storage, and sharing for the application. There have been occasional synchronization issues but never any data loss. The data are maintained in ExeVision databases, and all DOT and contractor personnel have specific access privileges.

Challenges Experienced Using Mobile IT Devices

WyDOT is a rural state with connectivity concerns; the ability to work disconnected is an advantage in any application. Another challenge is that the personal devices seem to be frequently exchanged for new models.

Benefits Experienced Using Mobile IT Devices

WyDOT is able to collect and update construction project data and records remotely and in real time when connectivity is available. This efficiency is a great benefit. Even when employees work disconnected, synchronization allows for data entry in a single remote occurrence, which saves time. The ability to use field technology for construction management and record keeping increases efficiency, especially when connectivity allows for real-time updates and communication with contractors who have system access.

Specific Uses of Mobile IT

WyDOT's main use of mobile IT is mini-laptop computers and the web-based construction management application offered by ExeVision.

CHAPTER SIX

MOBILE INFORMATION TECHNOLOGY USE IN DESIGN, CONSTRUCTION, AND ASSET MANAGEMENT

INTRODUCTION

One of the objectives of this synthesis was to review the practices of progressive adopters and capture their programmatic applications of mobile IT in design, construction, and asset management. The survey and interview process suggested that applications used programmatically were less than progressive, while it was the ad hoc uses that appeared to be the most advanced. Through literature review, survey analysis, and interviews, this study identified several promising uses of mobile IT devices for the field in design, construction, and asset management. The practices presented here face their own inherent challenges and will not fit every STA model. Before discussing these practices, some pros and cons of progressive mobile IT use are noted.

BARRIERS AND OPPORTUNITIES

Mobile IT faces several barriers or weaknesses for use in transportation design, construction, and asset management. Some of these barriers stem from resistance to change, connectivity and service issues, or from cost (considering the scale of programmatic incorporation of mobile IT devices). The mobile devices available for use in transportation design, construction, and asset management are primarily smartphones, tablets, and laptops. These devices offer a lot of opportunity and functionality, but they are dependent on applications. In other words, a smartphone, tablet, or data collector is only as good as the applications that allow the user to execute a task. A recurring comment of respondents was that application developers often do not understand the needs of STAs.

Perhaps as a result of the barriers and the lag in adoption, the technology and application development communities appear to have been slow to develop solutions for the transportation sector. In addition, mobile application development is often not a priority for transportation agency technology staff. These shortcomings offer opportunities for growth and development. When applications are available and easy to implement, use of mobile IT devices will likely increase in STAs.

Progressive and Practice-Ready Mobile Information Technology Approaches

The following practices are recognized as being progressive approaches among those that surfaced during the literature review, surveys, and interviews. These more progressive practices were typically in trial, with no documented, quantifiable benefits yet. In some cases, these technologies were adopted out of necessity to compensate for staffing or time demands. They suggest a direction and point out opportunities for the transportation industry.

Design

In the overall highway design process, field practices (excluding surveying activities) are limited in scope and therefore limit the ability to use mobile IT devices. Surveying was not covered in this study; the remaining fieldwork involves site visits to verify the locations of features such as streams, entrances, and utilities, and to gain an in-person perspective on the site, project fit as designed, and constructability. These visits could also entail field verification for maintenance of traffic plans; existing infrastructure, such as drainage structures, guardrails, and cross-slopes; and any adjacent property concerns or needs. Designers value field visits for confirming site geometry and features that are only rudimentarily communicated through surveying models. The importance of the field visit is in these experiences and this kind of data collection, and this is where opportunities for mobile IT devices come into play. Devices for field use might include GPS-equipped cameras, tablets, and multifunctional data collectors. Mobile IT devices are generally used during the design process for communication and data transfer; the most progressive field approach in this study involved the use of a multifunctional data collector and various software applications to geospatially locate project and physical features.

Geospatially Locating Project and Physical Features at KYTC

The Kentucky Transportation Cabinet reported that on a case-by-case basis it has attempted separate trials with mobile Windows data collectors and smartphones. These trials have enabled designers to conduct field visits to take geospatially referenced photographs and notes. The trials required extensive conversion between the device and the in-office design software to transfer the data for usability. The smartphone/tablet trials used out-of-the-box applications with direct connectivity to the in-office design software, although the mobile application had limited functionality

and did not support the device's GPS tagging. Although some benefits were realized in these trials, no programmatic adoption is planned.

Construction

The area of construction at STAs offers much more potential for mobile IT field applications such as SiteManager by AAHSTO, Bentley Field Supervisor, Autodesk BIM 360, and Trimble Contractor. Construction has numerous functions and needs at the field level, including project documentation; quality assurance; inspection; plan verification; as-built documentation; decision and change determination; plan, specification, and procedural reference; issue resolution; and general administration (process workflows, etc.). All these activities can be complemented or supplemented with the use of mobile IT devices. The literature review, surveys, and interviews of STAs identified the following progressive approaches to implementing mobile IT devices for construction field use.

Issue Resolution Through Video Capture and Conferencing

One of the most contentious and stressful aspects of a construction project is issue resolution. Many situations arise on a project site in which inconsistencies between documents, ambiguity in plans, unexpected field conditions, and so on lead to questions that need a quick resolution. In the past, resolution might incur phone calls, travel to offices, and other time-consuming activities. With the time sensitivity of construction projects, delays are a source of frustration for all involved. Several STAs noted that mobile IT devices can contribute to the timely resolution of problems; in fact, this was often the first benefit of mobile IT devices mentioned in the study surveys and interviews.

The interview with Ohio DOT, along with literature review of successful use by Michigan DOT, highlighted the use of mobile IT devices such as smartphones and tablets along with videotelephony applications (sometimes supplemented by Voice Over Internet Protocol where networking capabilities exist) to film and discuss problems in the field or to seek guidance, solutions, or references from staff who are not present at the site. Assuming that the application service is supported by the cellular or network services, this is a very powerful and easy-to-use solution that is readily implementable. Many mobile devices already come equipped with the necessary applications.

Georeferenced Documentation

Another convenient use of mobile IT devices for construction in the field is to document issues, landmarks, or features, including geospatial information. This allows for ease of relocating the feature, thus making the documentation very rich for future use. Postprocessing is typically required for geospatially referenced photographs; some devices have the capability to provide this service, but additional application development and compatibility are required to incorporate the information into individual STA systems. This practice is readily available for use with many devices but was specifically mentioned by only a few STAs, such as Michigan DOT (*13*).

Complete Mobile Construction Administration System

Several STAs use highly complex construction administration systems to manage record keeping, process payments, maintain materials testing and certification information, and conduct other construction management processes. Some STAs have worked mobile IT devices into these systems. Many of these efforts can be attributed to the paperless e-construction initiative in the FHWA's Every Day Counts (EDC) program. EDC is currently in its third year of seeking to identify and deploy innovative technologies to STAs. Because these systems are so complex, compatibility and direct integration can be challenging or impossible.

A few STAs have used web-based construction administration systems. These are typically developed in-house, although commercially available packages are also moving to a web-based platform. North Carolina DOT uses an in-house-developed client-based solution called HiCAMS for construction and materials management. Because it is client-based but accessible through Citrix, the integration with mobile devices has been relatively easy, assuming that cellular service is not an issue. Some agencies have compensated for the connectivity problem by creating standalone mobile applications that can function without connection and synchronize with the web-based system when connection is restored. Wyoming DOT uses a consultant-developed web application called ExeVision that runs project management software. It requires an Internet connection to run; however, it allows users to perform its functions in an offline state and will automatically process the data once an Internet connection is established.

Although the form and function of this solution vary, the benefits of immediate data entry and maintenance of data integrity will most certainly outweigh costs over time.

Easy Access to References and Plans

One simple yet recurring benefit mentioned throughout the study's interviews was the use of mobile IT devices in the field for document, plan, and resource references. In the recent past, any documentation required in the field had to be transported there in hard copy. With the use of tablets, smartphones, laptop computers, and other devices, these resources are readily available in the field, assuming that they are accessible through the web or there is a digital copy on the device. These uses alone provide substantial benefits,

especially in time savings. States such as Idaho, Kentucky, Ohio, and Vermont specifically mentioned the AASHTO software to view project plans.

E-construction

One final practice to mention is the use of e-construction, which can be considered the culmination of all the aforementioned uses plus many more practices that may or may not have anything to do with mobile IT devices. E-construction is a national initiative under the FHWA's Every Day Counts program, which seeks to identify and inform STAs about effective and innovative technologies to improve business practices. Mobile IT devices are an important aspect of the program's goal to move toward paperless projects. Some states have noted a high return on investment by using these strategies; for example, Florida DOT reported a 13.67% ROI (*17*).

Iowa's DOT contracted with a consultant to create paperless construction administration software that has a strong mobile component. The consultant, InfoTech, created a web-based service that allows employees to securely store, easily find, and digitally sign documents.

Asset Management

Another area with a lot to gain from the use of mobile IT devices in the field is asset management. The main needs of this functional unit of the STA are to conduct inventories and to quickly compile condition, status, and needs reports on the assets of the agency. The ability to gather and disseminate field information quickly and accurately is essential. Mobile IT devices deliver an important time savings in data collection. Agencies that have this solution in place can capture geospatially referenced information and have it immediately synchronized into reporting systems. The following are two specific uses noted in the study interviews.

Geospatially Identified Inventory

Nearly all the STAs that were interviewed commented that mobile IT devices help capture field data for asset management. One use that many devices can perform easily is to inventory assets with geospatial locations. This is a drastic improvement over the use of DMIs (distance measuring instruments) or other devices to record locations on the basis of mile points. Typically, a GPS-equipped device has a mechanism that can record locations and find assets. Mobile IT devices equipped with these features will also be able to use in-house or commercial applications to quickly capture data for inventories and synchronize this information with agency databases. Beyond merely locating assets, these applications can collect condition reports, photos, and other information.

For example, Vermont DOT has a simple yet effective approach for conducting asset inventory. Using an out-of-the-box solution (ESRI's Arc GIS) and GPS-enabled tablets, the agency is able to collect geospatially attributed inventories and quickly upload that information into its databases. Many other STAs discussed similar systems during the study interviews, noting that these approaches are easy to implement, may be commercially available, and provide immediate benefits over traditional methods.

Geospatially Collected and Reported Asset Conditions

Another use of mobile IT devices in asset management is to collect and report conditions on the fly. A few of the agencies interviewed said that mobile IT devices helped them respond to weather events. One progressive application is Idaho DOT's use of ATRs (automatic traffic recorders) to track snow and ice removal and quickly report conditions to the public through 511. IDOT has developed a mobility index based on the amount of snow and ice on the road. Conditions are measured by operations field personnel and uploaded to a control center, where managers decide not only how to react but what forces to use. The ATRs and technology-equipped trucks transfer information, including their current location and operations under way, through a system of drive-by synchronization stations. Operations managers can then call on trucks in the closest proximity or those that have the capacity to respond. In snow and ice events, efficiency and timeliness are essential, and this technology is giving IDOT additional tools to get the job done.

Some STAs have used mobile IT devices to capture asset condition data into reports of their current asset needs and priorities. One example is the Kentucky Transportation Cabinet, which is using multifunctional data collectors to collect and input information into its maintenance rating program. This approach eliminates the need to sketch maps or actions required by previous methods, and pavement condition evaluations can be quickly reported and made available in GIS-enabled maps. In the past, once data were collected, three to four staff members would work for 3 weeks to compile pavement rating information into an executive-level report. Using mobile IT enables fewer staff members to compile the report in 1 week. Additional savings of at least an hour a day were noted in field collection.

CHAPTER SEVEN

CONCLUSIONS

INTRODUCTION

As stated in the Summary, the objectives of this synthesis study are to identify—

- Processes for identifying, selecting, and evaluating mobile IT uses
- Potential mobile IT field uses in design, construction, and asset management
- Procedures for application development, integration, and optimization
- Potential benefits of adopting mobile IT in design, construction, and asset management
- Challenges and issues associated with mobile IT use in design, construction, and asset management
- Strategies for successful implementation of mobile IT use in design, construction, and asset management
- Strategies for managing the data collected by mobile IT devices
- Advances and emerging technologies to consider for mobile IT use in design, construction, and asset management.

Additionally, this chapter summarizes the current state of the practice related to mobile IT use in the field for design, construction, and asset management.

CONCLUSIONS

The following points highlight several of the findings of this synthesis according to the objectives of the study:

- Processes for identifying, selecting, and evaluating mobile IT uses
  - State transportation agencies vary in their flexibility to procure mobile IT devices, from an annual purchasing contract to being able to open-purchase devices. Agency IT groups vary in their involvement, from being in complete control of the solution procurement to offering various levels of support or even no support at all for the solution. The approach identified as optimal is for the end user to work collaboratively with the IT business unit to select a device and solution that will meet the needs of the end user; adapt it to the security, connectivity, and compatibility of the agency's systems; and ensure that there is a favorable cost-to-benefit ratio.
- Potential mobile IT field uses in design, construction, and asset management
  - Some advanced uses identified in this report are described in detail; however, the basic functions of many of the mobile IT devices are beneficial as well. Communication, photo and video capturing, and information referencing save time by reducing the need for travel. The following specific uses benefit individual functional units:
    - Design
      - › Geospatially locating physical and design features during field visits
      - › Referencing plans, specifications, and design guidance materials in the field
      - › Photo and video capturing during site visits.
    - Construction
      - › Geospatially locating physical and design features during construction to resolve questions or create as-built plans
      - › Referencing plans, specifications, and construction guidance materials in the field
      - › Recording work reports, entering quantities, processing change orders and payments (a key provision of e-construction)
      - › Timely communication and decision making, possibly incorporating photos, video, or videotelephony.
    - Asset management
      - › Geospatially locating physical and transportation features during inventory
      - › Capturing and updating condition report data for pavement, sign, or structure inventories
      - › Communication.
- Procedures for application development, integration, and optimization
  - STAs use three basic types of applications: those customized for the agency, whether developed in-house or by a consultant; out-of-the-box solutions in which the agency has adapted its process to the application; and out-of-the-box solutions modified for the agency's process. The findings of this synthesis suggest that the technology industry has not focused on the transportation industry's needs in application development. The few available appli-

cations can be customized to fit an agency very well, but many agencies do not maintain a technology group capable of developing and supporting these applications. This results in the need for consultant services, which are likely more costly than an out-of-the-box solution. Anecdotally, the cheapest approach would seem to entail adapting the agency process to a previously developed solution. However, there are no clear guidelines for this approach other than ensuring that the solution has a favorable cost-to-benefit ratio, meets the needs of the end user, and satisfies the agency with regard to IT security and compatibility. This process requires careful collaboration between the end user and agency IT staff.

- Potential benefits of adopting mobile IT in design, construction, and asset management
  - By far the most frequently identified benefit of mobile IT devices was time savings. The use of these devices reduces travel time to access resources, limits construction delays while seeking direction or approval of changes, and (assuming application and device connectivity) enables immediate data entry.
  - Another identified benefit is the quality of data captured. GPS locations are more accurate than using landmarks or some other means in lieu of surveying, and entering information once instead of transcribing notes maintains information quality.
- Challenges and issues associated with mobile IT use in design, construction, and asset management
  - The most significant reported challenge to mobile IT use was service availability. Each state interviewed commented on areas of low or unavailable cellular coverage. Some have been able to compensate by using devices or applications that operate when they are disconnected and synchronize with systems once service is restored.
  - Another challenge has been end user resistance to using the mobile IT devices. Training focused on the devices, their uses, and the associated benefits may help alleviate this issue.
- Strategies for successful implementation of mobile IT use in design, construction, and asset management
  - A key strategy for the successful implementation of mobile IT devices in design, construction or asset management involves close coordination between the end user and the IT provider or solution manager. The case studies suggest that if these two subject matter experts collaborate, they can create a strong solution that produces tangible benefits and is easy to implement and use.
  - Trials and follow-up lead to successful implementation. Trials should be carefully coordinated between IT and end users to identify pitfalls and determine resolutions. Follow-up efforts by IT are necessary after programmatic implementation of a new solution.
  - Once a solution is determined, training should specifically illustrate the ease of use and the benefits to the end user. Use of the device must be illustrated in a manner that is understandable and relevant to all technology skill levels. Multiple levels of training may be necessary.
  - Throughout the implementation process, internal champions and advocates for a mobile device can reinforce its benefits and use. Advocates can help ensure that employees do not fall back on traditional methods; they can support implementation from the user perspective rather than the IT perspective.
- Advances and emerging technologies to consider for mobile IT use in design, construction, and asset management. As mobile technologies advance, more tools will become available to end users.
  - The ability to capture and develop 3D models using photogrammetry or mobile LiDAR is becoming more readily available.
  - Increasing accuracy in GPS functional devices improves location services toward surveying grade capabilities.
  - Increasing cellular coverage and network speeds open doors to more applications and faster data sharing. Videoconferencing from the field is already possible and could become standard.

ADVANCING TECHNOLOGIES AND FUTURE RESEARCH

This synthesis identified two gaps in the transportation industry's use of mobile IT devices in the field. First, transportation seems to lag in comparison with the industrial and commercial industries. Second, there appears to be a significant gap between low-level implementers of mobile IT devices and those considered medium- and high-level implementers. These observations come from the literature review, surveys, and case study interviews, all of which suggest that medium- and high-level implementers are using or attempting to find uses for mobile IT in field applications, whereas many low-level implementers are maintaining their current operations. The strategy of many STAs is to allow a successful solution to develop and be vetted by other similar agencies. In this way, they can avoid the costs of trials with various technologies and make their investment in a sound and tested solution with minimal customization effort.

Another finding is that advancing technologies in mobile devices—such as smartphones and tablets and, to a lesser extent, mini-laptops and laptops—are narrowing the range of mobile IT devices used in the field for design, construction, and asset management. GPS components of these devices are meeting the accuracy needs of a majority of

uses in design, construction, and asset management. Additionally, these devices offer a multitude of uses, from communication (phone, e-mail, messaging, etc.) to capturing photos and video, and even data collection with connectivity to agency databases. This trend may leave multifunctional data collectors, digital cameras, and some other mobile IT devices with a very narrow band of specialized uses.

However, there is a lack of applications designed specifically to improve project performance in the transportation industry. Vendors such as Bentley and AutoDesk have developed tailored solutions to the building construction sector. AASHTO has made improvements to its existing software packages for mobile use. But until a software/application champion emerges, there will be a wide gap in both the potential and actual use of mobile devices.

Mobile IT devices, applications, and their connectivity are improving rapidly. Photogrammetry, GPS accuracy, mobile LiDAR, and UAVs, among other technologies, are on the rise and offer a multitude of possibilities for visualization and communication in the field and between the field and office functions.

The survey and case study findings show that STAs are embracing mobile IT devices to replace, improve, or supplement current business practices in design, construction, and asset management. Mobile IT devices are offering a multitude of benefits at a comparatively low cost. They have become an integral part of people's daily lives but have yet to be incorporated into full use in transportation agencies. Future research could not only investigate emerging technologies but could also provide guidance to the STAs for integrating the devices into their processes; research could clarify best practices, uses, and strategies for selection, function, and implementation. Ultimately, adoption of mobile devices will rely on their cost-effectiveness. STAs need a standard and appropriate cost-benefit methodology to effectively capture the value of mobile IT in the field. Guidance on a formal ROI methodology for mobile IT devices could also help STAs understand how to make sound decisions regarding their use of the devices.

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APPENDIX A

Survey Questionnaire

E-mail to Potential Participants

From: NCHRP Staff

To: Members of AASHTO Standing Committee on Finance and Administration Subcommittee on Information Systems

Subject: NCHRP Project 20-05/Synthesis Topic 46-06: Usage of Mobile IT Devices in the Field for Design, Construction, and Asset Management

Dear Members of the AASHTO Standing Committee on Information Systems:

The National Academy of Sciences (NAS), through the Transportation Research Board (TRB), conducts studies related to contemporary transportation issues. The National Cooperative Highway Research Program (NCHRP) was established within TRB to fund and execute these research projects and publish reports. I am writing to request your input regarding NCHRP Project 20-05/Synthesis Topic 46-06: Usage of Mobile IT Devices in the Field for Design, Construction, and Asset Management. This synthesis is being advanced on behalf of NCHRP, under the sponsorship of the American Association of State Highway and Transportation Officials and in cooperation with the Federal Highway Administration.

As part of TRB's ongoing research program, a need was identified to gather relevant information regarding how the transportation community is currently using mobile IT in the field for design, construction, and asset management. Synthesis 46-06 will document how states are using mobile IT, what devices they are using, what operating systems and applications are being used, how those applications were developed, and challenges experienced in the implementation process.

Your cooperation in completing the questionnaire will ensure the success of this effort. Please complete the survey at http://www.surveygizmo.com/s3/1969467/NCHRP-Synthesis-46-06-Use-of-Mobile-IT-Devices by the close of business on February 13, 2015. The survey is expected to take no more than 20–25 minutes to complete.

This research project is being conducted by Gabriel Dadi, from the University of Kentucky Research Foundation, who is under contract with TRB to perform this work. If you have any questions about this survey, how the data will be used, or how to obtain a copy of the final report for this project, please contact:

Dr. Gabriel Dadi

University of Kentucky Research Foundation

859-257-5416

gabe.dadi@uky.edu

Your time and effort are greatly appreciated in support of this important and timely research effort.

NCHRP SYNTHESIS TOPIC 46-06 USAGE OF MOBILE IT DEVICES IN THE FIELD FOR DESIGN, CONSTRUCTION, AND ASSET MANAGEMENT

Please identify your contact information. NCHRP will e-mail you a link to the online report when it is completed.

Agency: _____

Position/Title: _____

Street Address: _____

City: _____

State: _____

Zip: _____

In case of questions and for NCHRP to send you a link to the final report, please provide:

E-mail Address: _____

Phone Number: _____

_____

1) Does your agency use mobile IT devices in the field for design, construction, and asset management? (Please check one response.)

- ☐ Yes
- ☐ No
- ☐ Unsure

2) What state transportation agency do you work for? (Please check one response.)

- ☐ Alabama
- ☐ Alaska
- ☐ Arizona
- ☐ Arkansas
- ☐ California
- ☐ Colorado
- ☐ Connecticut
- ☐ Delaware
- ☐ Florida
- ☐ Georgia
- ☐ Hawaii
- ☐ Idaho
- ☐ Illinois
- ☐ Indiana
- ☐ Iowa
- ☐ Kansas
- ☐ Kentucky
- ☐ Louisiana
- ☐ Maine
- ☐ Maryland
- ☐ Massachusetts
- ☐ Michigan
- ☐ Minnesota
- ☐ Mississippi

- ☐ Missouri
- ☐ Montana
- ☐ Nebraska
- ☐ Nevada
- ☐ New Hampshire
- ☐ New Jersey
- ☐ New Mexico
- ☐ New York
- ☐ North Carolina
- ☐ North Dakota
- ☐ Ohio
- ☐ Oklahoma
- ☐ Oregon
- ☐ Pennsylvania
- ☐ Rhode Island
- ☐ South Carolina
- ☐ South Dakota
- ☐ Tennessee
- ☐ Texas
- ☐ Utah
- ☐ Vermont
- ☐ Virginia
- ☐ Washington
- ☐ West Virginia
- ☐ Wisconsin
- ☐ Wyoming

3) What division do you work for within your agency? (Please check one response.)

- ☐ Design
- ☐ Construction
- ☐ IT
- ☐ Maintenance
- ☐ Other: _____

4) What mobile IT device(s) does your agency issue (not including personally owned devices) for use in the field? (Please check all that apply.)

- ☐ Laptops
- ☐ Mini-laptops
- ☐ Handheld multifunctional data collectors (e.g., Trimble Yuma, Nomad, and Juno)

☐ Tablet

☐ Smartphone

☐ Digital camera

☐ GPS-equipped digital camera

☐ RFID readers

☐ Laser rangefinder

☐ None

☐ Other: _____

5) What operating system (OS) platform(s) does (do) your agency's mobile IT device(s) generally use? (Please check all that apply.)

☐ iOS (designed for mobile devices)

☐ OS (designed for laptops/desktops)

☐ Android

☐ Blackberry

☐ Windows RT (designed for mobile devices)

☐ Windows 8 (designed for laptops/desktops)

☐ Windows 7

☐ Linux

☐ I don't know

☐ Other: _____

6) To what degree has your agency adopted/implemented mobile IT? (Please check one response.)

☐ High-level implementer

☐ Medium-level implementer

☐ Low-level implementer

7) What percentage of your projects/functions currently use mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%
Your division (refer to Question 3)	( )	( )	( )	( )	( )
Agency (if known)	( )	( )	( )	( )	( )

8) What percentage of your agency's (division's) employees are provided with mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%
Your division (refer to Question 3)	( )	( )	( )	( )	( )
Agency (if known)	( )	( )	( )	( )	( )

9) What is (are) the main purpose(s) for your current use of mobile IT? (Please check all that apply.)

☐ Access standards and manuals

☐ Access and send e-mails

☐ Make phone calls/send text messages

- ☐ View and edit plans
- ☐ Take/view geotagged photos
- ☐ Take/view geotagged videos
- ☐ View 3D models
- ☐ RFID/barcode scanning
- ☐ GPS/GNSS coordinates
- ☐ GIS viewing
- ☐ Record entry
- ☐ Collect spatial geometry
- ☐ Other: _____

10) Considering the responses in Question 9, list specific tasks completed within each checked purpose; for example, using geotagged photos to specifically identify and locate corrective work on a construction project.

_____

11) What applications does (do) your agency''s mobile IT device(s) use? (Please check all that apply.)

- ☐ Microsoft Office
- ☐ Trimble TerraFlex
- ☐ Trimble TerraSync
- ☐ Trimble Contractor
- ☐ Trimble Inspector Pro
- ☐ AutoCAD 360
- ☐ Autodesk BIM 360 (including Glue, Layout, and Field)
- ☐ Autodesk InfraWorks 360
- ☐ Autodesk ConstructWare
- ☐ SketchUp Mobile Viewer
- ☐ Bentley Navigator Mobile
- ☐ Bentley Structural Synchronizer View
- ☐ Bentley ProjectWise Explorer Mobile
- ☐ Bentley Field Supervisor
- ☐ SiteManager by AASHTO
- ☐ BlueBeam (Revu, Vu, Xtreme)
- ☐ Adobe Pro
- ☐ Collector for ArcGIS
- ☐ ArcPad
- ☐ ArcGIS for Windows Mobile
- ☐ ArcGIS Runtime SDKs
- ☐ Agency developed applications
- ☐ I don't know
- ☐ Other: _____

12) Does your agency use purchased off-the-shelf, custom-developed, or purchased off-the-shelf and customized applications for your mobile IT devices? (Please check all that apply.)

- ☐ Purchased off the shelf or from app stores
- ☐ Custom developed in-house
- ☐ Custom developed by a consultant with in-house input
- ☐ Custom developed with a combined effort from consultants and agency employees
- ☐ Purchased off the shelf, then customized
- ☐ I don't know

13) What type of applications is your agency deploying? (Please check all that apply.)

- ☐ Native application (developed for a specific OS)
- ☐ Web-based application (built on a browser using HTML5, JavaScript, Bookstrap, etc.)
- ☐ Cross-platform SDKs (built using frameworks that allow for cross-platform native app development and deployment, such as Adobe Air, PhoneGap, etc.)

14) Does your agency standardize mobile IT devices to be used across multiple business areas? (Please check one response.)

- ☐ Yes
- ☐ No
- ☐ Unsure

15) Does your agency collaborate with other agencies in the development of mobile IT applications? (Please check one response.)

- ☐ Yes
- ☐ No
- ☐ Unsure

16) How does your agency deploy its devices? (Please check all that apply.)

- ☐ Informal process ("give and go")
- ☐ Formal training process
- ☐ Project-specific training and deployment
- ☐ Software-specific training and deployment
- ☐ Other: _____

17) How does your agency deploy and update its applications? (Please check all that apply.)

- ☐ Automatic program updates
- ☐ Submit device for maintenance by request
- ☐ Submit device for maintenance per schedule
- ☐ Request for end user acceptance of updates
- ☐ End user responsibility
- ☐ Download from the App Store
- ☐ Download from the web
- ☐ Other: _____

18) If your agency trains employees who are issued mobile IT devices, what level of training do they receive for their devices? (Please check all that apply.)

- ☐ My agency does not currently have a training plan for users
- ☐ Brief overview of the device's functionality
- ☐ Overview of functionality and how the device has been used on other projects
- ☐ Overview of functionality, rules and regulations for their use, and expectations for their use
- ☐ User groups that share experiences and best practices
- ☐ Software-specific training
- ☐ I don't know
- ☐ Other: _____

19) How are data shared within your agency? (Please check all that apply.)

- ☐ Stay with individual data collector
- ☐ Stay within agency project
- ☐ Shared on projects with other stakeholders
- ☐ Incorporated in project lessons learned
- ☐ Synthesized and centralized for future reference to entire agency
- ☐ Device is synced to land-based servers where data are stored and shared
- ☐ Data are synced to a cloud server where they are stored and shared
- ☐ Other: _____

20) When evaluating potential mobile IT devices, which selection criteria do you consider? (Rank with 1 being the most important; leave blank if you do not think a criterion is important at all.)

- _____ Cost
- _____ Interoperability
- _____ Operating system
- _____ Durability
- _____ Ease of use
- _____ Security of data
- _____ Available native applications
- _____ Agency standard
- _____ Other

If other, please write in here and give a brief description:

_____

21) What parties are involved in the selection of the mobile IT devices? (Please check all that apply.)

- ☐ IT professionals
- ☐ End users
- ☐ Purchasing agents
- ☐ Other: _____

22) What do you believe is the overall return on investment (ROI) from your agency's mobile IT use? [ROI = (benefit – cost)/(cost × 100)] (Please check one response.)

- ☐ Negative ROI
- ☐ >0–25%
- ☐ >25–50%
- ☐ >50–75%
- ☐ >75–100%
- ☐ 100%+

23) Which of the following challenges do you believe is most significant to mobile IT use? (Rank with 1 being the most significant; leave blank if you do not think that a challenge is significant at all.)

- _____ Cost-effectiveness
- _____ Training requirements
- _____ Electronic signatures/approval
- _____ Quality of collected data
- _____ Poor/ineffective applications
- _____ Connectivity issues (loss of cell signal)
- _____ Interoperability issues (software incompatibility)
- _____ Battery life
- _____ Lack of security of collected data
- _____ Poor durability/lack of ruggedness
- _____ Deploying devices to employees
- _____ End user resistance
- _____ Device maintenance and user support
- _____ Application maintenance and support
- _____ Other

If other, please write in here and give a brief description:

_____

24) When evaluating performance of the mobile IT devices, what metrics are considered? (Please check all that apply.)

- ☐ End user approval
- ☐ Efficiencies gained
- ☐ Cost-benefit analysis
- ☐ Durability and maintenance of devices
- ☐ Agility/flexibility for desired tasks
- ☐ Increase in quality
- ☐ Other: _____

Logic: Show/hide trigger exists.

25) Does your agency plan on expanding the number or use of mobile IT devices? (Please check one response.)

☐ Yes

☐ No

☐ Unsure

Logic: Hidden unless: Question #25 "Does your agency plan on expanding the number or use of mobile IT devices? (Please check one response.)" is answered "Yes."

26) If Yes, what are the immediate plans? (Please check all that apply.)

	Deploy additional devices to current division	Deploy additional devices to other divisions	Purchase new devices	Provide additional training	Investigate more progressive devices and uses	Optimize/ modify existing technologies used	Develop new apps	Other
Your division (refer to Question 3)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Agency (if known)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

If other, please write in here and give a brief description:

_____

27) Which of the following opportunities are you most excited about for the future of technology in the field? (Please check all that apply.)

☐ Handheld LiDAR/3D scanning

☐ Wearable IT (e.g., Google Glass, iWatch)

☐ Augmented reality

☐ Unmanned aerial vehicles

☐ Automated machine guidance system

☐ Remote inspection technologies

☐ Other: _____

_____

Thank You!

_____

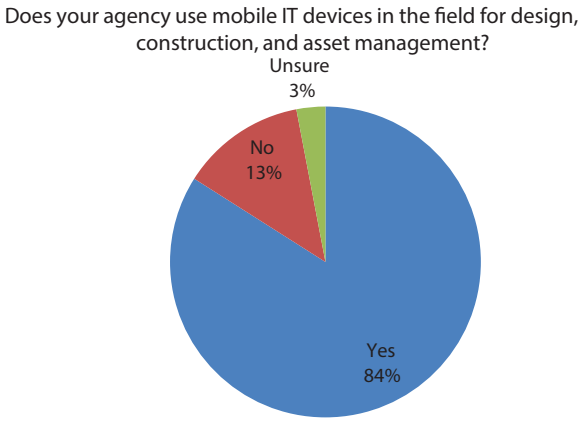
APPENDIX B

Survey Results

Summary Report

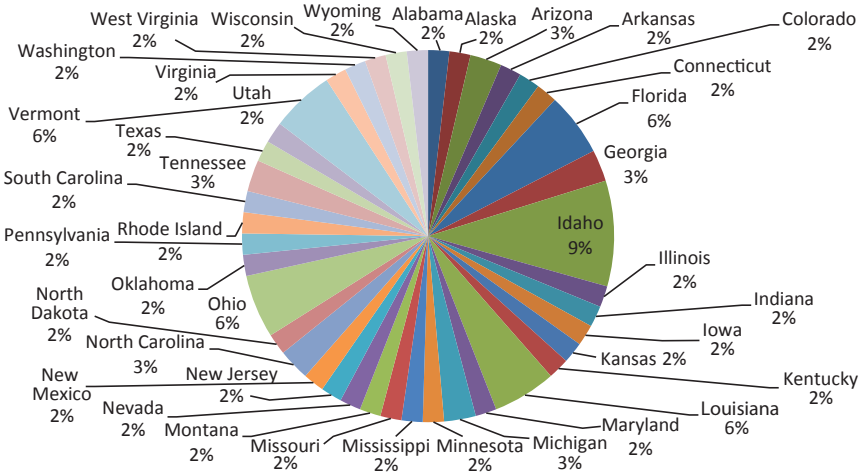
Survey: NCHRP SYNTHESIS TOPIC 46-06 USAGE OF MOBILE IT DEVICES IN THE FIELD FOR DESIGN, CONSTRUCTION, AND ASSET MANAGEMENT

1. Does your agency use mobile IT devices in the field for design, construction, and asset management? (Please check one response.)



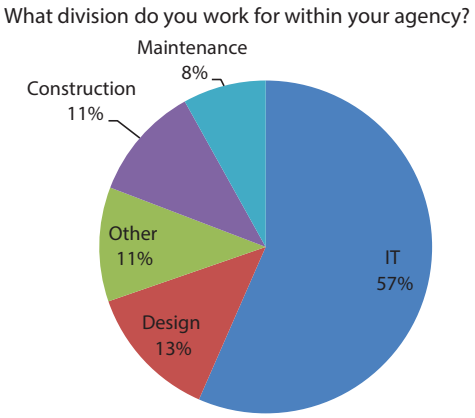
Value	Percent	Count
Yes	84%	52
No	13%	8
Unsure	3%	2
Total		62
Statistics		
Total Responses	62	

2. What state transportation agency do you work for? (Please check one response.)



Value	Percent	Count
Alabama	2%	1
Alaska	2%	1
Arizona	3%	2
Arkansas	2%	1
California	0%	0
Colorado	2%	1
Connecticut	2%	1
Delaware	0%	0
Florida	6%	4
Georgia	3%	2
Hawaii	0%	0
Idaho	10%	6
Illinois	2%	1
Indiana	2%	1
Iowa	2%	1
Kansas	2%	1
Kentucky	2%	1
Louisiana	6%	4
Maine	0%	0
Maryland	2%	1
Massachusetts	0%	0
Michigan	3%	2
Minnesota	2%	1
Mississippi	2%	1
Missouri	2%	1
Montana	2%	1
Nebraska	0%	0
Nevada	2%	1
New Hampshire	0%	0
New Jersey	2%	1
New Mexico	2%	1
New York	0%	0
North Carolina	3%	2
North Dakota	2%	1
Ohio	6%	4
Oklahoma	2%	1
Oregon	0%	0
Pennsylvania	2%	1
Rhode Island	2%	1
South Carolina	2%	1
South Dakota	0%	0
Tennessee	3%	2
Texas	2%	1
Utah	2%	1
Vermont	6%	4
Virginia	2%	1
Washington	2%	1
West Virginia	2%	1
Wisconsin	2%	1
Wyoming	2%	1
Total		62
Statistics		
Total Responses	62	

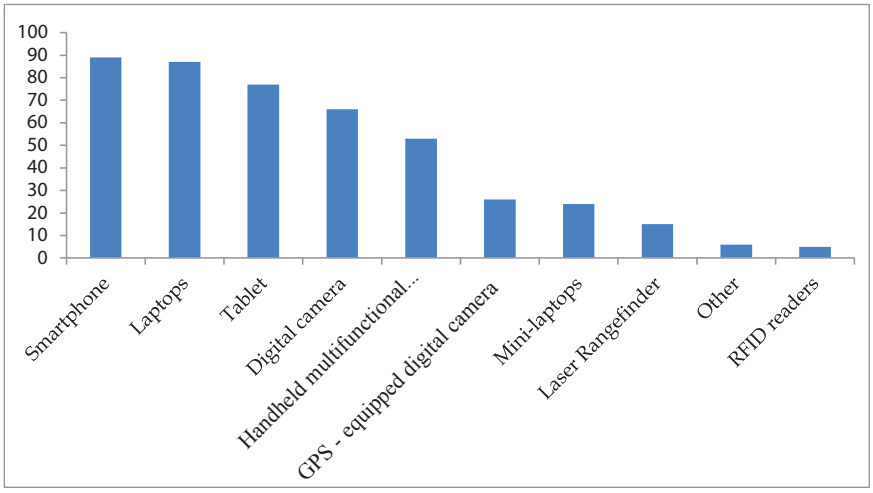
3. What division do you work for within your agency? (Please check one response.)



Value	Percent	Count
IT	56%	35
Design	13%	8
Other	11%	7
Construction	11%	7
Maintenance	8%	5
Total		62
Statistics		
Total Responses	62	

Responses "Other"	Count
Left blank	91
Asset Management	1
Asset Management and Performance	1
Design and Construction	1
IT Services is a unit in Support Services	1
IT, representing Construction	1
ITS	1
Transportation Systems	1

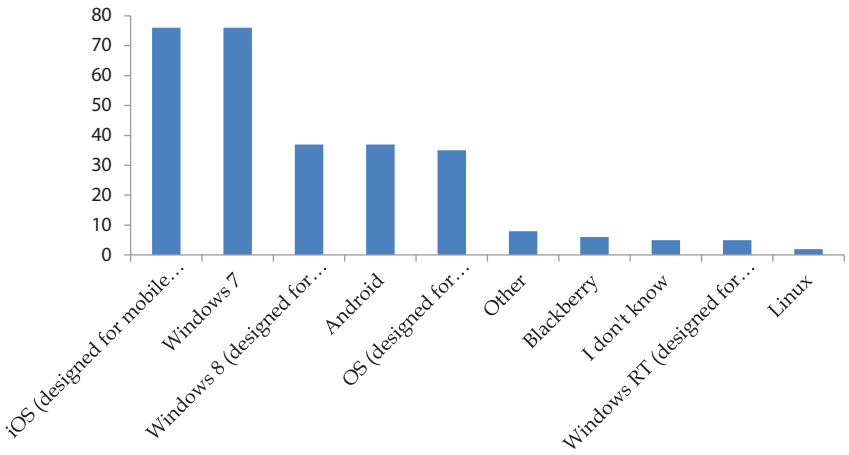
4. What mobile IT device(s) does your agency issue (not including personally owned devices) for use in the field? (Please check all that apply.)



Value	Percent	Count
Smartphone	89%	55
Laptops	87%	54
Tablet	77%	48
Digital camera	66%	41
Handheld multifunctional data collectors (e.g., Trimble Yuma, Nomad, and Juno)	53%	33
GPS-equipped digital camera	26%	16
Mini-laptops	24%	15
Laser Rangefinder	15%	9
Other	6%	4
RFID readers	5%	3
None	0%	0
Total		62
Statistics		
Total Responses	62	

Responses "Other"	Count
Left blank	94
Survey Grade GPS	1
We are in the process of procuring tablet for use with our Maintenance Management System	1
Barcode readers	1
We are just getting started in the use of tablets. We have been using smartphones for approximately 1 year.	1

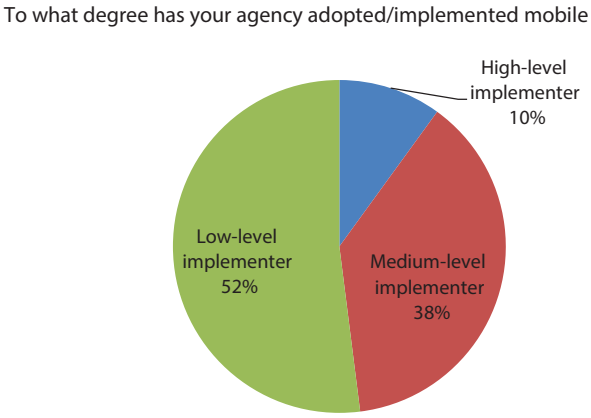
5. What operating system (OS) platform(s) does (do) your agency's mobile IT device(s) generally use? (Please check all that apply.)



Value	Percent	Count
iOS (designed for mobile devices)	76%	47
Windows 7	76%	47
Windows 8 (designed for laptops/ desktops)	37%	23
Android	37%	23
OS (designed for laptops/desktops)	35%	22
Other	8%	5
Blackberry	6%	4
I don't know	5%	3
Windows RT (designed for mobile devices)	5%	3
Linux	2%	1
Total		62
Statistics		
Total Responses	62	

Responses "Other"	Count
Left blank	93
IPhone	1
Windows 8.1 Mobile	1
Windows CE	1
XP	1
Again, we just have one tablet that we have begun trying/experimenting with here in Lewiston, Idaho.	1

6. To what degree has your agency adopted/implemented mobile IT? (Please check one response.)



Value	Percent	Count
High-level implementer	10%	6
Medium-level implementer	38%	23
Low-level implementer	52%	31
Total		60
Statistics		
Total Responses	60	

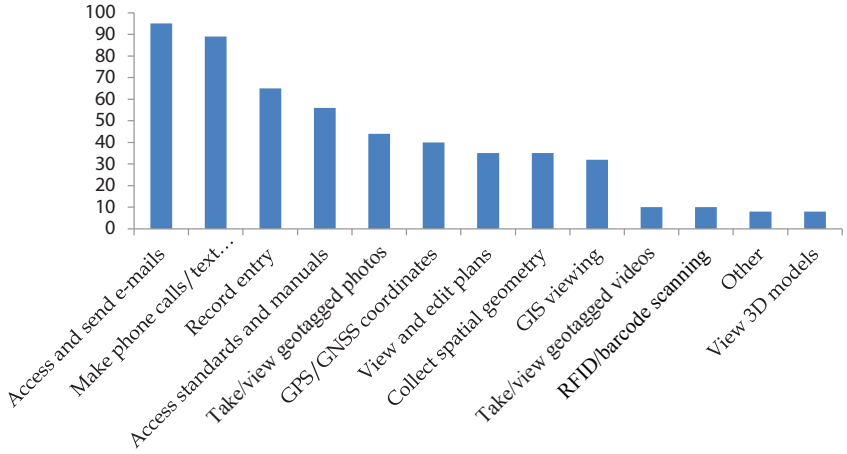
7. What percentage of your projects/functions currently use mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%	Responses
Your division (refer to Question 3)	3% 2	55% 33	17% 10	13% 8	12% 7	60
Agency (if known)	0% 0	72% 33	13% 6	9% 4	7% 3	46
What percentage of your projects/functions currently use mobile IT devices?	0% 0	0% 0	0% 0	0% 0	0% 0	0

8. What percentage of your agency's (division's) employees are provided with mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%	Responses
Your division (refer to Question 3)	0% 0	55% 33	18% 11	17% 10	10% 6	60
Agency (if known)	0% 0	58% 28	21% 10	17% 8	4% 2	48
What percentage of your agency's (division's) employees are provided with mobile IT devices?	0% 0	0% 0	0% 0	0% 0	0% 0	0

9. What is (are) the main purpose(s) for your current use of mobile IT? (Please check all that apply.)



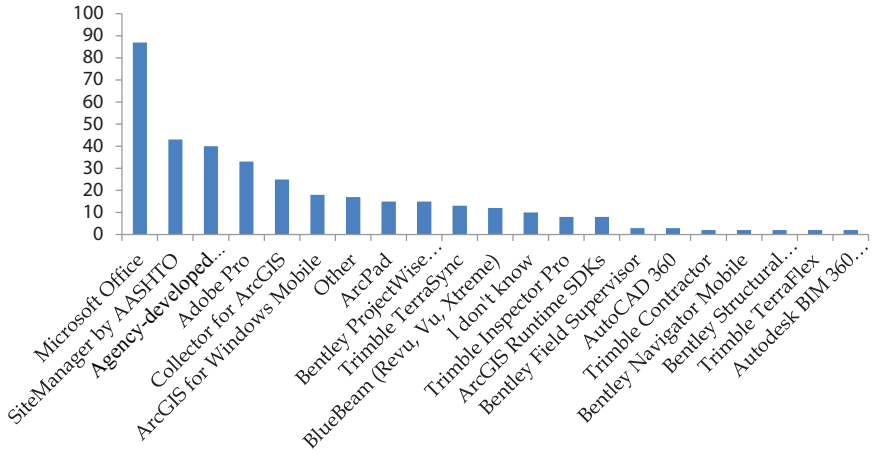
Value	Percent	Count
Access and send e-mails	95%	59
Make phone calls/send text messages	89%	55
Record entry	65%	40
Access standards and manuals	56%	35
Take/view geotagged photos	44%	27
GPS/GNSS coordinates	40%	25
View and edit plans	35%	22
Collect spatial geometry	35%	22
GIS viewing	32%	20
Take/view geotagged videos	10%	6
RFID/barcode scanning	10%	6
Other	8%	5
View 3D models	8%	5
Total		62
Statistics		
Total Responses	62	

Responses "Other"	Count
Left blank	95
GIS data collection	1
Take photographs in field	1
We are in the beginning stages of developing some in-house apps	1

10. Considering the responses in Question 9, list specific tasks completed within each checked purpose; for example, using geotagged photos to specifically identify and locate corrective work on a construction project.

Count	Response
1	Access Idaho Code for surveyors, survey with GPS
1	Access PDFs
1	File management and construction administration processes
1	Geotagging local aid projects
1	Geotagging of assets, construction inspection diaries, viewing plans, e-mail
1	Make phone calls/text messages to send current field conditions and problems
2	NA
1	Quantity documentation, equipment usage, and diary records
1	Record book entry (SiteManager), geotagged photos of bridge/roadway
1	Record entry—use SiteManager stand-alone for DWR entry
1	Record entry from the field via Citrix to state network.
1	Roadside inventory
1	To view plans, manuals, e-mails
1	Use GPS to track invasive species growth or reduction
1	Using tablets to collect and report maintenance activities of the team each day
1	Asset inventory
1	N/A
1	Laptops are used for construction diaries, smartphones for photos, data collection devices for GIS.
1	Most devices are used for communications back/forth to the office. Occasional use to review web-posted documents such as specifications and occasionally PDF-based plans. Construction is implementing eConstruction based on ProjectSolve.
1	Access Standards—We use this as electronic specification book. Accessing the e-mail system saves time from having to travel back to the office; phones calls save time and travel. Record Entry—We use this to make entries into diaries and make our payments to contractors on projects.
1	Construction field data entry, damage assessments, facility assessments, environmental field records, bridge inspections, permit inspections
1	Access PennDOT publications and construction manuals, contracts, award docs, as built drawings and specifications, geotagged pictures of project site activity and road conditions, access e-mail and other communication applications
1	Phone/e-mail: typical office communication. GIS viewing: see interactive maps to understand information. Collect GIS: capture assets, features, etc. Perform surveys/inspections.
1	Design and construction georeferenced photos used in projectwise, data collection for asset management, construction work reports, survey data for design
1	Take photographs of the future project site to help aid in the design. These are especially helpful to remember what things looked like. The phone is handy to call back to the office to ask questions about something or just in case somebody needs to get hold of you. We also gather GPS coordinates to specifically identify and locate work for a design project.
1	Geotag/GPS to identify and locate for construction projects, address conflicts using manuals, answer e-mails and phone calls in a timely matter, collect geospatial information
1	Using mobile devices for construction and bridge inspection. Materials sample tagging and tracking using barcode scanning. Collecting maintenance items and asset management
1	ADA compliance, storm water inspection, construction documentation, asset inventory, and work orders

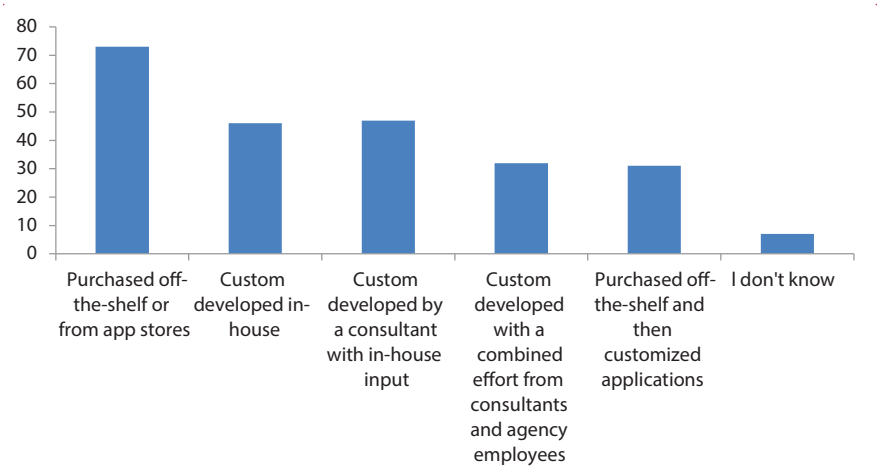
11. What applications does (do) your agency's mobile IT device(s) use? (Please check all that apply.)



Value	Percent	Count
Microsoft Office	87%	52
SiteManager by AASHTO	43%	26
Agency-developed applications	40%	24
Adobe Pro	33%	20
Collector for ArcGIS	25%	15
ArcGIS for Windows Mobile	18%	11
Other	17%	10
ArcPad	15%	9
Bentley ProjectWise Explorer Mobile	15%	9
Trimble TerraSync	13%	8
BlueBeam (Revu, Vu, Xtreme)	12%	7
l don't know	10%	6
Trimble Inspector Pro	8%	5
ArcGIS Runtime SDKs	8%	5
Bentley Field Supervisor	3%	2
AutoCAD 360	3%	2
Trimble Contractor	2%	1
Bentley Navigator Mobile	2%	1
Bentley Structural Synchronizer View	2%	1
Trimble TerraFlex	2%	1
Autodesk BIM 360 (including Glue, Layout, and Field)	2%	1
SketchUp Mobile Viewer	0%	0
Autodesk InfraWorks 360	0%	0
Autodesk ConstructWare	0%	0
Total		60
Statistics		
Total Responses	62	

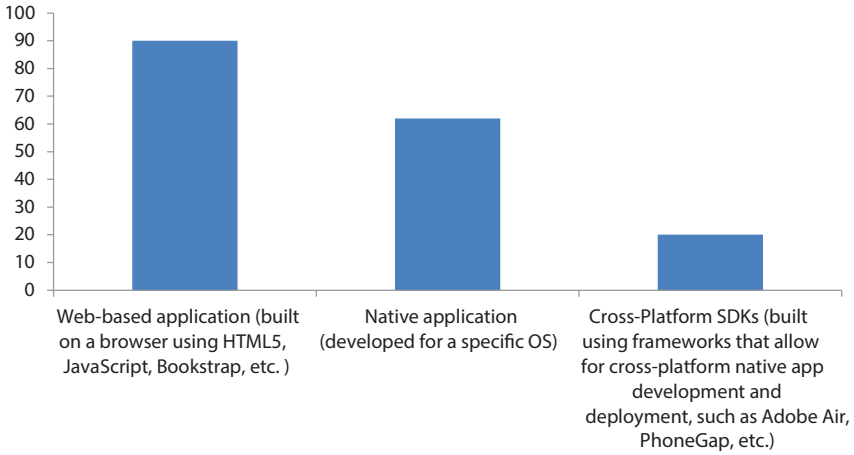
Responses "Other"	Count
Left blank	88
AASHTO field book	1
Bentley Inspectech	1
Currently we only use smartphones	1
SAP Agile	1
SharePoint, Google Maps with street view	1
SharePlus	1
Web-hosted applications	1
Windows mobile, Trimble Survey Controller	1
iCx	1
There is software that I know we use but I don't know what it is. Trimble for example. We use it. I don't know what its specific name is.	1

12. Does your agency use purchased off-the-shelf, custom-developed, or purchased off-the-shelf and customized applications for your mobile IT devices? (Please check all that apply.)



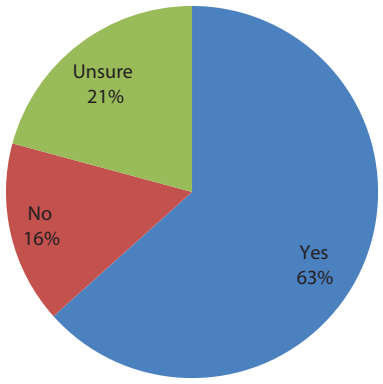
Value	Percent	Count
Purchased off-the-shelf or from app stores	73%	43
Custom developed in-house	46%	27
Custom developed by a consultant with in-house input	47%	28
Custom developed with a combined effort from consultants and agency employees	32%	19
Purchased off-the-shelf and then customized applications	31%	18
I don't know	7%	4
Total		59
Statistics		
Total Responses	59	

13. What type of applications is your agency deploying? (Please check all that apply.)



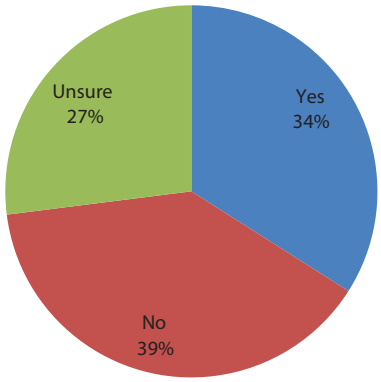
Value	Percent	Count
Web-based application (built on a browser using HTMLS, JavaScript, Bookstrap, etc.)	90%	45
Native application (developed for a specific OS)	62%	31
Cross-platform SDKs (built using frameworks that allow for cross-platform native app development and deployment, such as Adobe Air, PhoneGap, etc.)	20%	10
Total		50
Statistics		
Total Responses	50	

14. Does your agency standardize mobile IT devices to be used across multiple business areas? (Please check one response.)



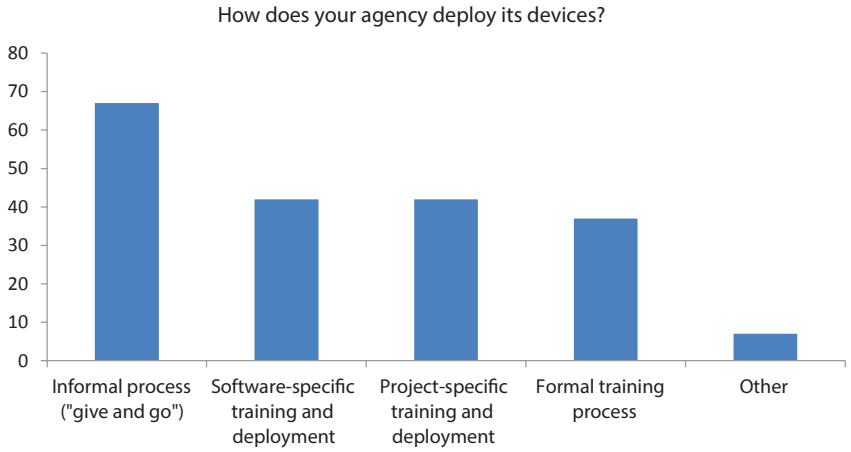
Value	Percent	Count
Yes	63%	37
No	16%	9
Unsure	21%	12
Total		58
Statistics		
Total Responses	58	

15. Does your agency collaborate with other agencies in the development of mobile IT applications? (Please check one response.)



Value	Percent	Count
Yes	34%	20
No	39%	23
Unsure	27%	16
Total		59
Statistics		
Total Responses	59	

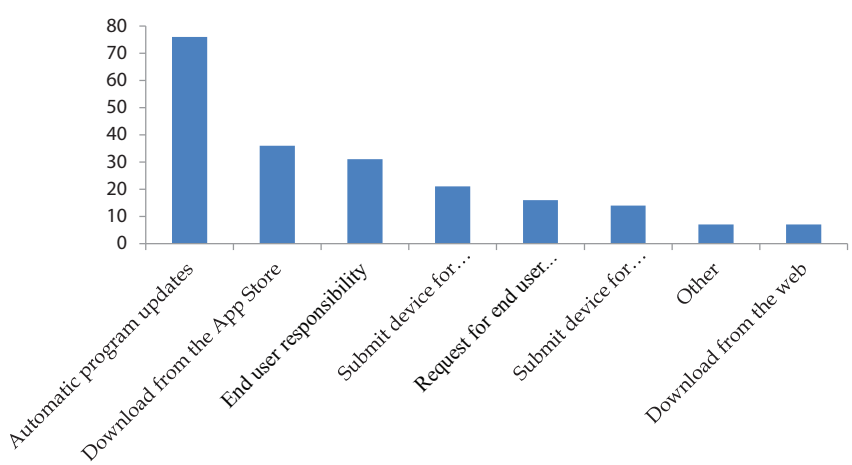
16. How does your agency deploy its devices? (Please check all that apply.)



Value	Percent	Count
Informal process (“give and go”)	67%	40
Software-specific training and deployment	42%	25
Project-specific training and deployment	42%	25
Formal training process	37%	22
Other	7%	4
Total		60
Statistics		
Total Responses	60	

Responses "Other"	Count
Left blank	94
Currently we only use smartphones; extensive training is not necessary	1
Don't know	1
Formal approval process for ordering equipment. No specific training provided across the board.	1
May become more formal in the next few months	1

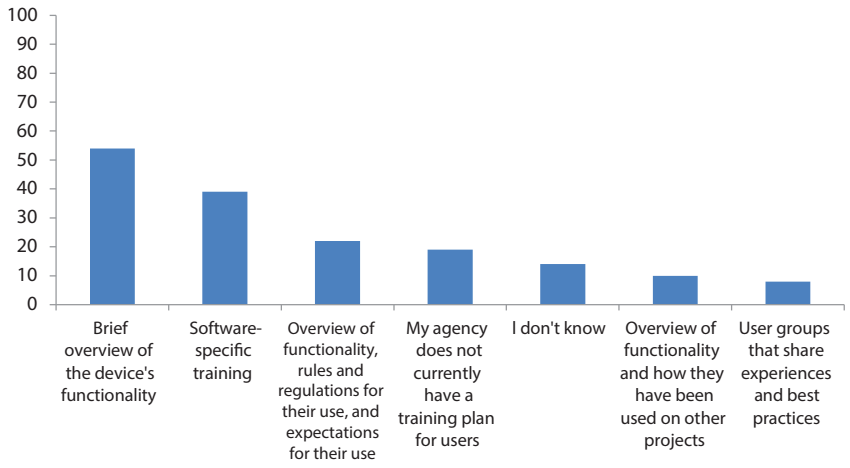
17. How does your agency deploy and update its applications? (Please check all that apply.)



Value	Percent	Count
Automatic program updates	76%	44
Download from the App Store	36%	21
End user responsibility	31%	18
Submit device for maintenance by request	21%	12
Request for end user acceptance of updates	16%	9
Submit device for maintenance per schedule	14%	8
Other	7%	4
Download from the web	7%	4
Total		58
Statistics		
Total Responses	58	

Responses "Other"	Count
Left blank	94
AirWatch MDM	1
Citrix Receiver	1
Will eventually use AirWatch	1
Don't know	1

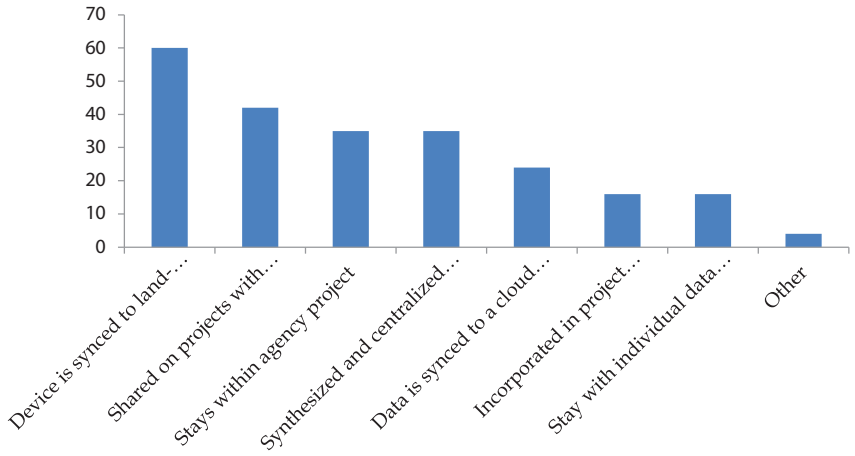
18. If your agency trains employees who are issued mobile IT devices, what level of training do they receive for their devices? (Please check all that apply.)



Value	Percent	Count
Brief overview of the device's functionality	54%	32
Software-specific training	39%	23
Overview of functionality, rules and regulations for their use, and expectations for their use	22%	13
My agency does not currently have a training plan for users	19%	11
I don't know	14%	8
Overview of functionality and how they have been used on other projects	10%	6
User groups that share experiences and best practices	8%	5
Other	0%	0
Total		59
Statistics		
Total Responses	59	

Responses "Other"	Count
Left blank	98

19. How are data shared within your agency? (Please check all that apply.)



Value	Percent	Count
Device is synced to land-based servers where data are stored and shared	60%	33
Shared on projects with other stakeholders	42%	23
Stays within agency project	35%	19
Synthesized and centralized for future reference to entire agency	35%	19
Data are synced to a cloud server where they are stored and shared	24%	13
Incorporated in project lessons learned	16%	9
Stay with individual data collector	16%	9
Other	4%	2
Total		55
Statistics		
Total Responses	55	

Responses "Other"	Count
Left blank	96
I don't know	1
Don't know	1

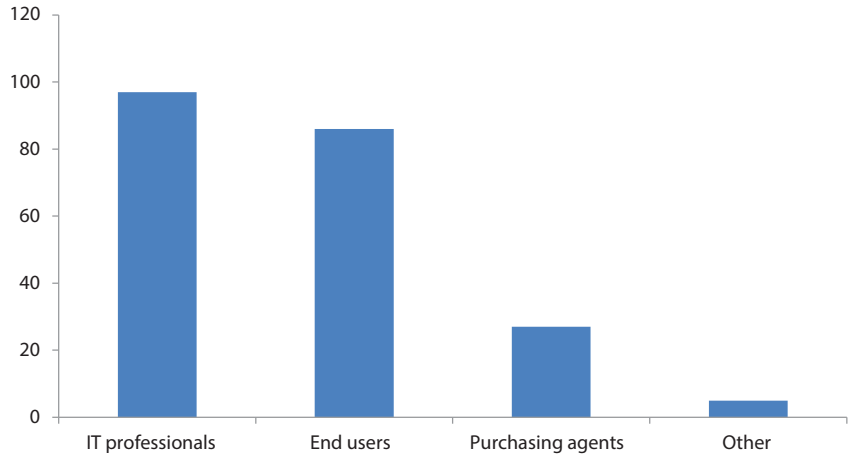
20. When evaluating potential mobile IT devices, which selection criteria do you consider? (Rank with 1 being the most important; leave blank if you do not think that a criterion is important at all.)

	Score*	Overall Rank
Cost	351	1
Security of data	310	2
Ease of use	302	3
Agency standard	276	4
Durability	257	5
Interoperability	236	6
Operating system	220	7
Available native applications	164	8
Other	27	9

*Score is a weighted calculation. Items ranked first are valued higher than the following ranks. The score is the sum of all weighted rank counts.

Count	Response
1	Best fit for the intended function
1	It has to do the job that needs done. If it can't, other factors don't matter.
1	Will required apps run on device?

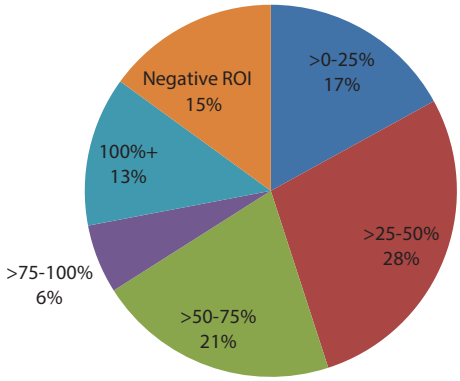
21. What parties are involved in the selection of the mobile IT devices? (Please check all that apply.)



Value	Percent	Count
IT professionals	97%	57
End users	86%	51
Purchasing agents	27%	16
Other	5%	3
Total		59
Statistics		
Total Responses	59	

Responses "Other"	Count
Left blank	95
A fair amount of executive management input.	1
Business mgmt.	1
Unknown	1

22. What do you believe is the overall return on investment (ROI) from your agency's mobile IT use? [ROI = (benefit – cost)/(cost × 100)] (Please check one response.)



Value	Percent	Count
>0–25%	17%	8
>25–50%	28%	13
>50–75%	21%	10
>75–100%	6%	3
100%+	13%	6
Negative ROI	15%	7
Total		47
Statistics		
Total Responses	47	
Sum	600	
Average	100	
Max	100	

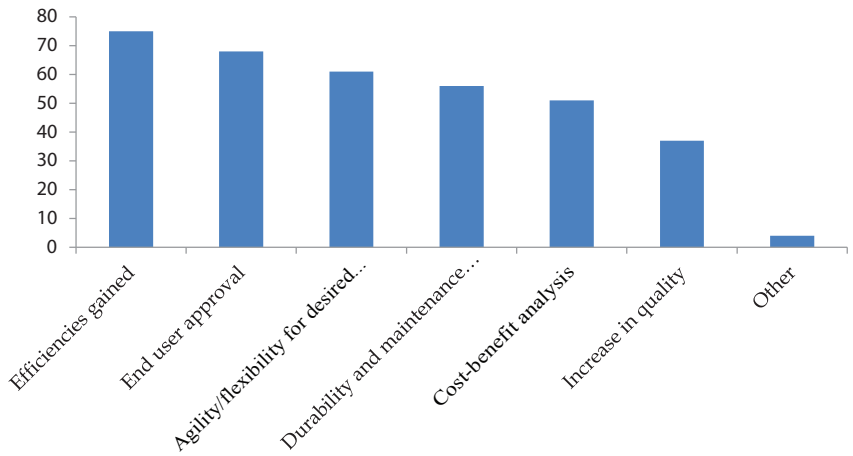
23. Which of the following challenges do you believe are most significant to mobile IT use? (Rank with 1 being the most significant; leave blank if you do not think that a challenge is significant at all.)

	Score*	Overall Rank
Connectivity issues (loss of cell signal)	453	1
Cost-effectiveness	405	2
Device maintenance and user support	359	3
Application maintenance and support	349	4
Poor/ineffective applications	348	5
Interoperability issues (software incompatibility)	333	6
Lack of security of collected data	279	7
Poor durability/lack of ruggedness	234	8
Quality of collected Data	211	9
Deploying devices to employees	202	10
Training requirements	193	11
End user resistance	189	12
Electronic signatures/approval	184	13
Battery life	166	14
Other	60	15
*Score is a weighted calculation. Items ranked first are valued higher than the following ranks. The score is the sum of all weighted rank counts.		

If other, please write in here and give a brief description

Count	Response
1	Lack of strategic direction for overall use
1	Perception
1	Legacy systems upgrade cost to take advantage of mobile computing
1	It has a job to do. Before you can get it, it has to fill a need. Once you have that sorted out, then it's money. Not cost-effectiveness. The money to get it to begin with.

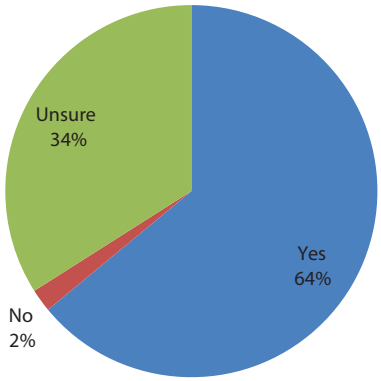
24. When evaluating performance of the mobile IT devices, what metrics are considered? (Please check all that apply.)



Value	Percent	Count
Efficiencies gained	75%	43
End user approval	68%	39
Agility/flexibility for desired tasks	61%	35
Durability and maintenance of devices	56%	32
Cost-benefit analysis	51%	29
Increase in quality	37%	21
Other	4%	2
Total		57
Statistics		
Total Responses	57	

Responses "Other"	Count
Left blank	97
We are in our mobile infancy, just seeing the potential. Measuring would mean that you have enough mobile IT devices to start tracking by an objective measure.	1

25. Does your agency plan on expanding the number or use of mobile IT devices? (Please check one response.)



Value	Percent	Count
Yes	64%	38
No	2%	1
Unsure	34%	20
Total		59
Statistics		
Total Responses	59	

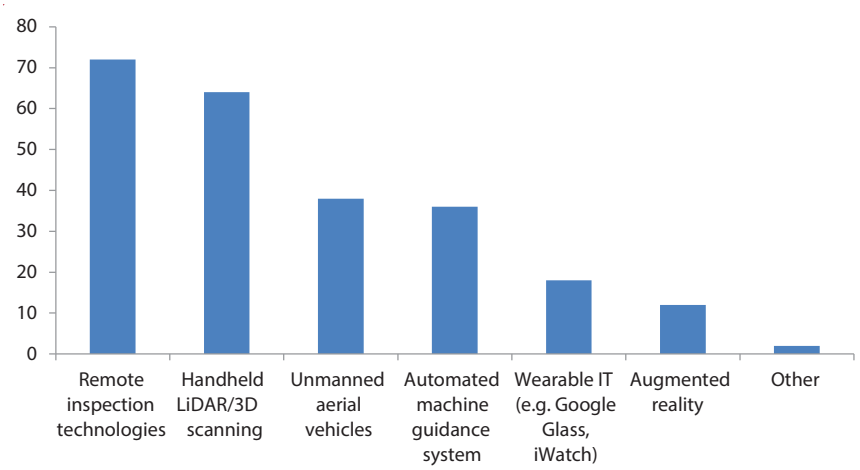
26. If Yes, what are the immediate plans? (Please check all that apply.)

	Deploy additional devices to current division	Deploy additional devices to other divisions	Purchase new devices	Provide additional training	Investigate more progressive devices and uses	Optimize/ modify existing technologies used	Develop new apps	Other	Responses
Your division (refer to Question 3)	69% 22	66% 21	69% 22	59% 19	78% 25	66% 21	59% 19	0% 0	32
Agency (if known)	58% 19	85% 28	85% 28	61% 20	76% 25	73% 24	76% 25	0% 0	33
If Yes, what are the immediate plans? (Please check all that apply.)	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0

If other, please write in here and give a brief description

Count	Response
1	Business decision, not IT

27. Which of the following opportunities are you most excited about for the future of technology in the field? (Please check all that apply.)



Value	Percent	Count
Remote inspection technologies	72%	36
Handheld LiDAR/3D scanning	64%	32
Unmanned aerial vehicles	38%	19
Automated machine guidance system	36%	18
Wearable IT (e.g. Google Glass, iWatch)	18%	9
Augmented reality	12%	6
Other	2%	1
Total		50
Statistics		
Total Responses	50	

Responses "Other"	Count
Left blank	97
Not sure	1

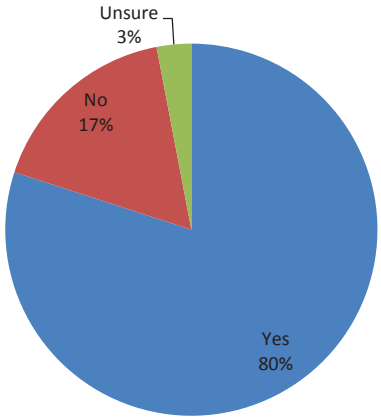
APPENDIX C

IT Survey Results

IT Responses

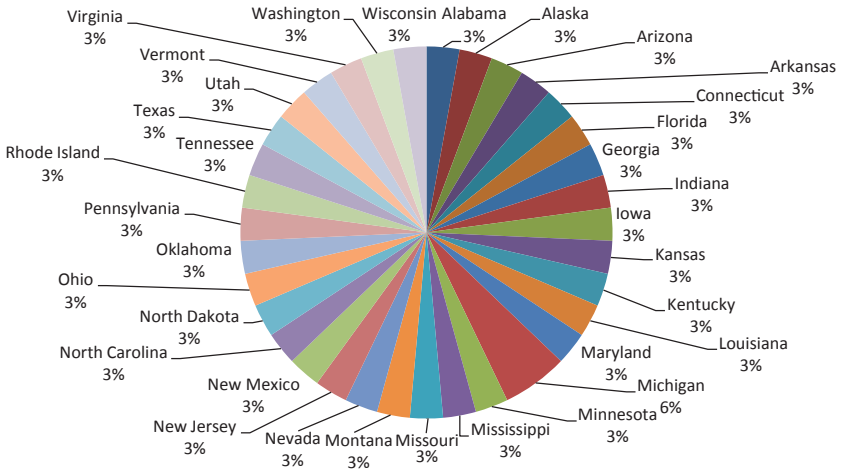
SURVEY: NCHRP SYNTHESIS TOPIC 46-06 USAGE OF MOBILE IT DEVICES IN THE FIELD FOR DESIGN, CONSTRUCTION AND ASSET MANAGEMENT

1. Does your agency use mobile IT devices in the field for design, construction and asset management? (Please check one response.)



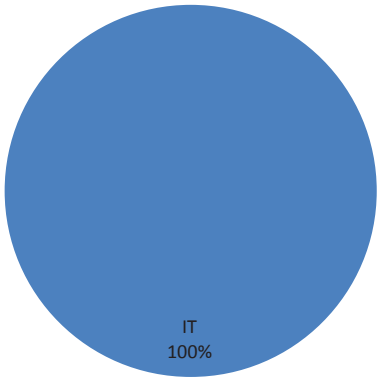
Value	Percent	Count
Yes	80%	28
No	17%	6
Unsure	3%	1
Total		35
Statistics		
Total Responses	35	

2. What state transportation agency do you work for? (Please check one response.)



Value	Percent	Count
Alabama	3%	1
Alaska	3%	1
Arizona	3%	1
Arkansas	3%	1
California	0%	0
Colorado	0%	0
Connecticut	3%	1
Delaware	0%	0
Florida	3%	1
Georgia	3%	1
Hawaii	0%	0
Idaho	0%	0
Illinois	0%	0
Indiana	3%	1
Iowa	3%	1
Kansas	3%	1
Kentucky	3%	1
Louisiana	3%	1
Maine	0%	0
Maryland	3%	1
Massachusetts	0%	0
Michigan	6%	2
Minnesota	3%	1
Mississippi	3%	1
Missouri	3%	1
Montana	3%	1
Nebraska	0%	0
Nevada	3%	1
New Hampshire	0%	0
New Jersey	3%	1
New Mexico	3%	1
New York	0%	0
North Carolina	3%	1
North Dakota	3%	1
Ohio	3%	1
Oklahoma	3%	1
Oregon	0%	0
Pennsylvania	3%	1
Rhode Island	3%	1
South Carolina	0%	0
South Dakota	0%	0
Tennessee	3%	1
Texas	3%	1
Utah	3%	1
Vermont	3%	1
Virginia	3%	1
Washington	3%	1
West Virginia	0%	0
Wisconsin	3%	1
Wyoming	0%	0
Total		35
Statistics		
Total Responses	35	

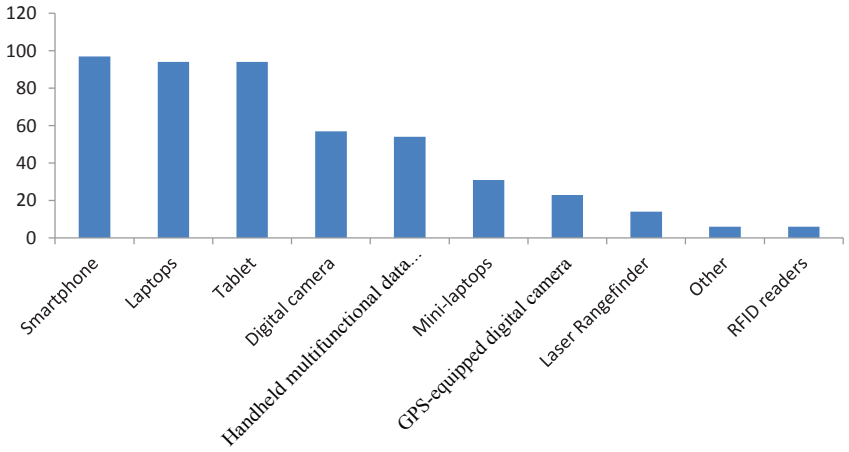
3. What division do you work for within your agency? (Please check one response.)



Value	Percent	Count
IT	100%	35
Other	0%	0
Maintenance	0%	0
Construction	0%	0
Design	0%	0
Total		35
Statistics		
Total Responses	35	

Responses "Other"	Count
Left blank	35

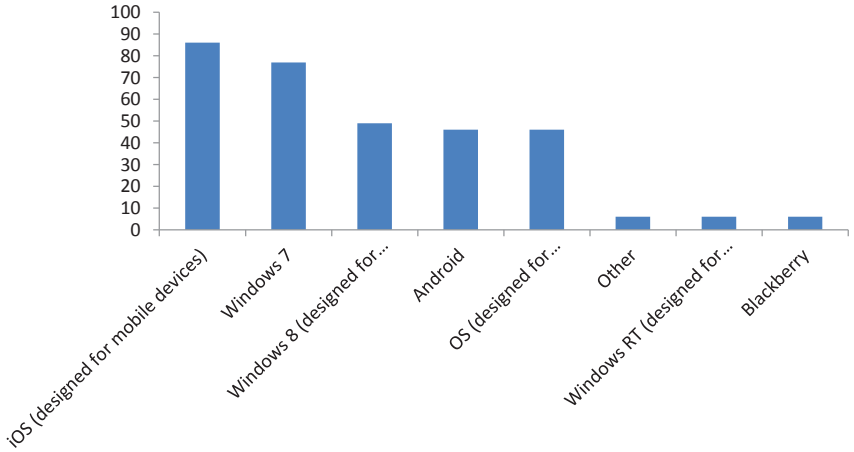
4. What mobile IT device(s) does your agency issue (not including personally owned devices) for use in the field? (Please check all that apply.)



Value	Percent	Count
Smartphone	97%	34
Laptops	94%	33
Tablet	94%	33
Digital camera	57%	20
Handheld multifunctional data collectors (e.g., Trimble Yuma, Nomad, and Juno)	54%	19
Mini-laptops	31%	11
GPS-equipped digital camera	23%	8
Laser rangefinder	14%	5
Other	6%	2
RFID readers	6%	2
None	0%	0
Total		35
Statistics		
Total Responses	35	

Responses "Other"	Count
Left blank	33
We are in the process of procuring tablets for use with our Maintenance Management System	1
Barcode readers	1

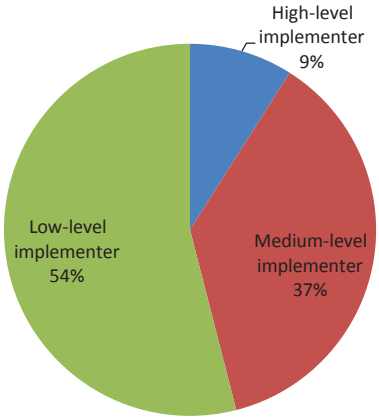
5. What operating system (OS) platform(s) does (do) your agency's mobile IT device(s) generally use? (Please check all that apply.)



Value	Percent	Count
iOS (designed for mobile devices)	86%	30
Windows 7	77%	27
Windows 8 (designed for laptops/ desktops)	49%	17
Android	46%	16
OS (designed for laptops/desktops)	46%	16
Other	6%	2
Windows RT (designed for mobile devices)	6%	2
Blackberry	6%	2
I don't know	0%	0
Linux	0%	0
Total		35
Statistics		
Total Responses	35	

Responses "Other"	Count
Left blank	33
Windows 8.1 Mobile	1
XP	1

6. To what degree has your agency adopted/implemented mobile IT? (Please check one response.)



Value	Percent	Count
High-level implementer	9%	3
Medium-level implementer	37%	13
Low-level implementer	54%	19
Total		35
Statistics		
Total Responses	35	

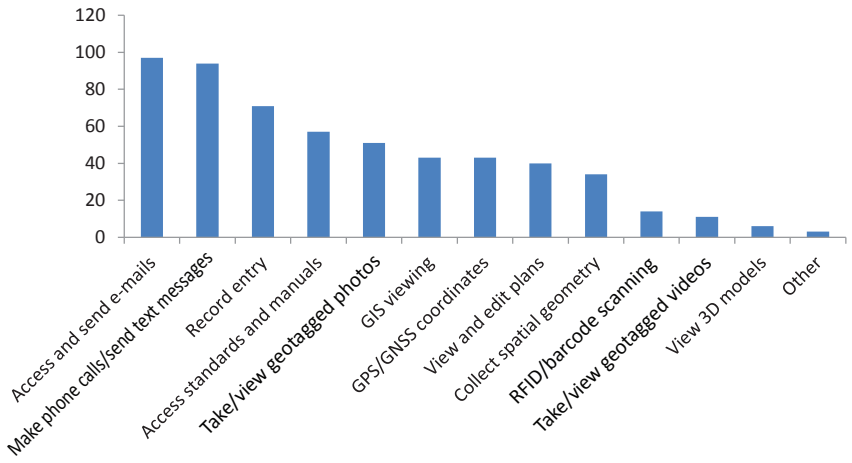
7. What percentage of your projects/functions currently use mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%	Responses
Your division (refer to Question 3)	6% 2	55% 18	15% 5	18% 6	6% 2	33
Agency (if known)	0% 0	71% 22	16% 5	10% 3	3% 1	31
What percentage of your projects/functions currently use mobile IT devices?	0% 0	0% 0	0% 0	0% 0	0% 0	0

8. What percentage of your agency (division) employees are provided with mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%	Responses
Your division (refer to Question 3)	0% 0	45% 15	21% 7	27% 9	6% 2	33
Agency (if known)	0% 0	53% 17	22% 7	25% 8	0% 0	32
What percentage of your agency (division) employees are provided with mobile IT devices?	0% 0	0% 0	0% 0	0% 0	0% 0	0

9. What is (are) the main purpose(s) for your current use of mobile IT? (Please check all that apply.)



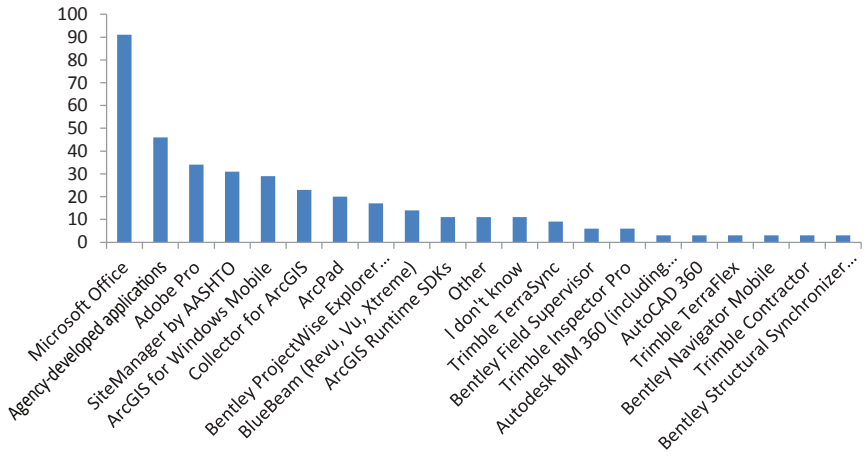
Value	Percent	Count
Access and send e-mails	97%	34
Make phone calls/send text messages	94%	33
Record entry	71%	25
Access standards and manuals	57%	20
Take/view geotagged photos	51%	18
GIS viewing	43%	15
GPS/GNSS coordinates	43%	15
View and edit plans	40%	14
Collect spatial geometry	34%	12
RFID/barcode scanning	14%	5
Take/view geotagged videos	11%	4
View 3D models	6%	2
Other	3%	1
Total		35
Statistics		
Total Responses	35	

Responses "Other"	Count
Left blank	34
We are in the beginning stages of developing some in-house apps	1

10. Considering the responses in Question 9, list specific tasks completed within each checked purpose; for example, using geotagged photos to specifically identify and locate corrective work on a construction project.

Count	Response
1	File management and construction administration processes
1	Geotagging local aid projects
1	Geotagging of assets, construction inspection diaries, viewing plans, e-mail
2	N/A
1	Record book entry (SiteManager), geotagged photos of bridge/roadway
1	Using tablets to collect and report maintenance activities of the team each day
1	Construction field data entry, damage assessments, facility assessments, environmental field records, bridge inspections, permit inspections
1	Access PennDOT publications and construction manuals, contracts, award docs, as-built drawings and specifications, geotagged pictures of project site activity and road conditions, access e-mail and other communication applications
1	Phone/e-mail: typical office communication; GIS viewing: see interactive maps to understand information; collect GIS: capture assets, features, etc.; perform surveys/inspections
1	Geotag/GPS to identify and locate for construction projects, address conflicts using manuals, answer e-mails and phone calls in a timely matter, collect geospatial information
1	Using mobile devices for construction and bridge inspection. Materials sample tagging and tracking using barcode scanning. Collecting maintenance items and asset management.
1	ADA compliance, storm water inspection, construction documentation, asset inventory and work orders

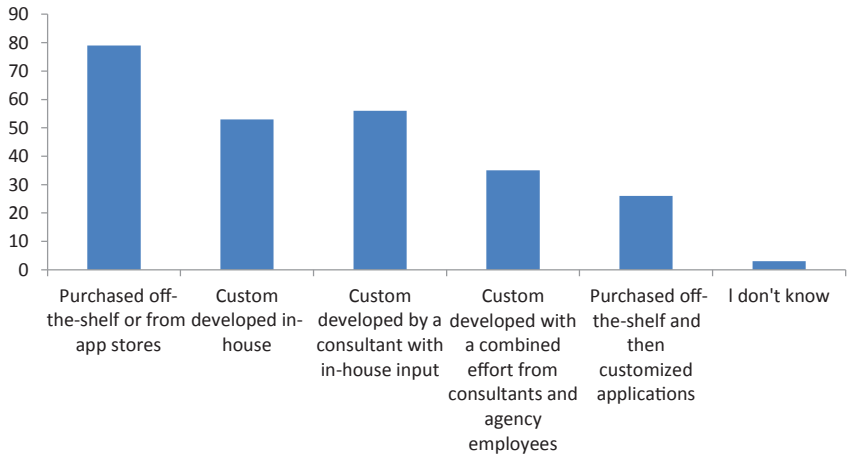
11. What applications does (do) your agency's mobile IT device(s) use? (Please check all that apply.)



Value	Percent	Count
Microsoft Office	91%	32
Agency-developed applications	46%	16
Adobe Pro	34%	12
SiteManager by AASHTO	31%	11
ArcGIS for Windows Mobile	29%	10
Collector for ArcGIS	23%	8
ArcPad	20%	7
Bentley ProjectWise Explorer Mobile	17%	6
BlueBeam (Revu, Vu, Xtreme)	14%	5
ArcGIS Runtime SDKs	11%	4
Other	11%	4
l don't know	11%	4
Trimble TerraSync	9%	3
Bentley Field Supervisor	6%	2
Trimble Inspector Pro	6%	2
Autodesk BIM 360 (including Glue, Layout, and Field)	3%	1
AutoCAD 360	3%	1
Trimble TerraFlex	3%	1
Bentley Navigator Mobile	3%	1
Trimble Contractor	3%	1
Bentley Structural Synchronizer View	3%	1
SketchUp Mobile Viewer	0%	0
Autodesk InfraWorks 360	0%	0
Autodesk ConstructWare	0%	0
Total		35
Statistics		
Total Responses	35	

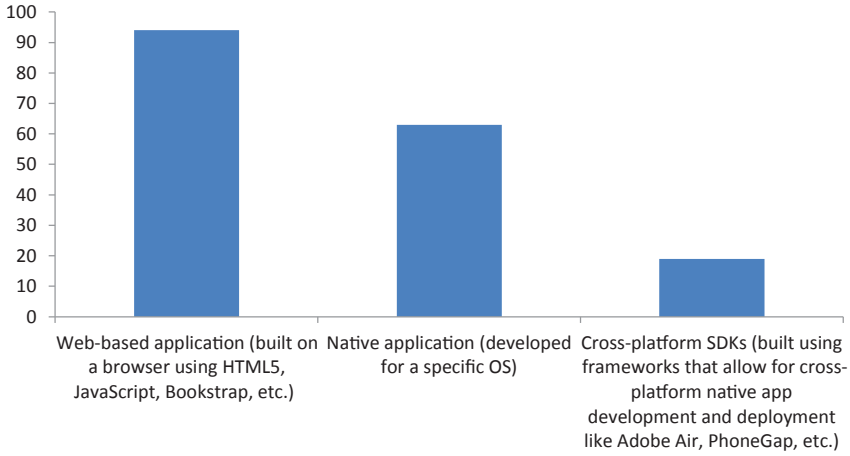
Responses "Other"	Count
Left blank	31
AASHTO field book	1
Bentley Inspectech	1
SAP Agile	1
Web-hosted applications	1

12. Does your agency use purchased off-the-shelf, custom-developed, or purchased-off-the-shelf and customized applications for your mobile IT devices? (Please check all that apply.)



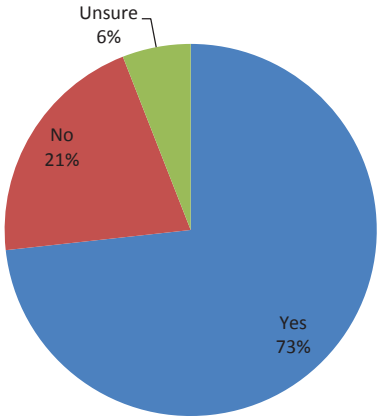
Value	Percent	Count
Purchased off the shelf or from app stores	79%	27
Custom developed in-house	53%	18
Custom developed by a consultant with in-house input	56%	19
Custom developed with a combined effort from consultants and agency employees	35%	12
Purchased off the shelf and then custom-ized applications	26%	9
l don't know	3%	1
Total		34
Statistics		
Total Responses	34	

13. What type of applications is your agency deploying? (Please check all that apply.)



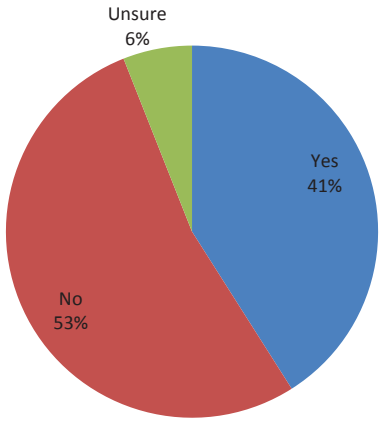
Value	Percent	Count
Web-based application (built on a browser using HTMLS, JavaScript, Bookstrap, etc.)	94%	30
Native application (developed for a specific OS)	63%	20
Cross-platform SDKs (built using frameworks that allow for cross-platform native app development and deployment like Adobe Air, PhoneGap, etc.)	19%	6
Total		32
Statistics		
Total Responses	32	

14. Does your agency standardize mobile IT devices to be used across multiple business areas? (Please check one response.)



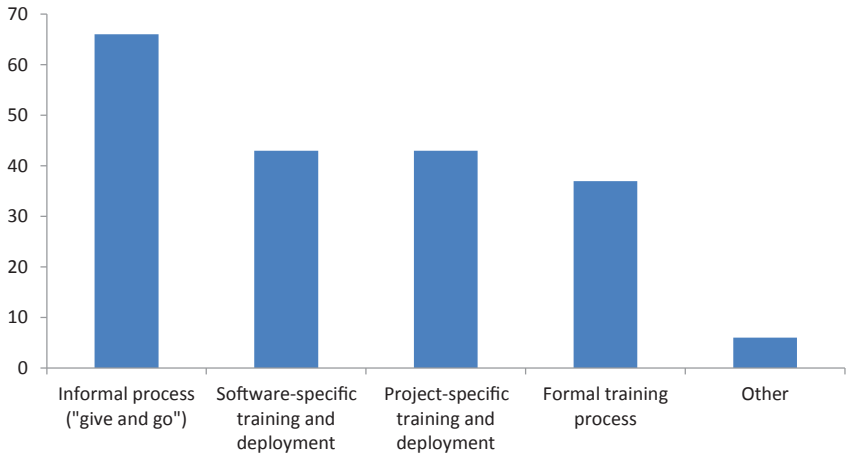
Value	Percent	Count
Yes	73%	25
No	21%	7
Unsure	6%	2
Total		34
Statistics		
Total Responses	34	

15. Does your agency collaborate with other agencies in the development of mobile IT applications? (Please check one response.)



Value	Percent	Count
Yes	41%	14
No	53%	18
Unsure	6%	2
Total		34
Statistics		
Total Responses	34	

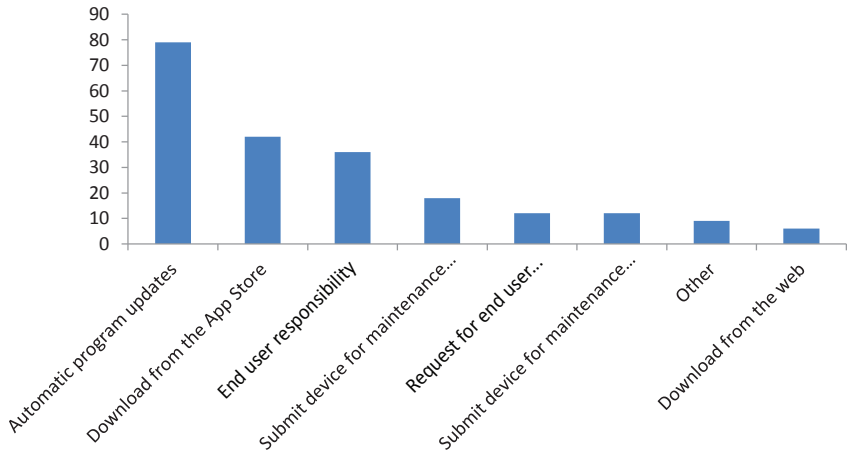
16. How does your agency deploy its devices? (Please check all that apply.)



Value	Percent	Count
Informal process ("give and go")	66%	23
Software-specific training and deployment	43%	15
Project-specific training and deployment	43%	15
Formal training process	37%	13
Other	6%	2
Total		35
Statistics		
Total Responses	35	

Responses "Other"	Count
Left blank	33
Formal approval process for ordering equipment. No specific training provided across the board.	1
May become more formal in the next few months	1

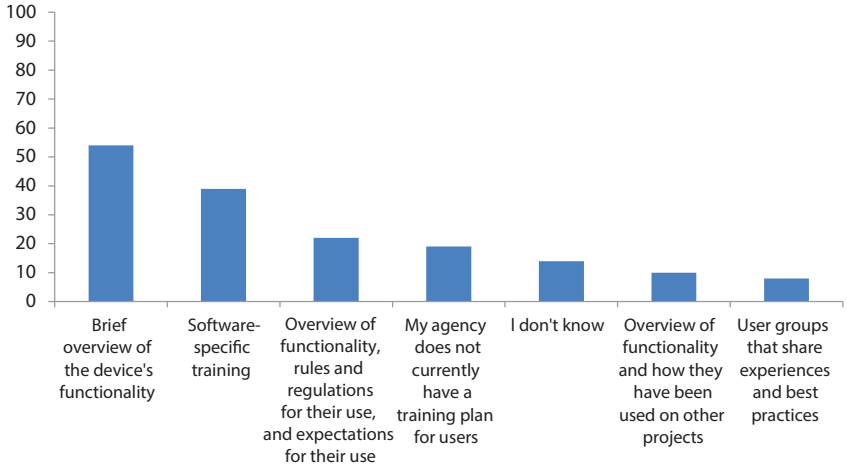
17. How does your agency deploy and update its applications? (Please check all that apply.)



Value	Percent	Count
Automatic program updates	79%	26
Download from the App Store	42%	14
End user responsibility	36%	12
Submit device for maintenance by request	18%	6
Request for end user acceptance of updates	12%	4
Submit device for maintenance per schedule	12%	4
Other	9%	3
Download from the web	6%	2
Total		33
Statistics		
Total Responses	33	

Responses "Other"	Count
Left blank	32
AirWatch MDM	1
Citrix Receiver	1
Will eventually use AirWatch	1

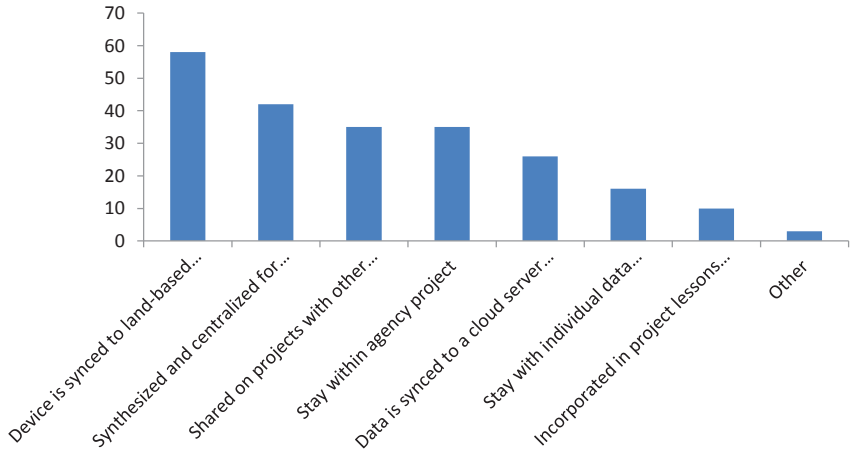
18. If your agency trains employees who are issued mobile IT devices, what level of training do they receive for their devices? (Please check all that apply.)



Value	Percent	Count
Brief overview of the device's functionality	56%	19
Software-specific training	35%	12
Overview of functionality, rules and regulations for their use, and expectations for their use	24%	8
My agency does not currently have a training plan for users	21%	7
User groups that share experiences and best practices	12%	4
I don't know	9%	3
Overview of functionality and how they have been used on other projects	9%	3
Other	0%	0
Total		34
Statistics		
Total Responses	34	

Responses "Other"	Count
Left blank	35

19. How are data shared within your agency? (Please check all that apply.)



Value	Percent	Count
Device is synced to land-based servers where data are stored and shared	58%	18
Synthesized and centralized for future reference to entire agency	42%	13
Shared on projects with other stakeholders	35%	11
Stay within agency project	35%	11
Data are synced to a cloud server where they are stored and shared	26%	8
Stay with individual data collector	16%	5
Incorporated in project lessons learned	10%	3
Other	3%	1
Total		31
Statistics		
Total Responses	31	

Responses "Other"	Count
Left blank	34
I don't know	1

20. When evaluating potential mobile IT devices, which selection criteria do you consider? (Rank with 1 being the most important; leave blank if you do not think that a criterion is important at all.)

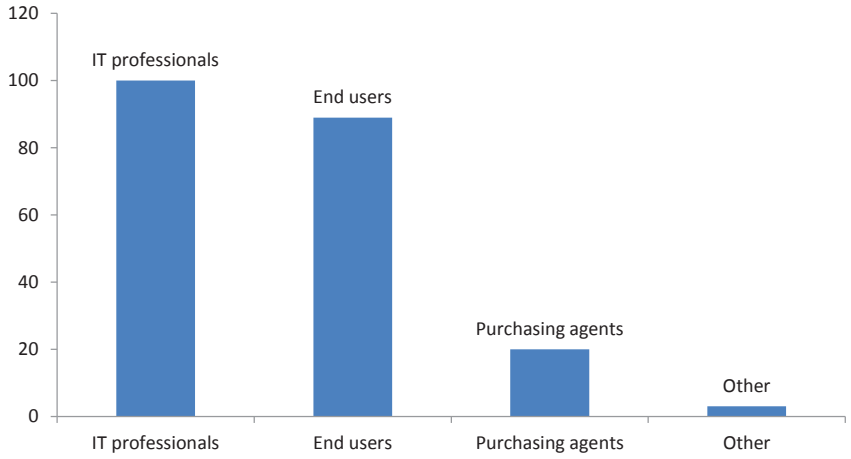
	Score*	Overall Rank
Security of data	214	1
Cost	205	2
Ease of use	188	3
Agency standard	184	4
Interoperability	156	5
Durability	142	6
Operating system	135	7
Available native applications	97	8
Other	15	9

*Score is a weighted calculation. Items ranked first are valued higher than the following ranks. The score is the sum of all weighted rank counts.

If other, please write in here and give a brief description.

Count	Response
1	Best fit for the intended function
1	Will required apps run on device?

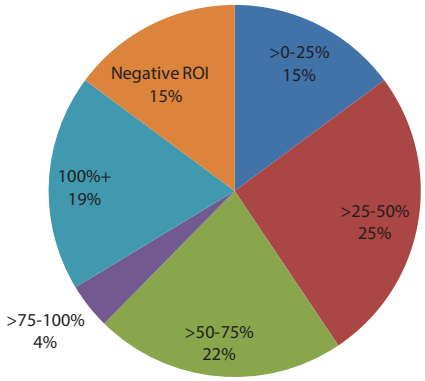
21. What parties are involved in the selection of the mobile IT devices? (Please check all that apply.)



Value	Percent	Count
IT professionals	100%	35
End users	89%	31
Purchasing agents	20%	7
Other	3%	1
Total		35
Statistics		
Total Responses	35	

Responses "Other"	Count
Left blank	34
Business mgmt.	1

22. What do you believe is the overall return on investment (ROI) from your agency's mobile IT use? [ROI = (benefit – cost)/(cost × 100)] (Please check one response.)



Value	Percent	Count
Negative ROI	15%	4
>0–25%	15%	4
>25–50%	25%	7
>50–75%	22%	6
>75–100%	4%	1
100%+	19%	5
Total		27
Statistics		
Total Responses	27	
Sum	500	
Average	100	
Max	100	

23. Which of the following challenges do you believe is most significant to mobile IT use? (Rank with 1 being the most significant; leave blank if you do not think that the challenge is significant at all.)

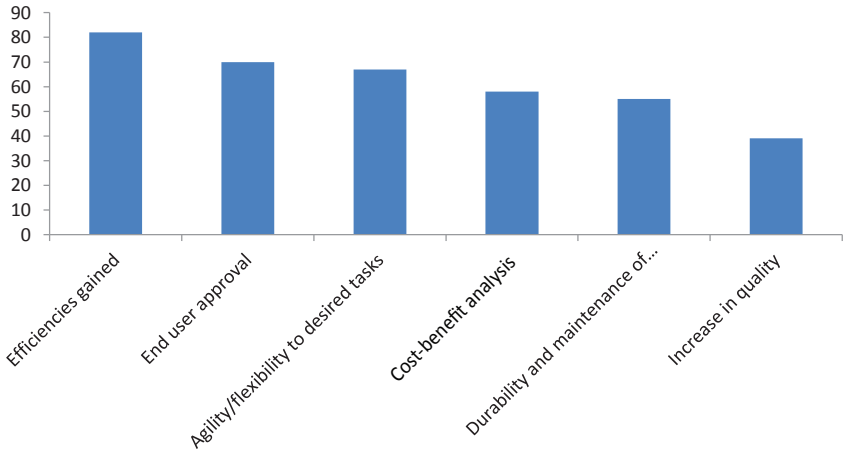
	Score*	Overall Rank
Connectivity issues (loss of cell signal)	241	1
Device maintenance and user support	214	2
Application maintenance and support	205	3
Cost-effectiveness	203	4
Poor/ineffective applications	193	5
Interoperability issues (software incompatibility)	174	6
Lack of security of collected data	171	7
Poor durability/lack of ruggedness	106	8
Electronic signatures/approval	101	9
Quality of collected data	95	10
End user resistance	89	11
Training requirements	86	12
Battery life	73	13
Deploying devices to employees	68	14
Other	27	15

*Score is a weighted calculation. Items ranked first are valued higher than the following ranks. The score is the sum of all weighted rank counts.

If other, please write in here and give a brief description.

Count	Response
1	Lack of strategic direction for overall use
1	Legacy systems upgrade cost to take advantage of mobile computing

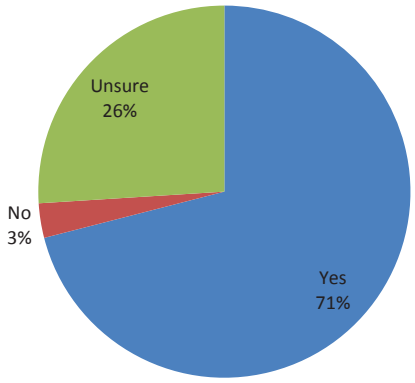
24. When evaluating performance of the mobile IT devices, what metrics are considered? (Please check all that apply.)



Value	Percent	Count
Efficiencies gained	82%	27
End user approval	70%	23
Agility/flexibility for desired tasks	67%	22
Cost-benefit analysis	58%	19
Durability and maintenance of devices	55%	18
Increase in quality	39%	13
Other	0%	0
Total		33
Statistics		
Total Responses	33	

Responses "Other"	Count
Left blank	35

25. Does your agency plan on expanding its number or use of mobile IT devices? (Please check one response.)



Value	Percent	Count
Yes	71%	24
No	3%	1
Unsure	26%	9
Total		34
Statistics		
Total Responses	34	

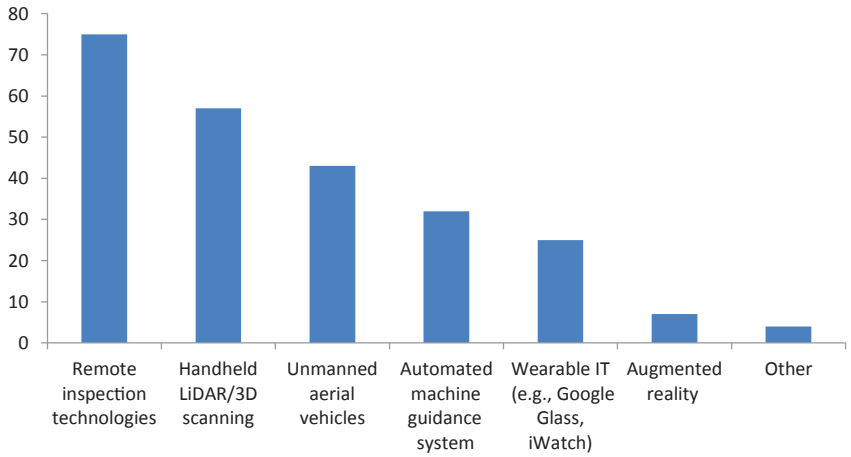
26. If Yes, what are the immediate plans? (Please check all that apply.)

	Deploy additional devices to current division	Deploy additional devices to other divisions	Purchase new devices	Provide additional training	Investigate more progressive devices and uses	Optimize/ modify existing technologies used	Develop new apps	Other	Responses
Your division (refer to Question 3)	65% 13	80% 16	70% 14	65% 13	70% 14	65% 13	65% 13	0% 0	20
Agency (if known)	54% 13	88% 21	83% 20	58% 14	71% 17	75% 18	79% 19	0% 0	24
If Yes, what are the immediate plans? (Please check all that apply.)	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0

If other, please write in here and give a brief description

Count	Response
1	Business decision, not IT

27. Which of the following opportunities are you most excited about for the future of technology in the field? (Please check all that apply.)



Value	Percent	Count
Remote inspection technologies	75%	21
Handheld LiDAR/3D scanning	57%	16
Unmanned aerial vehicles	43%	12
Automated machine guidance system	32%	9
Wearable IT (e.g., Google Glass, iWatch)	25%	7
Augmented reality	7%	2
Other	4%	1
Total		28
Statistics		
Total Responses	28	

Responses "Other"	Count
Left blank	34
Not sure	1

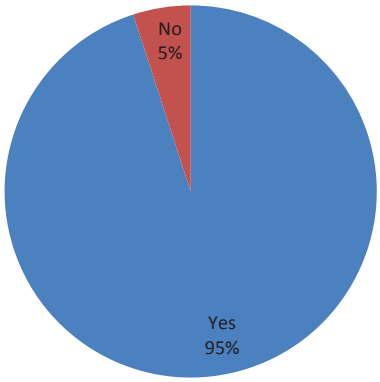
APPENDIX D

End User Survey Results

End User Responses

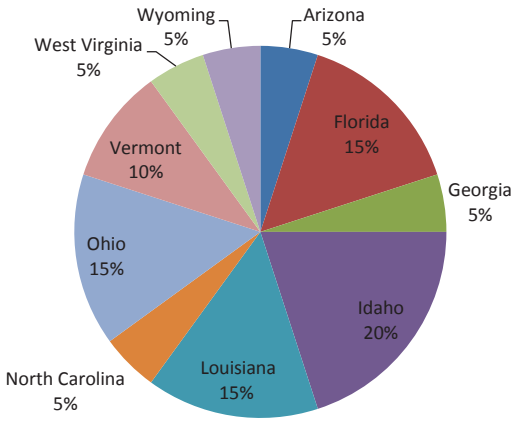
SURVEY: NCHRP SYNTHESIS TOPIC 46-06 USAGE OF MOBILE IT DEVICES IN THE FIELD FOR DESIGN, CONSTRUCTION, AND ASSET MANAGEMENT

1. Does your agency use mobile IT devices in the field for design, construction, and asset management? (Please check one response.)



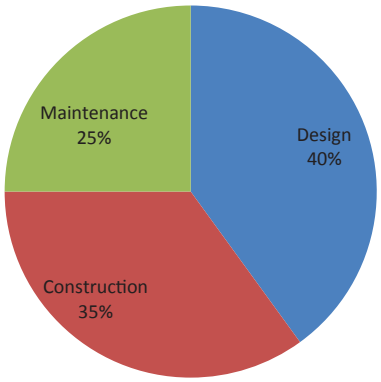
Value	Percent	Count
Yes	95%	19
No	5%	1
Unsure	0%	0
Total		20
Statistics		
Total Responses	20	

2. What state transportation agency do you work for? (Please check one response.)



Value	Percent	Count
Alabama	0%	0
Alaska	0%	0
Arizona	5%	1
Arkansas	0%	0
California	0%	0
Colorado	0%	0
Connecticut	0%	0
Delaware	0%	0
Florida	15%	3
Georgia	5%	1
Hawaii	0%	0
Idaho	20%	4
Illinois	0%	0
Indiana	0%	0
Iowa	0%	0
Kansas	0%	0
Kentucky	0%	0
Louisiana	15%	3
Maine	0%	0
Maryland	0%	0
Massachusetts	0%	0
Michigan	0%	0
Minnesota	0%	0
Mississippi	0%	0
Missouri	0%	0
Montana	0%	0
Nebraska	0%	0
Nevada	0%	0
New Hampshire	0%	0
New Jersey	0%	0
New Mexico	0%	0
New York	0%	0
North Carolina	5%	1
North Dakota	0%	0
Ohio	15%	3
Oklahoma	0%	0
Oregon	0%	0
Pennsylvania	0%	0
Rhode Island	0%	0
South Carolina	0%	0
South Dakota	0%	0
Tennessee	0%	0
Texas	0%	0
Utah	0%	0
Vermont	10%	2
Virginia	0%	0
Washington	0%	0
West Virginia	5%	1
Wisconsin	0%	0
Wyoming	5%	1
Total		20
Statistics		
Total Responses	20	

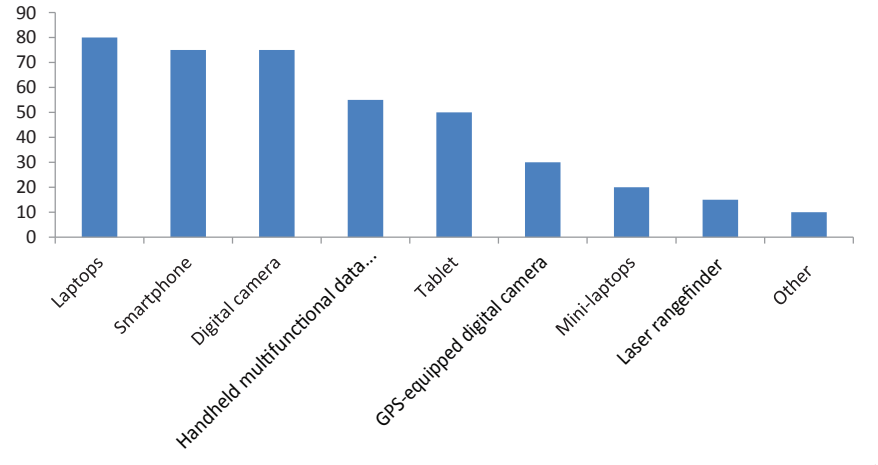
3. What division do you work for within your agency? (Please check one response.)



Value	Percent	Count
Design	40%	8
Construction	35%	7
Maintenance	25%	5
Other	0%	0
IT	0%	0
Total		20
Statistics		
Total Responses	20	

Responses "Other"	Count
Left blank	20

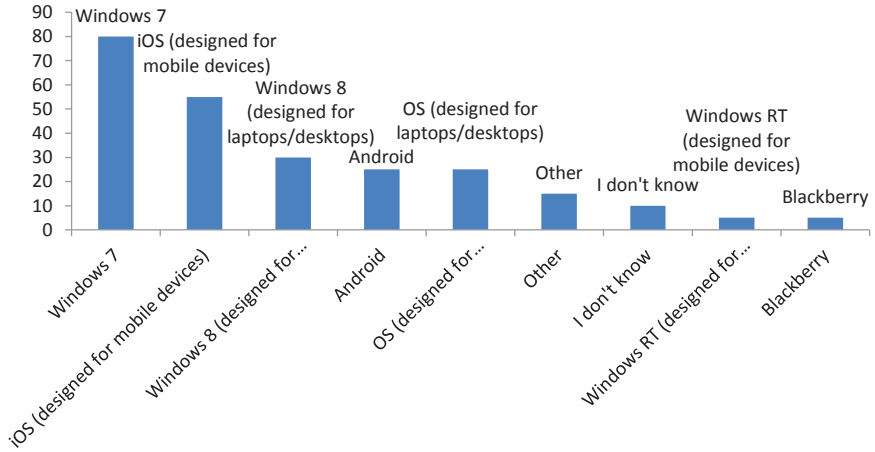
4. What mobile IT device(s) does your agency issue (not including personally owned devices) for use in the field? (Please check all that apply.)



Value	Percent	Count
Laptops	80%	16
Smartphone	75%	15
Digital camera	75%	15
Handheld multifunctional data collectors (e.g., Trimble Yuma, Nomad, and Juno)	55%	11
Tablet	50%	10
GPS-equipped digital camera	30%	6
Mini-laptops	20%	4
Laser rangefinder	15%	3
Other	10%	2
None	0%	0
RFID readers	0%	0
Total		20
Statistics		
Total Responses	20	

Responses "Other"	Count
Left blank	18
Survey grade GPS	1
We are just getting started in the use of tablets. We have been using smartphones for approximately 1 year.	1

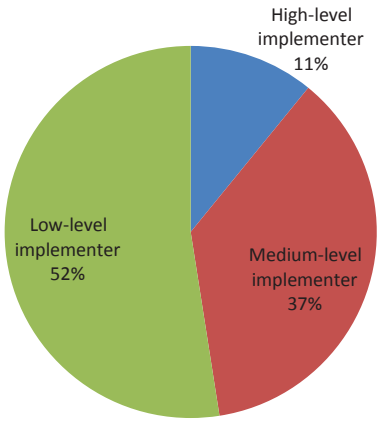
5. What operating system (OS) platform(s) does (do) your agency's mobile IT device(s) generally use? (Please check all that apply.)



Value	Percent	Count
Windows 7	80%	16
iOS (designed for mobile devices)	55%	11
Windows 8 (designed for laptops/ desktops)	30%	6
Android	25%	5
OS (designed for laptops/desktops)	25%	5
Other	15%	3
I don't know	10%	2
Windows RT (designed for mobile devices)	5%	1
Blackberry	5%	1
Linux	0%	0
Total		20
Statistics		
Total Responses	20	

Responses "Other"	Count
Left blank	17
iPhone	1
Windows CE	1
Again, we just have one tablet that we have been trying/experimenting with here in Lewiston, Idaho.	1

6. To what degree has your agency adopted/implemented mobile IT? (Please check one response.)



Value	Percent	Count
High-level implementer	11%	2
Medium-level implementer	37%	7
Low-level implementer	52%	10
Total		19
Statistics		
Total Responses	19	

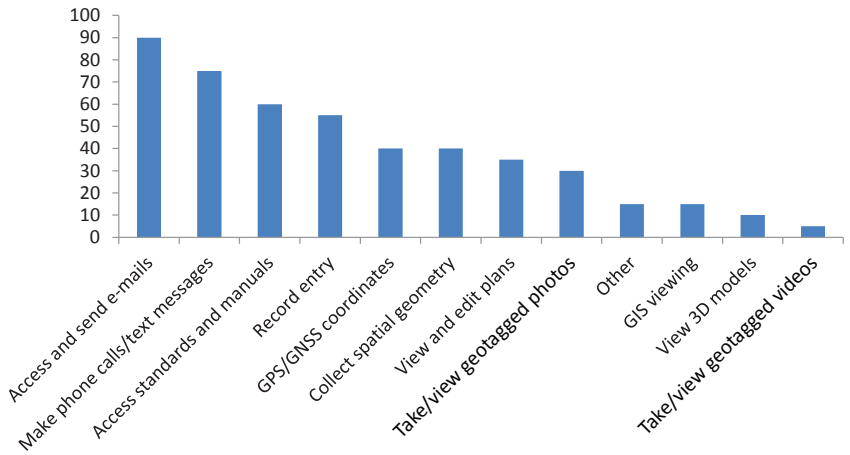
7. What percentage of your projects/functions currently use mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%	Responses
Your division (refer to Question 3)	0% 0	70% 14	5% 1	5% 1	20% 4	20
Agency (if known)	0% 0	80% 8	10% 1	0% 0	10% 1	10
What percentage of your projects/functions currently use mobile IT devices?	0% 0	0% 0	0% 0	0% 0	0% 0	0

8. What percentage of your agency (division) employees are provided with mobile IT devices?

	0%	>0–25%	>25–50%	>50–75%	>75–100%	Responses
Your division (refer to Question 3)	0% 0	75% 15	5% 1	0% 0	20% 4	20
Agency (if known)	0% 0	80% 8	10% 1	0% 0	10% 1	10
What percentage of your agency (division) employees are provided with mobile IT devices?	0% 0	0% 0	0% 0	0% 0	0% 0	0

9. What is (are) the main purpose(s) for your current use of mobile IT? (Please check all that apply.)



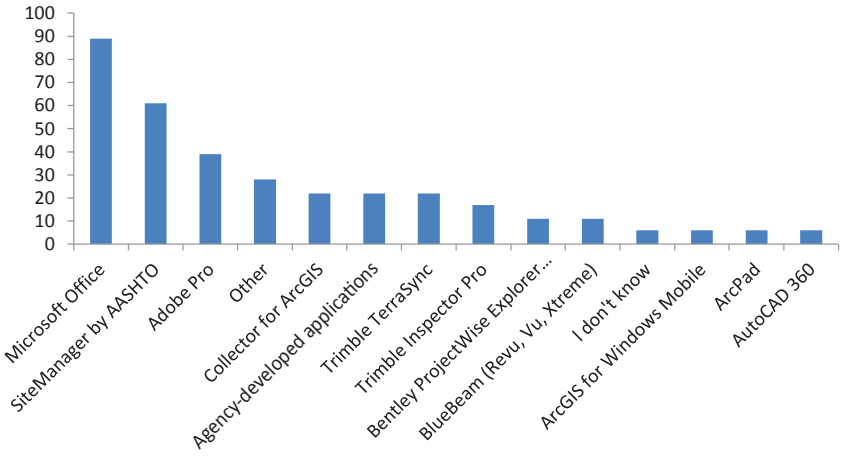
Value	Percent	Count
Access and send e-mails	90%	18
Make phone calls/send text messages	75%	15
Access standards and manuals	60%	12
Record entry	55%	11
GPS/GNSS coordinates	40%	8
Collect spatial geometry	40%	8
View and edit plans	35%	7
Take/view geotagged photos	30%	6
Other	15%	3
GIS viewing	15%	3
View 3D models	10%	2
Take/view geotagged videos	5%	1
RFID/barcode scanning	0%	0
Total		20
Statistics		
Total Responses	20	

Responses "Other"	Count
Left blank	18
GIS data collection	1
Take photographs in field	1

10. Considering the responses in Question 9, list specific tasks completed within each checked purpose; e.g., using geotagged photos to specifically identify and locate corrective work on a construction project.

Count	Response
1	Access Idaho Code for surveyors, survey with GPS
1	Access PDFs
1	Make phone calls/text messages to send current field conditions and problems
1	Quantity documentation, equipment usage, and diary records
1	Record entry from the field via Citrix to state network
1	To view plans, manuals, e-mails
1	Use GPS to track invasive species growth or reduction
1	Asset inventory
1	N/A
1	Laptops are used for construction diaries. Smartphones for photos. Data collection devices for GIS.
1	Most devices are used for communications back/forth to the office. Occasional use to review web-posted documents such as specifications and occasionally PDF-based plans. Construction is implementing e-construction based on ProjectSolve.
1	Access standards—we use this as electronic specification book. Accessing the e-mail system saves time from having to travel back to the office. Phone calls save time and travel. Record entry— we use this to make entries into diaries and make payments to contractors on projects.
1	Take photographs of the future project site to help aid in the design. These are especially helpful to remember what things looked like. The phone is handy to call back to the office to ask questions about something or just in case somebody needs to get hold of you. We also gather GPS coordinates to specifically identify and locate work for a design project.

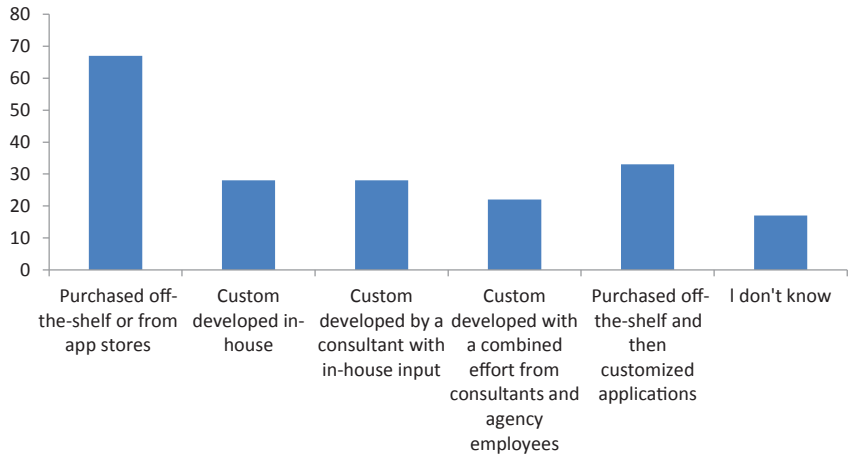
11. What applications does (do) your agency's mobile IT device(s) use? (Please check all that apply.)



Value	Percent	Count
Microsoft Office	89%	16
SiteManager by AASHTO	61%	11
Adobe Pro	39%	7
Other	28%	5
Collector for ArcGIS	22%	4
Agency-developed applications	22%	4
Trimble TerraSync	22%	4
Trimble Inspector Pro	17%	3
Bentley ProjectWise Explorer Mobile	11%	2
BlueBeam (Revu, Vu, Xtreme)	11%	2
I don't know	6%	1
ArcGIS for Windows Mobile	6%	1
ArcPad	6%	1
AutoCAD 360	6%	1
Bentley Navigator Mobile	0%	0
Bentley Structural Synchronizer View	0%	0
Bentley Field Supervisor	0%	0
ArcGIS Runtime SDKs	0%	0
SketchUp Mobile Viewer	0%	0
Trimble TerraFlex	0%	0
Trimble Contractor	0%	0
Autodesk BIM 360 (including Glue, Layout, and Field)	0%	0
Autodesk InfraWorks 360	0%	0
Autodesk ConstructWare	0%	0
Total		18
Statistics		
Total Responses	18	

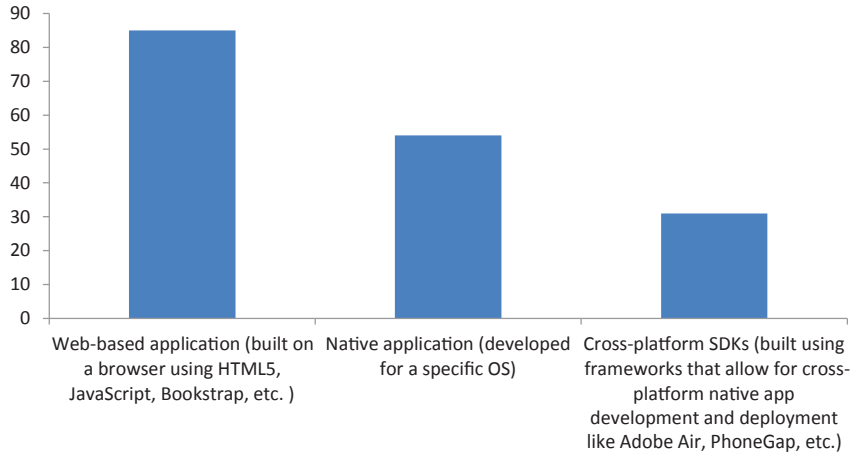
Responses "Other"	Count
Left blank	15
SharePoint, Google Maps with street view	1
SharePlus	1
Windows mobile, Trimble Survey Controller	1
iCx	1
There is software that I know we use but I don't know what it is. Trimble for example. We use it. I don't know what its specific name is.	1

12. Does your agency use purchased off-the-shelf, custom-developed, or purchased off-the-shelf and customized applications for your mobile IT devices? (Please check all that apply.)



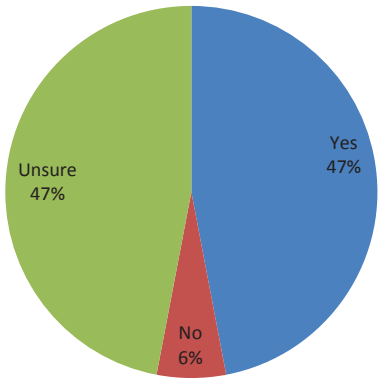
Value	Percent	Count
Purchased off the shelf or from app stores	67%	12
Custom developed in-house	28%	5
Custom developed by a consultant with in-house input	28%	5
Custom developed with a combined effort from consultants and agency employees	22%	4
Purchased off the shelf and then customized applications	33%	6
I don't know	17%	3
Total		18
Statistics		
Total Responses	18	

13. What type of applications is your agency deploying? (Please check all that apply.)



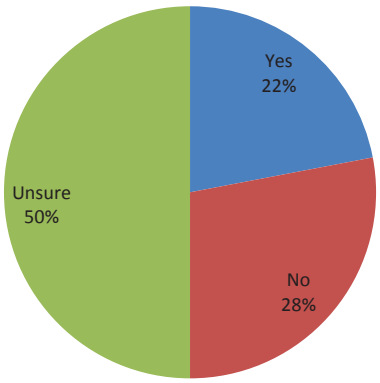
Value	Percent	Count
Web-based application (built on a browser using HTMLS, JavaScript, Bookstrap, etc.)	85%	11
Native application (developed for a specific OS)	54%	7
Cross-platform SDKs (built using frameworks that allow for cross-platform native app development and deployment like Adobe Air, PhoneGap, etc.)	31%	4
Total		13
Statistics		
Total Responses	13	

14. Does your agency standardize mobile IT devices to be used across multiple business areas? (Please check one response.)



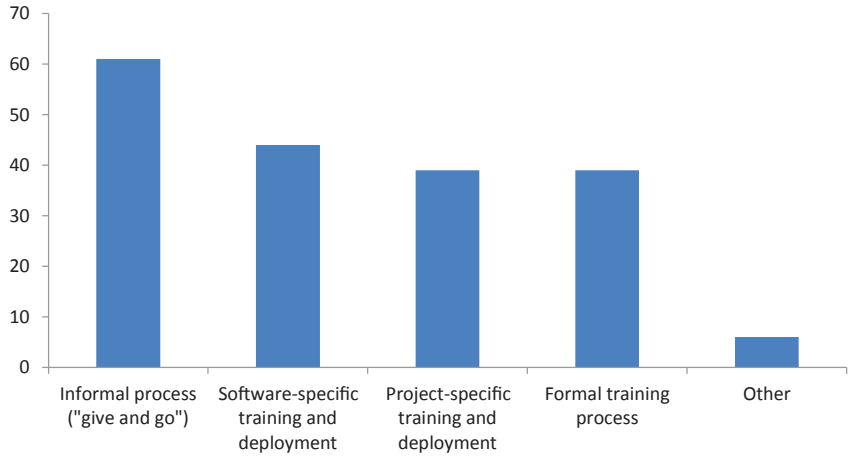
Value	Percent	Count
Yes	47%	8
No	6%	1
Unsure	47%	8
Total		17
Statistics		
Total Responses	17	

15. Does your agency collaborate with other agencies in the development of mobile IT applications? (Please check one response.)



Value	Percent	Count
Yes	22%	4
No	28%	5
Unsure	50%	9
Total		18
Statistics		
Total Responses	18	

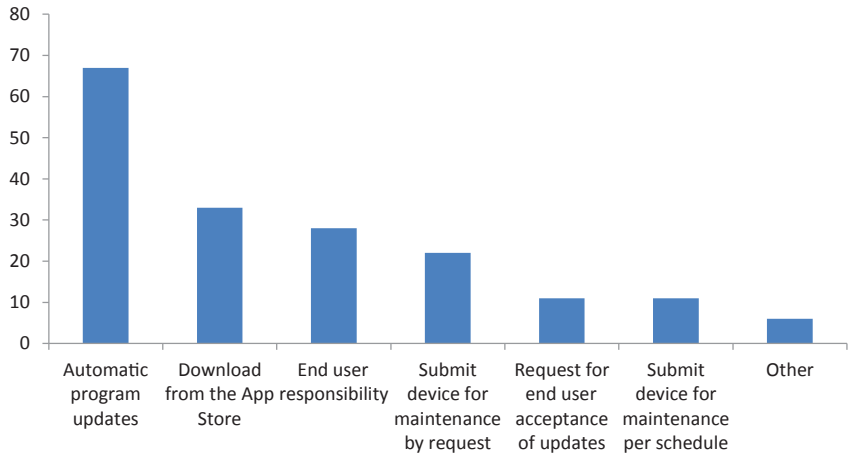
16. How does your agency deploy its devices? (Please check all that apply.)



Value	Percent	Count
Informal process (“give and go”)	61%	11
Software-specific training and deployment	44%	8
Project-specific training and deployment	39%	7
Formal training process	39%	7
Other	6%	1
Total		18
Statistics		
Total Responses	18	

Responses “Other”	Count
Left blank	19
Don’t know	1

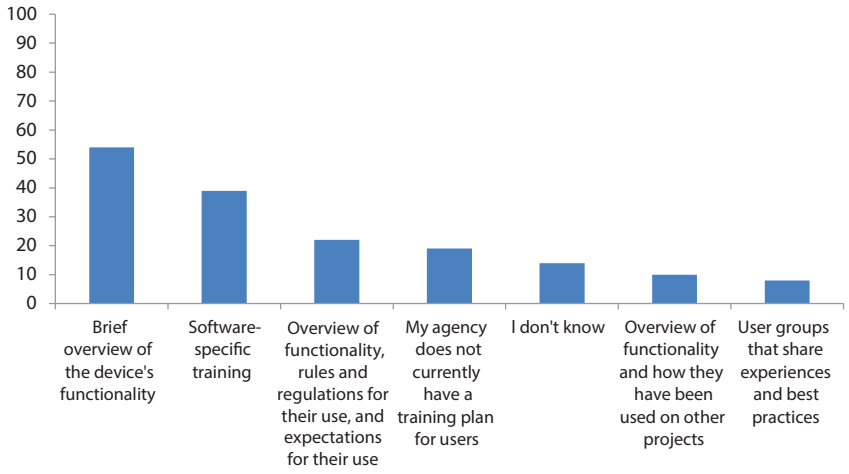
17. How does your agency deploy and update its applications? (Please check all that apply.)



Value	Percent	Count
Automatic program updates	67%	12
Download from the App Store	33%	6
End user responsibility	28%	5
Submit device for maintenance by request	22%	4
Request for end user acceptance of updates	11%	2
Submit device for maintenance per schedule	11%	2
Other	6%	1
Download from the web	0%	0
Total		18
Statistics		
Total Responses	18	

Responses "Other"	Count
Left blank	19
Don't know	1

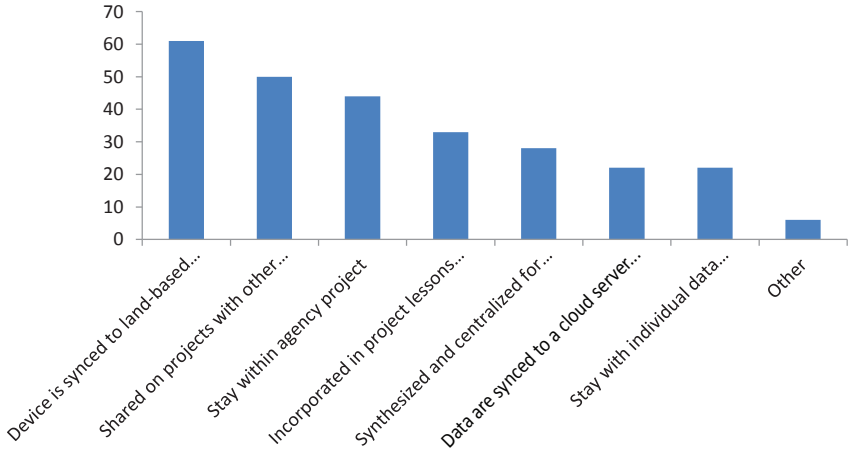
18. If your agency trains employees who are issued mobile IT devices, what level of training do they receive for their devices? (Please check all that apply.)



Value	Percent	Count
Brief overview of the device's functionality	56%	10
Software-specific training	44%	8
Overview of functionality, rules and regulations for their use, and expectations for their use	22%	4
I don't know	17%	3
My agency does not currently have a training plan for users	17%	3
Overview of functionality and how they have been used on other projects	11%	2
User groups that share experiences and best practices	6%	1
Other	0%	0
Total		18
Statistics		
Total Responses	18	

Responses "Other"	Count
Left blank	20

19. How are data shared within your agency? (Please check all that apply.)



Value	Percent	Count
Device is synced to land-based servers where data are stored and shared	61%	11
Shared on projects with other stakeholders	50%	9
Stay within agency project	44%	8
Incorporated in project lessons learned	33%	6
Synthesized and centralized for future reference to entire agency	28%	5
Data are synced to a cloud server where they are stored and shared	22%	4
Stay with individual data collector	22%	4
Other	6%	1
Total		18
Statistics		
Total Responses	18	

Responses "Other"	Count
Left blank	19
Don't know	1

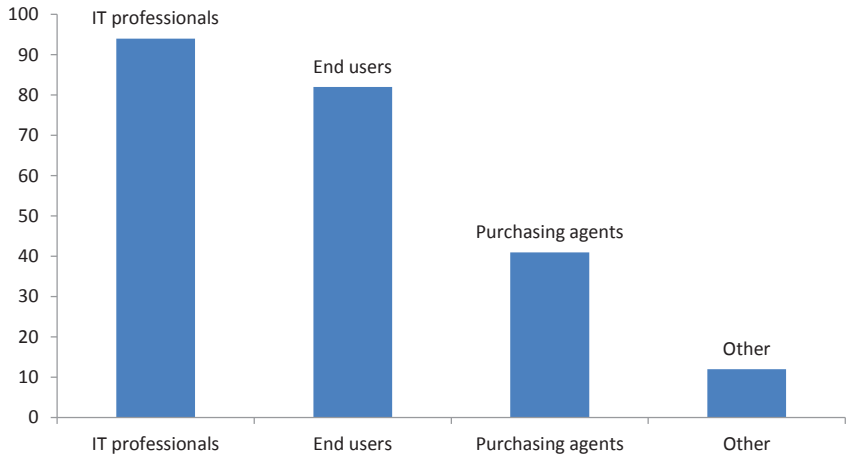
20. When evaluating potential mobile IT devices, which selection criteria do you consider? (Rank with 1 being the most important; leave blank if you do not think that a criterion is important at all.)

	Score*	Overall Rank
Cost	113	1
Ease of use	96	2
Durability	95	3
Operating system	67	4
Security of data	64	5
Available native applications	63	6
Agency standard	56	7
Interoperability	52	8
Other	11	9

*Score is a weighted calculation. Items ranked first are valued higher than the following ranks. The score is the sum of all weighted rank counts.

Count	Response
1	It has to do the job that needs done. If it can't, other factors don't matter.

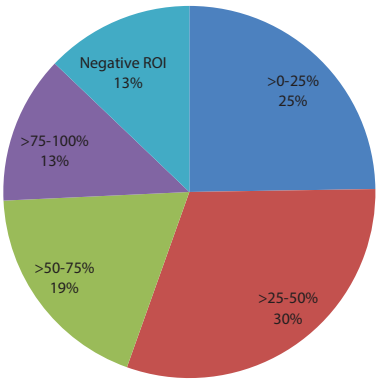
21. What parties are involved in the selection of the mobile IT devices? (Please check all that apply.)



Value	Percent	Count
IT professionals	94%	16
End users	82%	14
Purchasing agents	41%	7
Other	12%	2
Total		17
Statistics		
Total Responses	17	

Responses "Other"	Count
Left blank	18
A fair amount of executive management input	1
Unknown	1

22. What do you believe is the overall return on investment (ROI) from your agency's mobile IT use? [ROI = (benefit – cost)/(cost × 100)] (Please check one response.)



Value	Percent	Count
Negative ROI	13%	2
>0–25%	25%	4
>25–50%	30%	5
>50–75%	19%	3
>75–100%	13%	2
100%+	0%	0
Total		16
Statistics		
Total Responses	16	

23. Which of the following challenges do you believe is most significant to mobile IT use? (Rank with 1 being the most significant; leave blank if you do not think that the challenge is significant at all.)

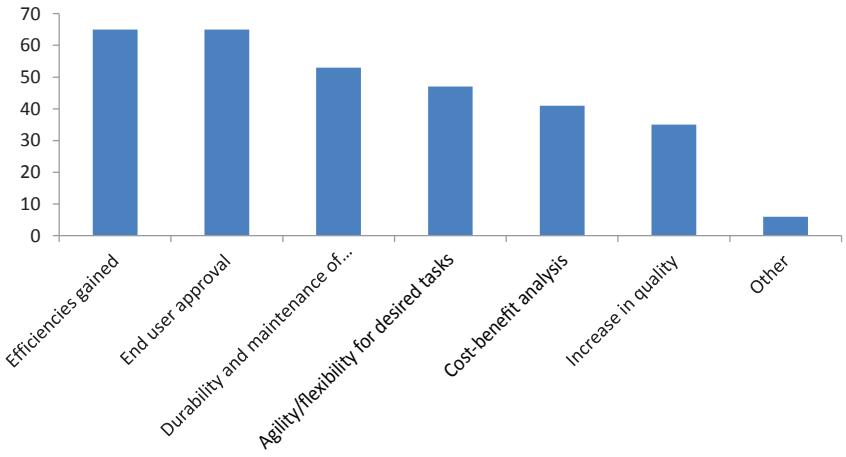
	Score*	Overall Rank
Cost-effectiveness	126	1
Connectivity issues (loss of cell signal)	114	2
Device maintenance and user support	97	3
Poor/ineffective applications	94	4
Deploying devices to employees	93	5
Application maintenance and support	93	6
Interoperability issues (software incompatibility)	88	7
Poor durability/lack of ruggedness	80	8
Training requirements	74	9
End user resistance	71	10
Quality of collected data	59	11
Battery life	55	12
Electronic signatures/approval	50	13
Lack of security of collected data	36	14
Other	28	15

*Score is a weighted calculation. Items ranked first are valued higher than the following ranks. The score is the sum of all weighted rank counts.

If other, please write in here and give a brief description.

Count	Response
1	Perception
1	It has a job to do. Before you can get it, it has to fill a need. Once you have that sorted out, then it's money, not cost-effectiveness. The money to get it to begin with.

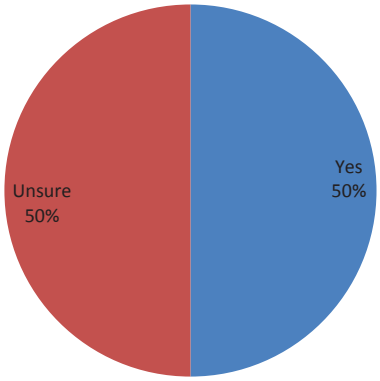
24. When evaluating performance of the mobile IT devices, what metrics are considered? (Please check all that apply.)



Value	Percent	Count
Efficiencies gained	65%	11
End user approval	65%	11
Durability and maintenance of devices	53%	9
Agility/flexibility for desired tasks	47%	8
Cost-benefit analysis	41%	7
Increase in quality	35%	6
Other	6%	1
Total		17
Statistics		
Total Responses	17	

Responses "Other"	Count
Left blank	19
We are in our mobile infancy just seeing the potential. Measuring would mean that you have enough mobile IT devices to start tracking by an objective measure.	1

25. Does your agency plan on expanding its number or use of mobile IT devices? (Please check one response.)

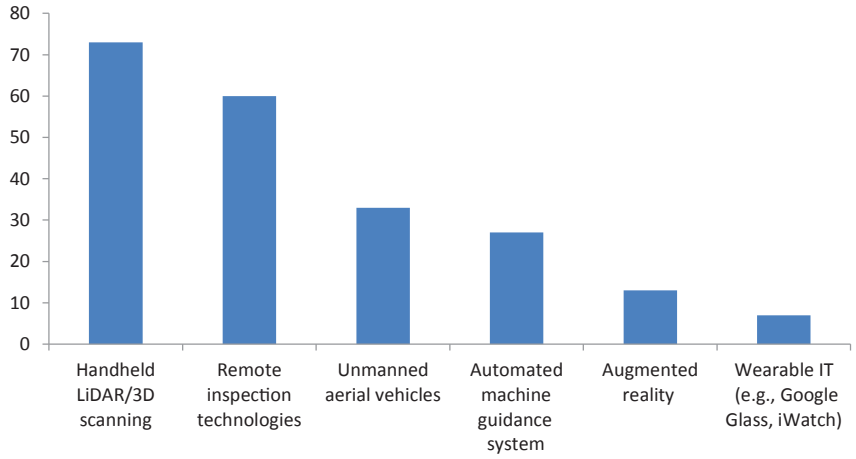


Value	Percent	Count
Yes	50%	9
No	0%	0
Unsure	50%	9
Total		18
Statistics		
Total Responses	18	

26. If Yes, what are the immediate plans? (Please check all that apply.)

	Deploy additional devices to current division	Deploy additional devices to other divisions	Purchase new devices	Provide additional training	Investigate more progressive devices and uses	Optimize/ modify existing technologies used	Develop new apps	Other	Responses
Your division (refer to Question 3)	86% 6	29% 2	71% 5	57% 4	86% 6	43% 3	43% 3	0% 0	7
Agency (if known)	60% 3	80% 4	80% 4	60% 3	80% 4	40% 2	60% 3	0% 0	5
If Yes, what are the immediate plans? (Please check all that apply.)	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0% 0	0

27. Which of the following opportunities are you most excited about for the future of technology in the field? (Please check all that apply.)



Value	Percent	Count
Handheld LiDAR/3D scanning	73%	11
Remote inspection technologies	60%	9
Unmanned aerial vehicles	33%	5
Automated machine guidance system	27%	4
Augmented reality	13%	2
Wearable IT (e.g., Google Glass, iWatch)	7%	1
Other	0%	0
Total		15
Statistics		
Total Responses	15	

Responses "Other"	Count
Left blank	20

APPENDIX E

Case Study Questions

NCHRP Project 20-05/Synthesis Topic 46-06

Use of Mobile IT Devices in the Field for Design, Construction, and Asset Management

Case Study Questions

- What process was used to select mobile devices and applications (e.g., was a cost-benefit analysis conducted)?
- How are applications already developed being adapted for the transportation sector?
- Who develops or customizes applications: in-house staff, consultants, or vendors?
- What (if any) specific state DOT standards or specifications exist for applications, hardware, or support systems?
- What (if any) specific standard procedures or policies exist for how state DOTs are storing, securing, and sharing data collected by mobile IT devices?
- What specific challenges has your DOT experienced and how they have been overcome?
- What specific benefits of the use of mobile IT devices has your DOT realized?

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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ISBN: 978-0-309-27212-4