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Assessing the impacts of mobile technology on public transportation project inspection

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ABSTRACT

Advancements in mobile technology capabilities and affordability allow many Departments of Transportation (DOT) the opportunity to use these technologies to improve the time-consuming nature of collecting, documenting, and distributing project inspection information. A mobile technology system for project inspection, called *HeadLight*, is piloted with the Washington, Minnesota, and Texas Departments of Transportation on 31 projects over a 3-month time span. Field measurements and interviews are used to quantify improvements offered by mobile technology over current practice. This empirical data is evaluated using standard software and process change evaluation metrics: time savings, data volume, data variety, data completeness, data timeliness, and data availability. Results indicate that project inspectors using the mobile technology system experienced productivity gains on the order of 25%, collected and shared twice as many observations, and improved the timeliness of daily reports and overall data availability. Additionally, the mobile technology solution is found to enable more complete and consistent data, improved accessibility throughout a project office and DOT. All these outcomes indicate mobile technology for project inspection allows the inspection workforce to work more efficiently. Further study into improved data quality and availability may identify more impacts within the construction inspection process and to a DOT's decision making processes.

1. Introduction

Project inspectors working for Departments of Transportation (DOT) are responsible for collecting vast amounts of data and information in the field. Acquiring timely and accurate inspection information assists in tracking project control elements such as cost, schedule, and materials that aid project delivery. However, public spending on transportation infrastructure projects has been steadily declining and budget limitations have generally led DOTs to reduce their workforce levels [1–5] making it difficult for a reduced inspection workforce to collect a growing amount of information each year.

On average, project inspectors spend nearly half of their shift collecting inspection information in the field [6–10]. The remaining portion of their shift is typically spent performing administrative tasks such as entering information into a computer and looking up information in the project reference documents such as plans and specifications [9–11]. Studies [6–11] indicate that project inspectors are not able to inspect elements of the project for half of their shift, potentially failing to collect crucial inspection information that may have an impact on the progress, quality, and cost of the project.

Mobile technology, defined as the hardware and software that can be used in concert to allow integrated real-time entry and access of project-related information, and data communication capabilities, continue to improve and have become affordable, allowing many DOTs the opportunity to use these technologies to improve the time-consuming nature of collecting, documenting, and distributing project inspection information. While mobile technology has been around since the early 1990s, device connectivity has improved allowing personnel to reliably download and upload information directly onsite. However, industry may be hesitant to adopt new technology due to the lack of empirical data on user performance benefits needed to justify the investment [12,13]. Majority of research reporting the user benefits of this technology have based their findings on qualitative data, such as participant interviews and surveys, and have not examined how the technology impacts the quality of data collected on site in detail. Furthermore, finding and customizing mobile technology to meet a specific DOT's business, administrative, and inspection process can be challenging.

This research contributes to the existing body of knowledge by collecting empirical data used to measure changes in productivity and data quality associated with the implementation of a mobile technology system that was developed specifically for DOT project inspection

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practices. Quantifying the end user benefits and understanding data quality changes resulting from the adoption of mobile technologies can help transportation agencies understand and articulate the benefits of investing in such technology solutions.

2. Scope

This paper describes the second phase of the multi-stage DOT research effort that investigates the use of a cloud-based mobile project inspection application to improve personnel productivity and the inspection workflow processes. The first phase, conducted in 2013, examined the user requirements for developing the technology which warranted its development and deployment [9]. This paper focuses on the second phase of this research effort where a cloud-based mobile technology system, called *HeadLight*, is developed by the Washington State DOT (WSDOT) with a Seattle-based Company Pavia Systems, Inc., and piloted with the WSDOT, Minnesota, and Texas DOTs (WSDOT, MnDOT, and TxDOT respectively) on 31 projects over a 3-month time span. Field measurements and interviews are used to quantify improvements offered by mobile technology over current practice. This empirical data is evaluated using standard software and process change evaluation metrics: time savings, data volume, data variety, data completeness, data timeliness, and data availability [9,14–17]. These quantified metrics can be used to better describe the likely benefits of mobile technology, evaluate its adoption implications, and include resulting benefits in business process models.

3. Previous work

Research on using mobile technology to reduce administrative efforts associated with construction field documentation have been conducted since the 1990s (e.g. [8,10–13,18–21]). Past studies have generally presented details on the development, functionality, and the application of the mobile system. Literature on the impacts of mobile technology for project inspection have not discussed in detail how the data collected onsite changes with the use of tools such as tablet computers. Few authors have examined the benefits and process changes resulting from the adoption of these technologies and only a small portion of these studies have collected empirical performance data, and even then only over a short period of time with a small group of participants. Information on the time savings and productivity improvements of using mobile technology in construction applications have typically been collected through survey responses and similar qualitative data. McCullouch and Gunn [11] developed and field tested a time keeping application for DFM Travelite pen-based handheld computers on two industrial construction projects. The authors concluded that end user perception of data collection time was similar to that of the paper based method but they saved time from not having to duplicate their timekeeping data in their electronic data management system. Liu [20] developed and tested an electronic tunnel inspection form identical to the paper form on a handheld PC which automatically uploaded the information to a web server. Comments from ten participants that used the system for one day concluded that the users saved time in filling out inspection reports but the mobile hardware was not rugged enough to endure the rough constriction site environment. Saidi et al. [8] estimated the time consumption differences between the paper-based method and the handheld computer method for six construction field activities and showed activities can be performed more efficiently by using handheld computers onsite. Bowden et al. [12] assembled case studies and previous research related to mobile technology use in construction and found that these technologies can potentially help reduce construction time and cost, defects, accidents, waste, and operation and maintenance costs while improving productivity. The study identified major barriers to innovative IT technology adoption in the industry which included the lack of empirical performance and benefit data as well as the mismatch between information technology developed by researchers compared to the actual needs of the end users in the construction industry. Kimoto et al. [19] conducted interviews with construction managers working on building projects to identify key user requirements that were used to develop a building inspection application. The mobile data collection system developed by the researchers allowed text based field data to be collected on a mobile personal digital assistant (PDA) device and saved to a memory card for further PC analysis at the office. This approach eliminated the duplication of data collected from the field to the PC and reduced the time taken for such administrative work. Rojas et al. [22] examined the use of paper forms, laptop computers, digital pens, and handheld computers in capturing existing facility as-built information and found handheld computers to be the most time and cost efficient method. Direct measurements of task completion times revealed that handheld computer users were able collect as-built data approximately three times faster than the paper-based method.

Research on mobile technology specific to use in DOTs have focused on similar impacts, typically discussing process time savings and improved access to project reference documentation. Asbahan and DiGirolamo [6] provided tablet computers, preloaded with project reference documents, to ten inspectors working on Pennsylvania DOT projects for one month. Participant surveys revealed that inspectors perceived the use of tablet computers helped them save about 20 min per day on tasks related to finding content in the project reference documents. The resulting time savings allowed them to spend more time on general field inspection activities. The participants perceived no time savings from filling out paperwork and daily reports. Valdes and Perdomo's [10] documented the development of a prototype application for tablet computers that creates inspection daily reports for the inspectors working for the Puerto Rico Highway and Transportation Authority. The prototype was field tested to an unspecified amount of inspectors for few weeks but the study did not collect any data that measured performance impacts.

3.1. Current state of inspection practice

DOTs still rely, at least partly if not wholly, on a paper-based approach in field data collection for project inspection. According to a 2017 AASHTO survey [23], 21 out of 26 DOTs surveyed use a mix of manual and electronic system to track inspection and material test results (e.g., data is collected in the field on paper and transferred to the DOT's electronic documentation system later), while another three rely completely on paper methods and do not use electronic documentation systems [23]. The other two DOTs use electronic systems to track all inspection and material test results. Earlier work by Valdes and Perdomo [10] corroborate these findings.

4. Method

This study evaluates the changes in the business practice and field inspection data resulting from the use of a mobile technology system through empirical field testing conducted with WSDOT, MnDOT, and TxDOT. The business practice and data changes were determined by comparing the traditional inspection process with the mobile technology system process using several evaluation metrics. This section discusses the mobile technology system's software and hardware, the research participants and their roles, the business practice affected by the process change, the evaluation metric, and the information gathering process used for this study.

4.1. Software and hardware of the mobile technology system

The research team chose to run the mobile technology system as an application on the Apple iPad Air. Each iPad Air was outfitted with a waterproof protective casing and a hand-strap to carry the device in the field. Android tablets and Microsoft's Surface tablets also met the