Preliminary Investigation

Caltrans Division of Research, Innovation and System Information

Mobile Applications for Reporting Maintenance Issues

Requested by
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The Caltrans Division of Research, Innovation and System Information (DRISI) receives and evaluates numerous research problem statements for funding every year. DRISI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field. The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this publication are for clarity only.

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Executive Summary

Background

Several channels are available for the public to notify Caltrans of highway maintenance issues, but better methods may exist. Caltrans is interested in learning about apps (used on mobile phones or other portable devices) that can be used to facilitate communication between the public and DOTs about the condition of transportation facilities. Although Caltrans' primary focus is on maintenance-related uses, such as pothole reporting by the public, the customer team is interested in any apps that could be useful to transportation agencies.

To assist in this effort, CTC & Associates conducted an online search for apps of this type that are actively being used by state, local or private entities, as well as app ideas or prototypes in development.

Summary of Findings

In recent years, many cities and counties have integrated smartphone apps into their 311 systems (used to report nonemergency maintenance issues). Utah DOT has customized a 311 app to focus on maintenance issues specific to state highways, and Vermont is testing a similar system. These apps allow users to mark the problem location on a map and upload a photo of the issue. Caltrans' IT division created a demo mobile app a few years ago that had similar functionality and was designed to integrate with the department's Maintenance Service Request (MSR) system.

Other applications of smartphone apps for reporting maintenance issues include:

- Several state DOTs have partnered with the navigation app Waze to share traffic data that includes Waze users' reports of potholes, signal outages and other maintenance issues.
- In Utah, trained "citizen reporters" submit reports on winter road conditions via a smartphone app. These reports supplement Utah DOT's own pavement condition information, especially on rural roads that have fewer weather sensors and traffic cameras.
- Boston's Street Bump app uses a smartphone's accelerometer and GPS to automate the detection and location of potholes and other road defects. Users record their trips and upload the data to the city. To take advantage of the same technology, many agencies and developers are working on apps designed to capture pavement condition (road roughness). This technology seems promising, and these apps may be available for widespread use in the next couple of years.

This Preliminary Investigation also describes apps that maintenance staff can use internally, apps they can use to report to the public on maintenance issues, and a sampling of apps that gather information from the public beyond the maintenance realm. Highlights of these apps are summarized below by topic area.

Apps for Public Reporting of Maintenance Issues

Most apps for public reporting of maintenance issues integrate with an agency's work-order system so that problems are immediately routed to the correct person. In general, the apps offer two-way communication, allowing the public to see the status of submitted reports.

- **General maintenance issues (311 systems):** 311 apps are typically used by cities and counties to allow residents to report a range of maintenance issues. Utah DOT and the Vermont Agency of Transportation (VTrans) have tailored the SeeClickFix reporting app to focus on issues specific to state roadways.
    - Issues covered include potholes, guardrail damage, highway lighting, ramp meter problems, camera outages, rockfall debris, litter and dumping, flooding and drainage issues, graffiti, and animal carcasses.
    - To report a problem, users drop a marker on a map, answer a few questions, and attach a photo. Reported issues are posted publicly, and agency staff can mark a problem as acknowledged or closed.
    - Companion apps for government staff are also available.
- **Reporting maintenance issues via 511 systems:** Some agencies' 511 apps (which provide real-time traveler information, similar to Caltrans' QuickMap) include the capability for users to report roadway maintenance issues. The Google-owned navigation app Waze has begun data-sharing partnerships with state DOTs and other agencies, which include sharing Waze users' reports of potholes and other issues with the DOTs.
- **Potholes:** The Street Bump app (City of Boston) identifies potholes and other road defects using a smartphone's accelerometer and GPS. Drivers record and upload their trips; bump detection is automated. Data analysis separates true road defects from false positives such as speed bumps.
- **Littering:** Part of the Don't Mess with Texas campaign, Texas DOT's Litterer app has a user-friendly interface that lets drivers report litterers via voice control or by selecting details from a graphics-based menu.
- **Winter road conditions:** Following brief training, Utah DOT's Citizen Reporters use an app to report weather-related road conditions on state roadways.
- **Rest area conditions:** While not strictly an app, several state DOTs collect real-time feedback by posting scannable Quick Response (QR) codes on signs inside rest areas. Visitors scan the codes with their smartphones, and issue reports are immediately routed to appropriate staff.

Internal DOT Maintenance Apps

- **Pavement condition (road roughness):** Several agencies and developers are working on apps designed to capture road roughness using a mobile device's accelerometer and GPS. These apps are expected to be used primarily by DOT staff rather than the public.
    - Recent Arizona research looked at using this type of app to assess the condition of bike trails and prioritize trail maintenance.

- **Winter road conditions:** A recent Pennsylvania DOT project tested the feasibility of using an Android camera and computer vision algorithms to create a road condition monitoring system. The cameras were mounted on snowplows during the study.
- **Bridge inspection:** Researchers in China developed an iPhone-based cable force measurement app and tested its accuracy against a wireless sensor network.
- **Traffic counts:** Illinois DOT tested a smartphone application for conducting traffic counts.
- **Reference materials:** A few agencies are using apps to provide easy access to frequently used reference materials. The apps include an FHWA pavement preservation tool, several apps from Ohio DOT, and a work zone layout guide.

DOT Reporting to Public on Maintenance

- **Snowplow tracking**: Several states use their 511 traveler information apps to let the public track their snowplows in real time.
- **Dynamic message signs (DMS):** Virginia researchers are testing the feasibility of displaying DMS alerts on smartphones rather than on roadside signs.

Other Apps That Gather Data from the Public

- **Planning:** DOTs are exploring using apps to collect data on bicycle travel and for travel surveys.

Selected Additional Apps

Other innovative apps being explored by states and cities include:

- **Traffic signals:** Several cities are using an app that tells drivers how long a traffic signal will stay green or red.
- **Sustainable mobility:** Texas DOT is among a few agencies that offer apps to help residents identify sustainable travel choices.
- **Safety:** Minnesota DOT is testing the feasibility of using an app to provide in-vehicle alerts about speed reduction at high-risk rural curves. Another Minnesota project is exploring an app-based system for recording and documenting work zone intrusion incidents.
- **Accessibility:** Researchers in London have developed an app that helps vision-impaired users navigate transit stations.

Detailed Findings

Public Reporting of Maintenance Issues

General Maintenance Issues (311 Systems)

Many cities use 311 systems to allow residents to report a range of nonemergency maintenance issues; the 311 phone number is designed to be the nonemergency counterpart to 911 dispatch systems. Although 311 systems are typically used by cities and counties, Utah DOT has customized a popular issue-reporting app (SeeClickFix) for use at the state level. The Vermont Agency of Transportation (VTrans) is testing the app as well, and Massachusetts has used the SeeClickFix platform to create a statewide 311 network serving more than 60 communities.

Caltrans' IT division created a demo mobile app a few years ago that had functionality similar to the 311 issue-reporting apps described below, including the ability to mark an issue location on a map via GPS and upload a photo of it. The app was designed to integrate with the department's Maintenance Service Request (MSR) system. For more information on the MSR Mobile demo app, see Appendix A or contact Diane Heth (916-654-6126, diane.heth@dot.ca.gov).

SeeClickFix (Developer: SeeClickFix Inc.)
http://www.seeclickfix.com/
To report a problem, users drop a marker on a map, answer a few questions, and attach a photo. Typically, open problem reports are displayed publicly, and city staff can tag them as acknowledged or closed, or follow up with the submitter by email. Users can also comment on existing reports.

Utah DOT and VTrans have tailored SeeClickFix to focus on issues specific to state roadways, including potholes, guardrail damage, highway lighting, ramp meter problems, camera outages, rockfall debris, litter and dumping, flooding and drainage issues, graffiti, and animal carcasses.

The app is designed to increase efficiency by routing maintenance issues directly to the appropriate staff in each region. This Utah DOT case study describes the department's transition to the SeeClickFix request management system:

> **Developing New Models for SeeClickFix Use on the State Level**
> http://gov.seeclickfix.com/customers/udot

SeeClickFix can be integrated with an agency's existing work order system, or agencies can use additional SeeClickFix tools, including:

> **Request Management**
> http://gov.seeclickfix.com/products/hosted-crm
> SeeClickFix's work order system includes a mapping tool and data analysis capability.
>
> **Mobile Apps for Officials**
> http://gov.seeclickfix.com/products/mobile-apps-for-officials
> Companion apps are available for agency staff.

City Notifications
http://gov.seeclickfix.com/products/city-notifications
Residents can be emailed about issues based on their location.

According to the SeeClickFix website, hundreds of communities use the app; more than 80 city-branded SeeClickFix apps are available through the online app stores. California communities using SeeClickFix include Sacramento County, Oakland, South San Francisco, and Vallejo. Agency app pages include:

Utah DOT Click 'n Fix: http://www.udot.utah.gov/main/f?p=100:pg:0:::t,v:376

VTrans Click2Fix
iPhone: http://itunes.apple.com/us/app/vtrans-click2fix/id977837829?mt=8
Android:
http://play.google.com/store/apps/details?id=com.seeclickfix.vtransclick2fix.app&hl=en
This app appears to be at the internal testing stage. VTrans staff began testing the app in 2015; see page 15 of this staff newsletter for an article about the test:

Operations Connection newsletter, July 2015
http://vtransoperations.vermont.gov/sites/aot_operations/files/Operations%20Connection%20Newsletter%2007012015.pdf

Massachusetts: Commonwealth Connect
http://commonwealthconnect.io/
Building on the success of Boston's Citizens Connect app, Massachusetts has established a statewide network of 311 systems. The Commonwealth Connect app can be used to report issues to the appropriate municipality even if the user doesn't know which department or municipality should respond.

Spot Reporters (Developer: Connected Bits)
http://www.connectedbits.com/
Similar to the SeeClickFix platform, the Spot Reporters app is used by San Francisco, Boston, Dallas, and other cities. It offers a City Worker companion app for maintenance staff. Agency app pages include:

San Francisco: http://mobile311.sfgov.org/

Boston: https://mayors24.cityofboston.gov/

Dallas: http://dallas311.dallascityhall.com/

Other 311 app platforms include:

CitySourced (CitySourced Inc.): http://www.citysourced.com/

GORequest (Accela): http://www.accela.com/civic-apps/go-request

PublicStuff (Accela): http://www.publicstuff.com/

Open311
http://www.open311.org/learn/
Open311 is a standard protocol for location-based civic issue tracking designed to foster interoperability, collaboration and transparency. SeeClickFix, Spot Reporters and other major 311 apps use the Open311 standard.

Reporting Maintenance Issues via 511 Apps

Traveler information apps have become commonplace at both state DOTs and local agencies across the country. Some states' apps are part of a statewide 511 system, named for the federally designated phone number for traveler information services. Caltrans does not operate a statewide 511 phone service, but Caltrans' QuickMap site (http://quickmap.dot.ca.gov/) provides the same type of traveler information (including relative traffic speeds; locations of road closures, traffic incidents, and construction zones; and images from traffic cameras and roadside message signs). The QuickMap site also provides links to regional 511 services across the state.

Some 511 apps include the capability for users to report maintenance issues, similar to the functionality in the 311 apps described above.

Waze Connected Citizens Program
https://www.waze.com/ccp
Waze, a navigation app purchased by Google in 2013, identifies traffic incidents through crowdsourcing. By running the app while they drive, users passively contribute traffic speed data, and they can also actively report traffic incidents.

In 2014, Waze launched the Connected Citizens Program, initiating data-sharing partnerships with state DOTs and other government agencies. Through these partnerships, government agencies "are encouraged to share data on road closures (both scheduled and real-time) and traffic incidents (construction, accidents, etc.)." In return, Waze shares information on traffic congestion detected by users' speed data, as well as "user-reported traffic incidents (including jams, accidents, hazards, construction, potholes, roadkill, stopped vehicles, objects on road, and missing signs)."

State DOTs incorporate these user-reported issues into the traveler information that they communicate through their 511 apps, and agencies can incorporate the issues into their maintenance work-order systems as well.

"Waze Is Driving into City Hall," *Fast Company,* April 2015.
http://www.fastcompany.com/3045080/waze-is-driving-into-city-hall
Excerpt from the article:

> Jose Colon, Washington, D.C., DOT's chief information officer, is using Waze data for a district-wide "war on potholes" called Potholepalooza. Noting that there are approximately 650,000 Waze users in the Washington metropolitan area—roughly equivalent to the population of the District itself, excluding the suburbs—Colon explained how Waze is helping to crowdsource the discovery of potholes. So far in the 2015 fiscal year, 11,510 potholes were reported to the city by conventional methods like 311 calls from citizens and data entry by city DOT employees. After the city began collecting pothole data from Waze users on March 21, 2015, more than 10,000 pothole reports were made through Waze in

> less than a month. And that number is growing by the day, says the Department of Transportation.

"Waze and the Traffic Panopticon," *The New Yorker,* June 2015.
http://www.newyorker.com/business/currency/waze-and-the-traffic-panopticon
This article describes Waze's partnership with the city of Los Angeles. An excerpt:

> Traditionally, traffic management has been a largely top-down process. In Los Angeles, it is coordinated in a bunker downtown, several stories below the sidewalk, where engineers stare at blinking lights representing traffic and live camera feeds of street intersections. L.A.'s sensor-and-algorithm-driven Automated Traffic Surveillance and Control System is already one of the world's most sophisticated traffic-mitigation tools, but it can only do so much to manage the city's eternally unsophisticated gridlock. Los Angeles appears to see its partnership with Waze as an important step toward improving the bridge between its subterranean panopticon and the rest of the city still further, much like other metropolises that have struck deals with Waze under the company's Connected Cities program.

State DOTs participating in Waze's Connected Citizens Program include Florida, Iowa, Kentucky, Maine, Massachusetts, New Hampshire, Oregon, Pennsylvania, Tennessee, Utah, Vermont, Washington, and the District of Columbia.

Potholes

Street Bump (Developers: City of Boston, Connected Bits and other collaborators)
City of Boston: http://www.cityofboston.gov/doit/apps/streetbump.asp
Developer site: http://www.streetbump.org/about

From the city website:

> Residents use Street Bump to record "bumps" which are identified using the device's accelerometer and located using its GPS. Bumps are uploaded to the server for analysis. Likely road problems are submitted to the City via Open311, so they get fixed (e.g. potholes) or classified as known obstacles (e.g. speed bumps).

Although bump detection is automated, drivers must launch the app and click to record and upload specific trips. Users cannot run the app in the background or use other apps simultaneously.

Emerging Applications

"Google Is Developing a System to Map Potholes Using a Car's GPS," Ethan Wolff-Mann, *Money,* August 2015.
http://time.com/money/4009901/google-patent-gps-potholes-tracking-map/
From the article:

> "Last week, Google filed a patent to help solve pothole problems, describing a system that uses the GPS from cars' navigation systems in conjunction with another bump sensor that detects vertical movement to map out potholes. Then, the system uploads the data to the cloud."

Related Resource:

"Systems and Methods for Monitoring and Reporting Road Quality," U.S. Patent 9,108,640 B2, Google Inc., August 2015.
http://www.freepatentsonline.com/9108640.pdf
Abstract:

> Systems and methods for monitoring vehicle sensors to determine and report road quality using a communication device are disclosed. The communication device determines the vehicle's location on a road, such as by use of a GPS-enabled head unit or similar device and appropriate mapping software. Monitoring road quality may be achieved by adding a sensor to the shocks, by use of a vertical displacement sensor present on the head unit, and the like. Various combinations of sensors may be employed. A horizontal displacement sensor may be used. The signals from the sensors are monitored by the head unit and analyzed to judge the quality of the road by the amount of vertical vibration that is encountered. This data, together with the vehicle's location, may be transmitted through a mobile network to a central server for distribution in road quality reports and to improve driving directions in mapping software.

Littering

Litterer (Developer: Texas DOT)
iPhone: https://itunes.apple.com/us/app/litterer/id882082348?mt=8
Android: https://play.google.com/store/apps/details?id=com.thunderdog.dmwt.app
A component of the Don't Mess with Texas campaign, this stand-alone app includes a voice control option and graphics that walk users through submitting a report of littering on state highways.

Winter Road Conditions

Utah DOT Citizen Reports (Developer: Utah DOT)
http://udottraffic.utah.gov/CitizenReporting.aspx
While several states use trained "citizen reporters" to report on winter road conditions, Utah appears to be the first state to collect this data solely through a smartphone app. Utah DOT (UDOT) uses the reports to supplement data gathered by weather sensors, cameras and plow crews, especially in rural areas. According to an FHWA fact sheet on the program (see below):

> The Citizen Reporting Program involves deploying citizen reporters to provide road weather conditions to help fill gaps in the existing road condition reports and support more timely and accurate forecasts. The citizen reports are not expected to replace existing infrastructure sources or information from the maintenance field personnel. Rather, these reports provide an important supplemental dataset to the UDOT forecast, operations and maintenance staff.

Related Resource:

"Citizen Reporting Program for Road Weather Information at Utah Department of Transportation," FHWA, 2013.
http://udottraffic.utah.gov/PDFFiles/Citizen_Reporting_Program.pdf
Excerpt from the fact sheet:

The main functions of the citizen reporting program are to:

- Generate road weather reports at a minimum of every 2 hours for some or all of the roadway segments identified by UDOT.
- Provide fresher data and better coverage on rural roadways.
- Support Section 1201 requirements by providing real-time reporting on roads throughout the state.
- Actively control weather quality reports using staff meteorologists.
- Provide quality assurance through a reporter selection process and training.
- Provide more information at a fraction of the cost of other alternatives.
- Indirectly improve forecasts by providing meteorologists with more and better field data.

"Citizen Reporting of Current Road Conditions: Experiences at Five Departments of Transportation," FHWA, 2015.
http://www.ops.fhwa.dot.gov/weather/best_practices/citizenreportingcrc/index.htm
This best-practices document provides a detailed review of citizen reporting programs at Idaho, Iowa, Minnesota, Utah, Wyoming DOTs. Of these, Utah DOT is the only agency using a smartphone app.

Rest Area Conditions

While not technically an app, a few states have begun collecting real-time feedback on rest area conditions by posting scannable Quick Response (QR) codes on signs inside rest areas. Visitors scan the codes with their smartphones and submit issue reports that are immediately routed to appropriate staff.

Opiniator
http://www.opiniator.com/
Florida DOT uses Opiniator software to collect rest-area feedback through the QR codes; Minnesota and Washington State DOTs use the service as well.

Related Resource:

"Florida DOT Implements Instant Driver Feedback System," *Government Technology,* December 2014.
http://www.govtech.com/transportation/Florida-DOT-Implements-Instant-Driver-Feedback-System.html
Excerpt from the article:

> The Florida Department of Transportation (DOT) is using technology to gather feedback and improve engagement with drivers that utilize its public facilities statewide.
>
> Last summer, the department implemented software from Portland-based Opiniator to allow them to gather feedback from drivers or visitors at their rest stops and welcome centers via SMS, phone or Web. The agency now gets real-time feedback, and can

contact citizens within minutes to fix an issue. The new system replaces their previous manual comment card system. …

Using the new Opiniator system, drivers can provide feedback instantly using their smartphone or another electronic device of their choice. Signs posted at the site solicit the feedback and contain a code that indicates which facility was visited. …

The system also allows Florida DOT to better manage their subcontractors. The state subcontracts maintenance services for all their rest areas. "We now have this system to have some accountability for the contractors as far as how quickly they respond to customers and resolve their concerns," said [Tim Lattner, director of Florida DOT's Office of Maintenance].

Internal DOT Maintenance Apps

Pavement Condition (Road Roughness)

Much like Street Bump (Boston's pothole-sensing app), emerging apps that estimate pavement roughness typically use a smartphone's accelerometer and GPS. Several agencies and developers have been working to develop apps that can accurately estimate road roughness, and this technology may become more widespread within a couple of years.

Research projects involving these apps tend to indicate that the apps would be used primarily by DOT staff, either on smartphones or tablets.

At least two apps for estimating road roughness are available in the app stores, but we did not identify documentation of specific agencies having used them.

- **BumpRecorder** (Developer: BumpRecorder Co., Ltd.; based in Japan)
  Android:
  https://play.google.com/store/apps/details?id=jp.traffichazard.BumpRecorder&hl=en

- **RoadBump** (Developer: Grimmer Software)
  http://www.grimmersoftware.com/

Related Resource:

RoadBump developer David Grimmer contributed an article on his app to *Roads & Bridges* magazine:

"Speaker Phone: New App Tells You Degree of Road Roughness," David Grimmer, *Roads & Bridges* magazine, October 2015.
http://www.roadsbridges.com/speaker-phone
Excerpt from the article:

Many cities and counties don't have access to the high-end inertial profilers that produce roughness profiles expressed as the industry-standard International Roughness Index (IRI). Even at the state level, many highways are only evaluated

every two or three years. The high-end inertial profilers require large capital investments and trained staff to operate them.

A new Android smartphone app aims to address these problems. The recently released RoadBump app utilizes an Android phone or tablet's accelerometer and GPS sensors to estimate the roughness of a road. RoadBump was developed in consultation with the staff at the National Center for Asphalt Technology at Auburn University and the Civil Engineering Department at the University of Arkansas.

Related Research

Evaluating Roadway Surface Rating Technologies, Michigan DOT (MDOT), June 2015.
http://deepblue.lib.umich.edu/bitstream/handle/2027.42/111891/103192.pdf
Excerpt from the abstract:

> The key project objective was to assess and evaluate the feasibility and accuracy of custom software used in smartphones to measure road roughness from the accelerometer data collected from smartphones and compare results with PASER (Pavement Surface and Evaluation Rating System) and IRI (International Roughness Index) measurement values collected from the same roadway segments. This project is MDOT's first large implementation of a customized Android smartphone to collect road roughness data using a methodology developed from previous research work performed by UMTRI. Accelerometer data collection was performed via Android-based smartphones using a customized software application called DataProbe. During the project's initial phase smartphones were installed in each of nine Michigan Department of Transportation (MDOT) vehicles driven by MDOT employees.
>
> Analysis of the data collected in 2014 showed multiple regression models with variance among accelerometer measurements and speed accounting for 37 percent of the variance, while the ordinal logistic regression accurately predicted the IRI (3 level/5 level) categories 86/83 percent of the time. These results are promising when considering the near term application of the DataProbe technology for smaller locales that drive over their local roads more often, generating web-based road roughness visuals of each of the roads in their jurisdiction. In the longer term, statewide road roughness measurement may be performed through the crowd-sourcing model available through Connected Vehicle initiatives, where all vehicles will be equipped with devices that support safety applications as well as other applications such as those that measure road roughness.

"Identifying Deficient Pavement Sections Using an Improved Acceleration-Based Metric," Virginia DOT and University of Virginia, *TRB Annual Meeting,* Paper #15-5410, January 2015.
http://docs.trb.org/prp/15-5410.pdf
Excerpt from the abstract:

> This study introduces an improved acceleration-based metric, an index normalized by vehicle operating speed, to be used on a regular basis to "prescreen" pavement segments that are likely to deficient, and then a profile van can be sent to measure the accurate roughness condition. A profile van collected pavement profile data on a total of 50 miles (80 km) of roadway, which was then used to calculate the International Roughness Index (IRI). Meanwhile, two tablets were placed on the vehicle floor to collect data, including 3-way accelerations, GPS coordinates, and vehicle speeds. A normalized acceleration-based index was created by incorporating a speed factor. Furthermore, logistic regression models

were created to evaluate the effectiveness of the proposed index in identifying deficient pavement sections (IRI ≥ 140 in/mile or 2.21 m/km). It was found that the proposed acceleration-based metric is able to correctly identify between 80 and 93 percent of all deficient pavement sections. In conclusion, this research points to the feasibility of using a cost-effective acceleration-based application for the purpose of network screening. The network screening process will reduce the total mileage of pavement sections that need to be measured and meanwhile still identify locations where maintenance work is necessary.

"Measurement of Pavement Roughness Using Android-Based Smartphone Application," Shahidul Islam, William G. Buttlar, Roberto G. Aldunate and William R. Vavrik, University of Illinois, *Transportation Research Record 2457*, pages 30–38, 2014.
http://trid.trb.org/view/2014/C/1289976
Excerpt from the abstract:

Pavement roughness … is predominantly characterized by the international roughness index (IRI), which is often measured with inertial profilers. Inertial profilers are equipped with sensitive accelerometers, a height-measuring laser, and a distance-measuring instrument for measuring vehicle vertical acceleration data and the pavement profile. Modern smartphones are equipped with several sensors including a three-axis accelerometer, which was used in this project to collect vehicle acceleration data with an Android-based application. In the study, acceleration data were double integrated numerically to obtain a pavement profile, which was input into the software program ProVAL. The pavement roughness was then calculated. For the initial validation, pavement profile and acceleration data were collected with both an inertial profiler and the newly developed smartphone application from three test sites. The initial validation results suggest that the newly developed smartphone application can measure IRI with good correspondence to the inertial profiler and with good repeatability between measurement replications. However, calibration is needed for rougher pavement sections because the current analysis techniques do not directly account for acceleration damping resulting from vehicle suspension systems. With improvements in analysis that consider the vehicle suspension effects and additional validation, the approach could be used to reduce the cost of acquiring pavement roughness data for agencies and to reduce user costs for the traveling public by providing more robust feedback about route choice and its effect on estimated vehicle maintenance cost and fuel efficiency.

Bike Trail Roughness

"Application of Geographic Information Systems and Vibration Mobile Apps in Road Condition Assessment of Bike Trails," Chun Hsing-Ho, Gerjen Slim and Jeremy DeGeyter, Northern Arizona University, TRB Annual Meeting, Paper #16-1424, January 2016.
https://annualmeeting.mytrb.org/interactiveprogram/Details/2930
Excerpt from the abstract:

This paper discusses the application of smartphone technology in conjunction with geographic information systems (GIS) software to develop a pavement management system and relate the pavement deterioration to vibration intensity. … Combining vibration intensity data with a GIS platform can help public agencies with a strategic plan to prioritize maintenance schedules for bike trails. Using affordable and readily available smartphone applications to collect vibration and location data presents new possibilities for pavement evaluation. The objective of this paper is to investigate the suitability of integrating this method of data collection into a GIS software to spatially relate and analyze the data to

identify maintenance priorities, while reducing the time and cost spent collecting data. A demonstration project was implemented on the Northern Arizona University campus while riding bicycles along designated biking routes. A level platform accommodating two phones was attached to the bike to ensure consistent and synchronous data collection. Vibration data were analyzed, interpreted, digitized, and displayed to a GIS platform for identification of pavement deterioration based on gravity of acceleration values recorded during biking. Maintenance staff can review pavement problem points as listed on GIS maps, make a visit to evaluate the severity of pavement conditions, and prioritize areas that will need immediate maintenance or repair.

Winter Road Conditions

Road Condition Reporting, Pennsylvania DOT, January 2015.
http://www.dot7.state.pa.us/BPR_PDF_FILES/Documents/Research/Complete%20Projects/Operations/Road_Condition_Reporting_Final_Report.pdf
Abstract:

This report documents the findings of the road condition reporting project where the feasibility of live reporting of the road conditions with an Android camera and computer vision algorithms was tested. An app was developed that can collect videos or images and tag them with global positioning system (GPS) and other information. During the 2013/14 snow season the system was mounted on two snow plows and data from several snow events was collected. With this data a computer vision algorithm was developed and tested that is able to detect the percentages of snow, slush or normal road in the images. From these percentages the road condition can be calculated. Overall this project demonstrated that it is feasible to develop a road condition monitoring system.

Bridge Inspection

"Portable and Convenient Cable Force Measurement Using Smartphone," Xuefeng Zhao et al., *Journal of Civil Structural Health Monitoring,* Volume 5, Issue 4, pages 481-491, September 2015.
Abstract: http://trid.trb.org/view/2015/C/1369326
iPhone: https://itunes.apple.com/us/app/orion-cc/id951253417?mt=8

Abstract:

Cable force measurement is an essential step in bridge construction and structural health evaluation; it has developed rapidly in recent years and can be achieved using a wireless sensor network, which greatly reduces the monitoring cost and improves the efficiency of monitoring compared with traditional monitoring methods. However, expensive sensors, devices, transfer systems, and professionally trained technicians are needed in a wireless network system. Therefore, it is necessary to develop a portable and convenient method that requires less professional components. Smartphones with powerful operating systems are becoming popular; some have built-in high-performance sensors and a network that can transmit data. Based on these facts, a novel cable force measuring method using smartphone was proposed in this work. An iPhone-based cable force measurement software named Orion-Cloud Cell (Orion-CC) was developed and launched in the Apple App Store by our group. It has the advantages of being low cost, convenient, time saving, and easy-to-operate. First, a comparison test between an iPhone and a wireless monitoring method was conducted to verify the feasibility of a cable force measuring method using smartphones. Second, Orion-CC was applied to laboratory cable model tests. A

comparison of the results from Orion-CC and MATLAB post-processing data proved the accuracy and operability of this method. Finally, this method was applied to the Dalian Xinghai Bay Cross-sea Bridge, which demonstrated its efficiency in an actual engineering application.

Traffic Counts

TrafficTurk Evaluation, Illinois DOT, April 2014.
https://www.ideals.illinois.edu/bitstream/handle/2142/48995/FHWA-ICT-14-008.pdf
Excerpt from the abstract:

> This report summarizes a project undertaken by the University of Illinois on behalf of the Illinois Department of Transportation to evaluate a smartphone application called TrafficTurk for traffic safety and traffic monitoring applications. TrafficTurk is a smartphone-based turning movement counter that was developed at the University of Illinois to allow large-scale traffic data collection during large events. TrafficTurk data can be used for real-time decision-making or to assist in future event traffic management plans. … The collected traffic data was specifically used to analyze the arrival rates of traffic at each of the counting locations and the possibility of re-routing traffic from the eastern, northern, and western approaches to the show. The application also collected information on the data latency and energy efficiency of the application in order to provide insights on the feasibility, scalability, and scope of future deployments. The analysis of data focused on estimating the traffic density across the road network surrounding the show. An algorithm was developed to quantify traffic congestion on each road segment, which was then used to analyze traffic re-routing.

Reference Materials

Pavement Preservation Tool, FHWA
iTunes: https://itunes.apple.com/us/app/pavement-preservation-tool/id840223003?mt=8
According to the app description, “These checklists are a series created to guide State and local highway maintenance and inspection staff in the use of innovative pavement preventive maintenance processes.”

Ohio DOT Roadside Safety Field Guide
iPhone: https://itunes.apple.com/us/app/odot-roadside-safety-field/id987542248?mt=8
This app summarizes guidelines established in the AASHTO Roadside Design Guide for the installation and maintenance of roadside safety hardware. It contains basic principles, descriptions and images of various roadside safety hardware and their best uses, design considerations, and maintenance information.

Ohio DOT Basic Traffic Sign Installation Guide
https://www.dot.state.oh.us/Divisions/Operations/Traffic/miscellaneous/Pages/ODOT-Traffic-Apps.aspx
This app summarizes standards and guidelines established in the Ohio Manual for Uniform Traffic Control Devices and the Ohio DOT Traffic Engineering Manual for the installation of traffic signs common in local agency use. It contains basic principles and images for various types of sign installation scenarios.

Ohio DOT Work Zone Pocket Guide
iPhone: https://itunes.apple.com/us/app/odot-work-zone-pocket-guide/id909406255?mt=8

Android:
https://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/pocketguide/Pages/default.aspx
This app "summarizes … guidelines established in the Ohio Manual of Uniform Traffic Control Devices (OMUTCD). It contains basic principles, a description of the standard traffic control devices used in work areas and traffic incident management areas, guidelines for the application of the devices, and typical application diagrams. Information concerning proper flagging is also presented."

Ohio DOT (ODOT) Location Finder
iPhone: https://itunes.apple.com/us/app/odot-location-finder/id703100312?mt=8
Android: https://play.google.com/store/apps/details?id=com.odottraffic.odotlocationfinder&hl=en
Description:

> Find your current location on the Ohio road network using the ODOT classification system: County, Route, and Section (county log point or state mile marker). The location information can be exported via email.
>
> This app was first implemented by ODOT District 11 as a website and developed into a mobile app by the ODOT Office of Traffic in partnership with ODOT IT.

Work Zone Safety, FHWA and American Traffic Safety Services Association (ATSSA)
http://www.atssa.com/WorkZoneSafetyGrant/App
This app "aims to help facilitate proper work zone layout and setup as well as act as a reference manual for work zone attributes and safety procedures."

DOT Reporting to the Public on Maintenance

As noted earlier, many apps described in this Preliminary Investigation allow two-way communication between state DOTs and the public about maintenance issues. The apps described below focus on one-way communication from the DOT to the public.

Snowplow Tracking

Several DOTs allow the public to view the location of their snowplows within their 511 apps. Note that in some 511 apps, this feature is deactivated (and invisible) when no plows are on the streets.

Agency app pages:

> **Utah DOT:** http://udottraffic.utah.gov/RoadWeatherForecast.aspx
>
> **Pennsylvania DOT:** http://www.511pa.com/mobileApp.aspx
>
> *Related Resource:*
>
> > **"Track Location of PennDOT Snow Plows Online,"** WFMJ, January 2016.
> > http://www.wfmj.com/story/30935355/track-location-of-penndot-snow-plows-online
> > This article gives details on this recently launched initiative.

Dynamic Message Signs

Prototyping and Evaluating a Smartphone Dynamic Message Sign (DMS) Application, Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC), December 2015.
http://cvi-utc.org/wp-content/uploads/2015/12/Smith_Prototyping-and-Evaluating-a-Smartphone-Dynamic-Message-Sign-Application_Final.pdf
From the abstract:

> One of the most commonly used ways to provide real-time, en route traveler information to motorists is through Dynamic Message Signs (DMSs). Despite their effectiveness, they are costly and limited in terms of the amount of information they can deliver. The wide availability of smart mobile devices can provide traveler information through in-vehicle devices (without incurring huge infrastructure costs) and (in a more flexible manner) to selected individuals and locations without geographical constraints. Research was conducted to comprehensively develop and evaluate this concept.

Other Apps That Gather Data from the Public

This section presents a sampling of other apps that DOTs are using or evaluating that involve gathering information from the public.

Planning

"Rapidly Expanding Mobile Apps for Crowd-Sourcing Bike Data to New Cities," Florida DOT. In progress; expected completion in March 2016.
http://trid.trb.org/view/2015/P/1372525
Abstract:

> Cities such as San Francisco, Atlanta, and Portland are using novel methods of data collection to find out more about the use of their bicycle infrastructure. This data can help transportation planners better design or upgrade bicycle facilities. San Francisco created an open-source project "Cycle Tracks" (San Francisco County Transportation Authority, 2015), a mobile app which was used to collect bike path data from bicyclists' smartphones. This data was then used in the SF-CHAMP travel demand model to forecast how attractive Bike Facility A would be compared to Bike Facility B, to understand the potential mode shifts that could occur with implementation of bike infrastructure, and to better understand the impact of new SF bike infrastructure on bicyclist travel behavior. A similar project, Cycle Atlanta (Cycle Atlanta, 2015), was implemented in Atlanta, GA, and was based on the Cycle Tracks open-source code, as was ORcycle for Portland, OR (Portland State University, 2015). These methods of gathering data from the public via mobile apps can be referred to as "crowd-sourcing." While open-source crowd-sourcing mobile apps can provide a wealth of information to transportation planners, there is at least one major obstacle to deploying these projects in new cities: software engineers for iOS and Android are required to modify and re-deploy these apps for each city. As a result, deploying these apps in new cities can be very costly. This cost limits adoption and removes opportunities for innovation based on data collected from such apps. This project seeks to overcome the barriers to wide-scale adoption of bike data crowd-sourcing mobile apps through a "multi-region" solution, which would allow cities to share the same set of mobile apps on the respective apps stores, while setting up their own server specific to their own geographic area. This solution reduces the cost of deployment by leveraging the mobile apps that already exist, rather than each city

needing to modify and launch their own version of the apps. This work will draw from some of the lessons learned during the multi-region design and deployment for the OneBusAway open-source project, which had a similar purpose of making real-time transit apps easily available in new cities (Barbeau et al, 2014).

Evaluation of Existing Smartphone Applications and Data Needs for Travel Surveys, Texas DOT, April 2015.
Report: http://tti.tamu.edu/documents/0-6767-1.pdf
Summary: http://tti.tamu.edu/documents/0-6767-S.pdf
Excerpt from the abstract:

> This project evaluated existing smartphone applications for conducting travel surveys. The project compiled a list of the pioneering smartphone travel survey efforts and lessons learned, compared them, and analyzed their applicability to serve Texas Department of Transportation (TxDOT) survey needs. The project identified and installed a list of smartphone travel survey applications to thoroughly evaluate and compare their capabilities. The project summarized and classified the data elements collected by TxDOT surveys and built a prototype smartphone household survey app to validate that all the survey data can be collected using smartphones. The project discussed the opportunities and challenges in fully realizing the potential of using smartphone applications for travel surveys.

Smartphone-Based System for Automated Detection of Walking – Year 2 (2013-14), Pacific Northwest Transportation Consortium (PacTrans), U.S. DOT University Transportation Center for Federal Region 10, August 2015.
http://depts.washington.edu/pactrans/wp-content/uploads/2013/11/PacTrans-51-UW-Hurvitz3.pdf
Abstract:

> Walking is the most effective mode of travel to access transit: transit hubs with higher residential and employment densities have higher ridership levels because they serve areas where a large population is within a short walk of transit service. Walking has additional benefits: it is well-known as a low impact mode of travel for short trips to and from, as well as within, commercial areas; and it is the most popular form of physical activity. However, current data on walking are notoriously poor. Travel surveys and diaries underestimate walking activity and lack information on walking paths taken, thereby undermining transportation policies that can encourage sustainable travel. Objective data on how often, how long and where people walk are essential to support environmentally friendly and safe transportation systems.

Selected Additional Apps

This section highlights a few other innovative apps that state DOTs and other agencies are using or investigating.

Traffic Signals

EnLighten (Developer: Connected Signals)
https://connectedsignals.com/enlighten.php
This app gives drivers real-time information about how long traffic signals will stay green or red. This information can help reduce red-light running and help drivers improve their gas mileage and reduce emissions.

EnLighten's developers partner with cities to obtain information on traffic signals. The app is available in cities including Las Vegas; Salt Lake City; Portland, Oregon; and Walnut Creek and Arcadia, California (soon to be available in Palo Alto and Pasadena).

Sustainable Mobility

Several DOTs are exploring apps that encourage residents to make environmentally sustainable travel choices.

Roadcents, Texas DOT
http://roadcents.org
iPhone: http://itunes.apple.com/us/app/roadcents/id1018445598?mt=8
Android: http://play.google.com/store/apps/details?id=com.bhw.roadcents

Description: "Roadcents lets you track vehicle maintenance and learn ways to reduce vehicle emissions and save money by driving smart and maintaining your vehicle. Features include: annual fuel cost calculator for your vehicle, maintenance log, maintenance reminders, safety tips, and safety checklists."

Related Resource:

> **"Texas DOT Launches App to Help Texans Drive Cleaner, Cheaper, Safer,"** *Midland Reporter-Telegram,* March 2015.
> http://www.mrt.com/business/article_e194e794-cf39-11e4-a8fe-0fd7993b29ea.html
> Excerpt from the article:
>
> > "With this app, you get gas savings tips that can help cut gas costs and also tailpipe emissions," said Gene Powell, public information officer for TxDOT in Midland and Odessa.
> >
> > One of the main goals of the app, which was recently reintroduced during a spring break in Corpus Christi is to "improve the efficiency of vehicles," Powell said.
> >
> > Roadcents is offered as part of the department's Drive Clean Texas campaign, and officials said the timing of the release is because spring and summer, with their warmer weather, are when traffic increases and ozone levels can spike. In major metropolitan areas like Dallas and Houston, where air quality is a concern, if the app can prompt

drivers to take better care of their vehicles and improve efficiency and emissions, that's a benefit, he said.

"Quantified Traveler: Travel Feedback Meets the Cloud to Change Behavior," Raja Sengupta and Joan L. Walker, *Access*, Volume 47, Fall 2015.
http://www.accessmagazine.org/wp-content/uploads/sites/7/2015/11/access47.1sengupta.pdf
This article describes a 2013 University of California Transportation Center study in which subjects used a smartphone app to track their travel habits. Below is an excerpt from the article, which references the impact of surface transportation on greenhouse gas (GHG) emissions.

> While many people are aware of the environmental damage caused by GHGs, that knowledge has not resulted in substantially less car travel. If travelers knew more about the impacts of their travel decisions, they might change their trip modes, routes, or departure times. If they could compare their trips to those of their peers or the national standard, they might change their travel habits even more. To test this idea, the authors built and evaluated an information technology called Quantified Traveler (QT). QT is meant to encourage travelers to be more mindful of their travel decisions and encourage drivers to walk, bike, ride transit, or forego a trip altogether. UC Berkeley affiliates were recruited to use the app and take an entry and exit survey. Analysis of the before and after surveys suggests that computational systems may have the ability to alter users' intentions and actions involving travel mode shifts.

Final report: http://escholarship.org/uc/item/2dh952gj#page-1

Empowering Individuals to Make Environmentally Sustainable and Healthy Transportation Choices in Mega-Cities Through a Smartphone App, University Transportation Research Center—Region 2, April 2015.
http://www.utrc2.org/sites/default/files/pubs/Smart-Transportation-Choices-Mega-Cities-Smartphone-App.pdf
This study assessed the impacts of a behavioral nudge intervention consisting of a new smartphone app, onTrac. The app was developed to report personalized knowledge of carbon emission and calories burned associated with user-specified travel modes, with walking and bicycling automatically detected through the phone's accelerometer.

Safety

"In-Vehicle Dynamic Curve Speed Warnings at High Risk Rural Curves," Minnesota DOT, project planned for Fiscal Year 2017.
http://www.dot.state.mn.us/research/RFP/FY2017/Summaries/2.%20In-Vehicle%20Dynamic%20Curve%20Speed%20Warnings%20at%20High%20Risk%20Rural%20Curves.pdf
Excerpt from the project description:

> This project seeks to determine the efficacy of in-vehicle dynamic curve speed warnings as deployed on a smartphone app. First, a warning method must be selected that is effective but also does not distract the driver from navigating the curve. This will be incorporated into an app capable of displaying the warning to drivers based on their speed and distance to the curve. The app will be evaluated using rural Minnesota drivers in a naturalistic field study. Data will be collected to determine how well the system affects change in the drivers' behavior.

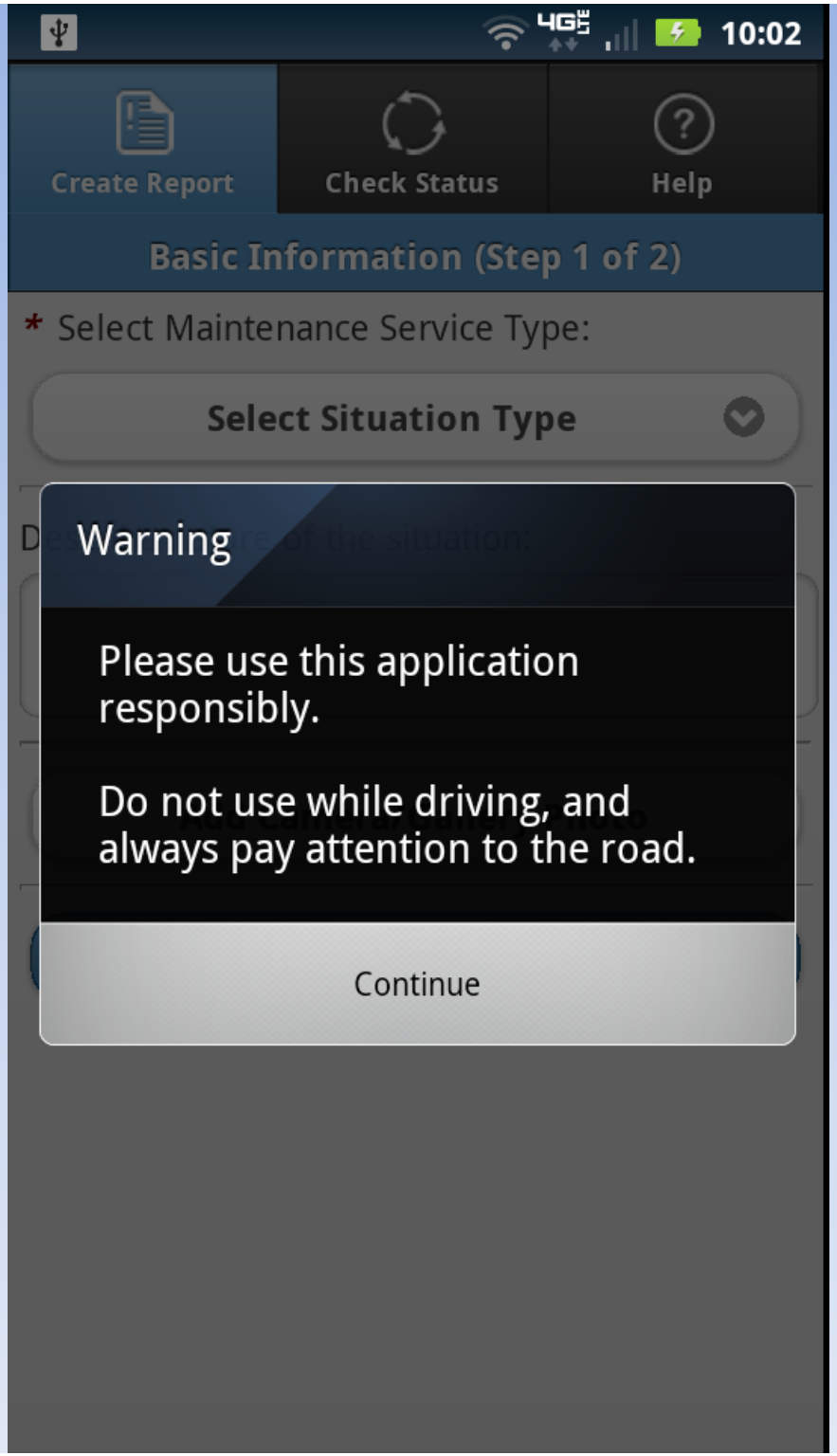
"Work Zone Intrusion Report Interface Design," Minnesota DOT (MnDOT), project planned for Fiscal Year 2017.
http://www.dot.state.mn.us/research/RFP/FY2017/Summaries/10.Work%20Zone%20Intrusion%20Report%20Interface%20Design.pdf
Excerpt from the project description:

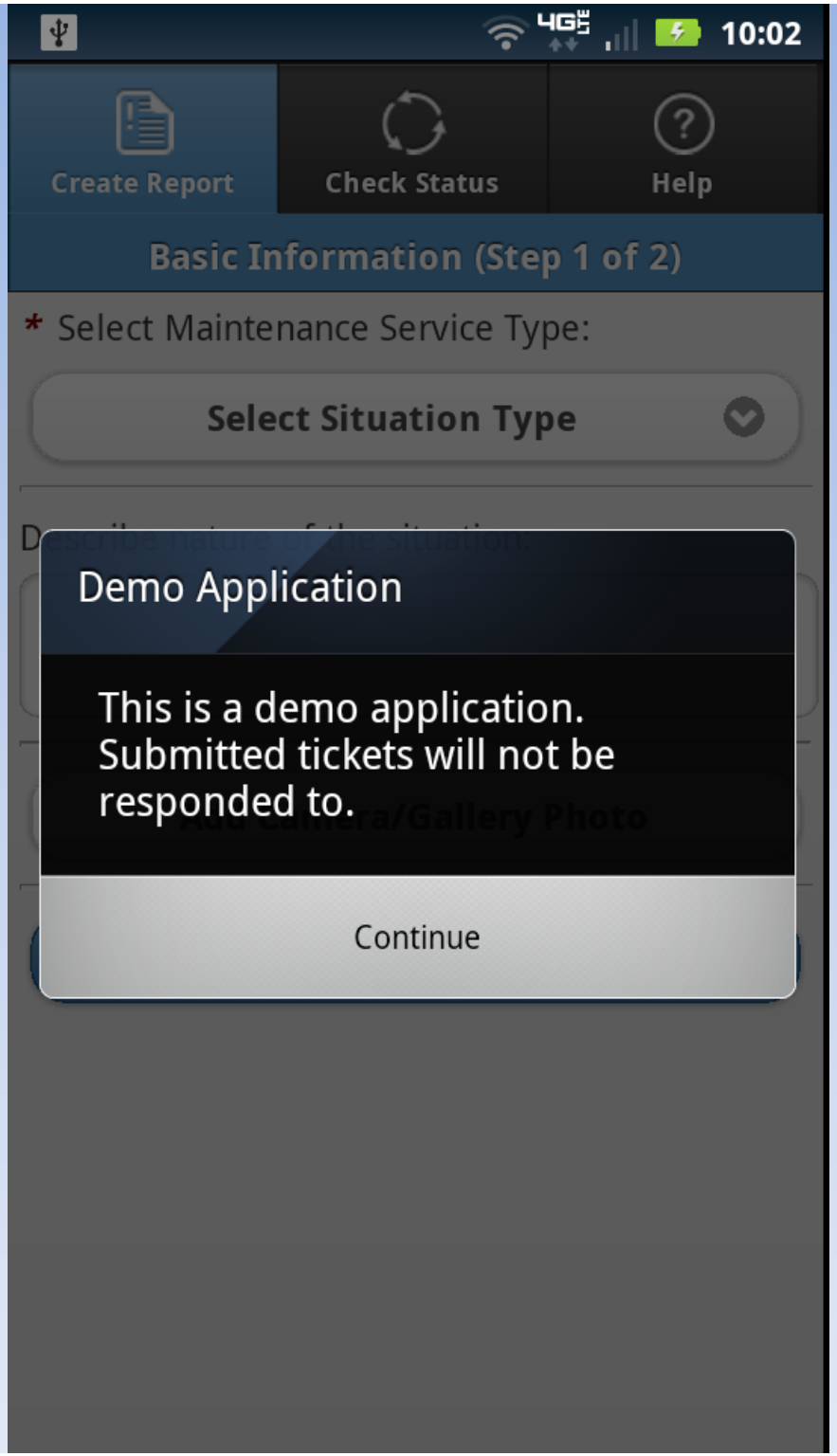
> Work zone intrusions are a serious safety concern for crew workers, as motorists are known to intentionally or unintentionally breach the boundaries of construction, maintenance, and mobile operations. Understanding the factors that contribute to work zone intrusions is largely unknown because the method and standards for capturing data surrounding the events statewide and nationally are not well established, according to a recent transportation research synthesis (CTC, 2015).
>
> The [project] objectives are: (1) Establish a sound methodology for work zone intrusion reporting that accurately provides a holistic understanding of intrusion characteristics, setting a national standard for work zone reporting (2) Design a smartphone application to capture video and report intrusions using human factors usability standards (3) Provide MnDOT with a for critical data insight into the intrusion attributes that allow for policy or procedural action.

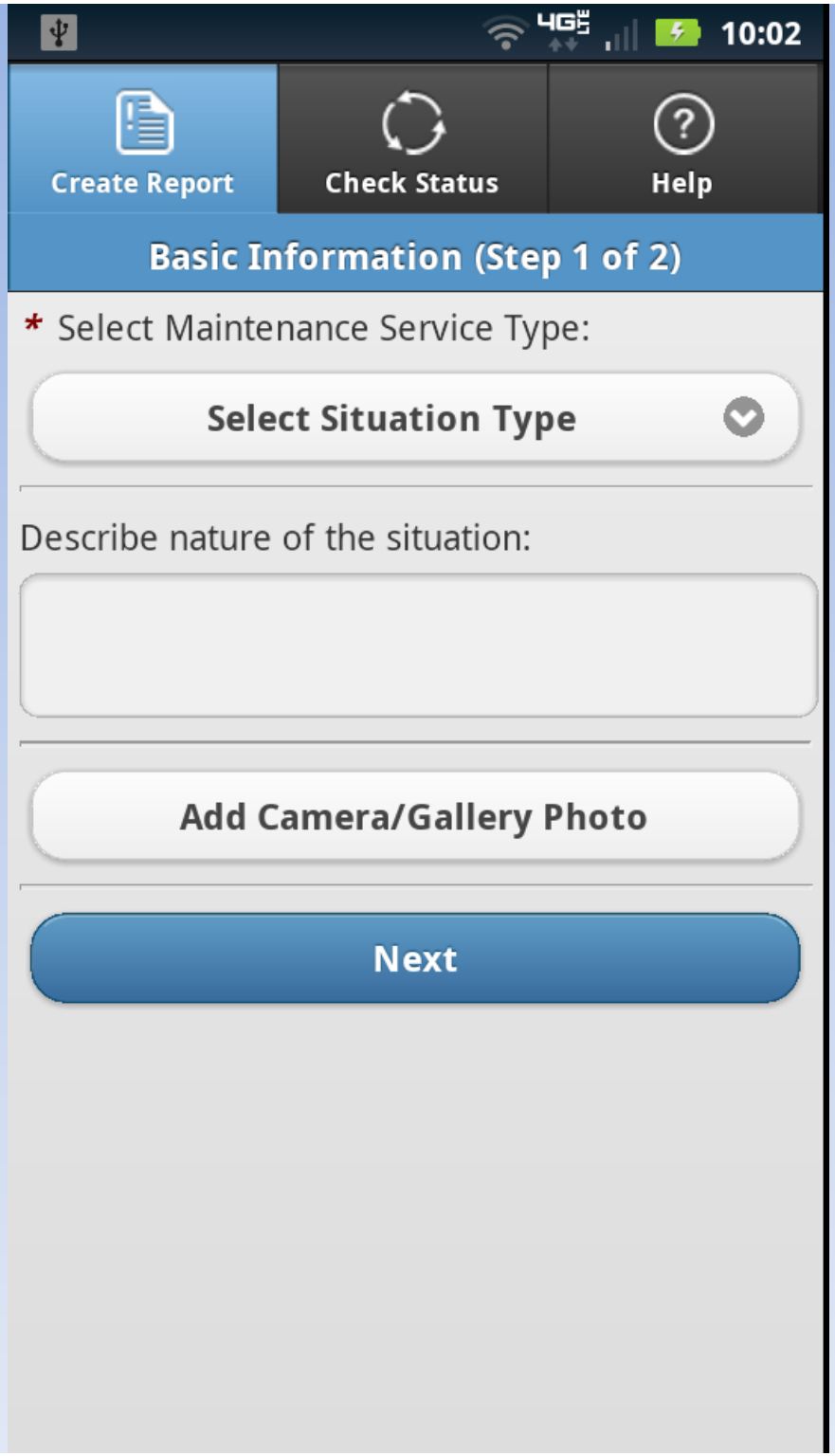
Accessibility

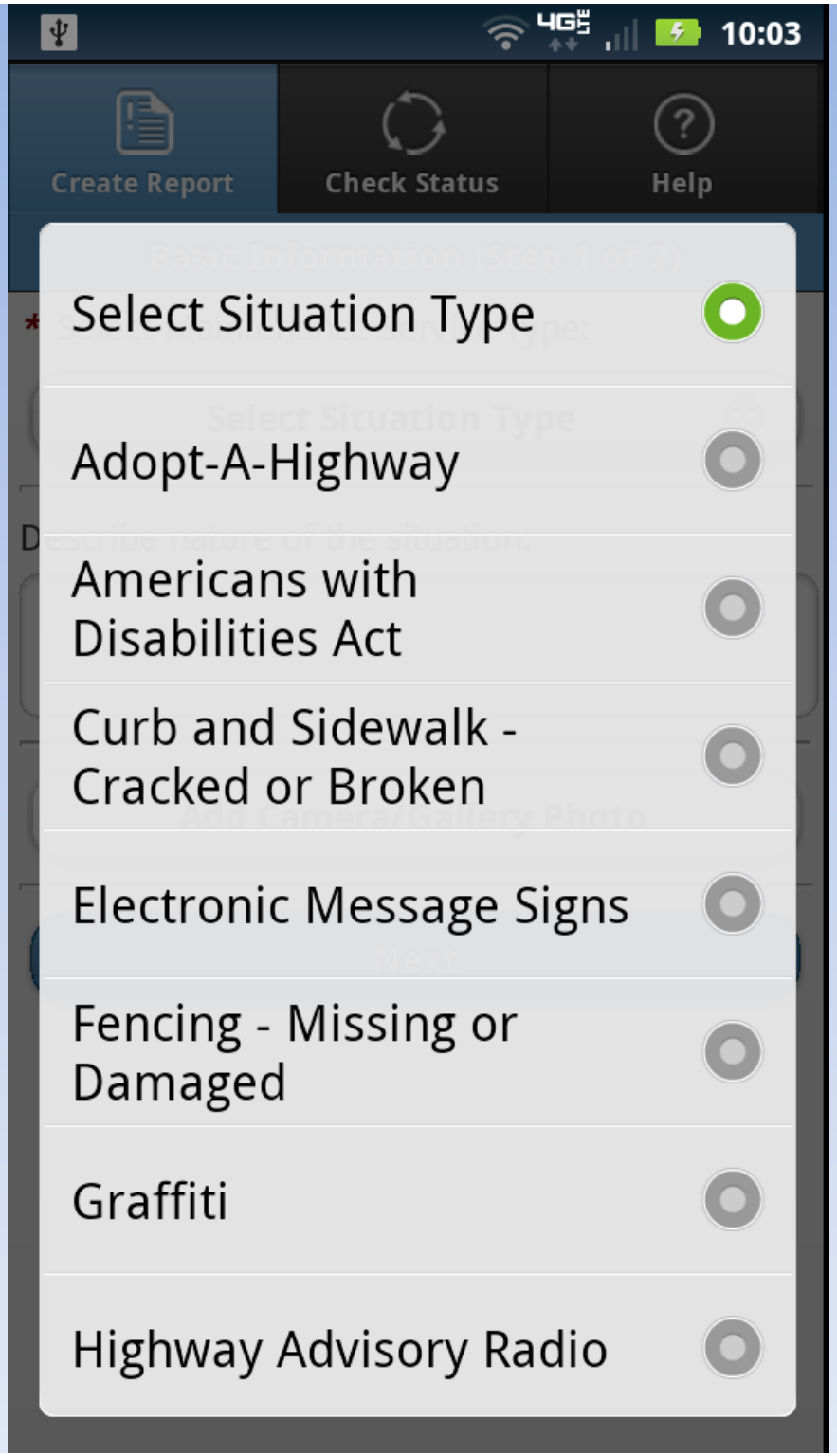
"Finding Your Way: New App Improves Navigation for Blind Passengers," *International Railway Journal,* September 2015.
http://www.railjournal.com/index.php/metros/finding-your-way-new-app-improves-navigation-for-blind-passengers.html
Abstract: "A strong potential to transform transit station navigation for vision impaired passengers has been shown in trials of a new smartphone app, as presented in this article."

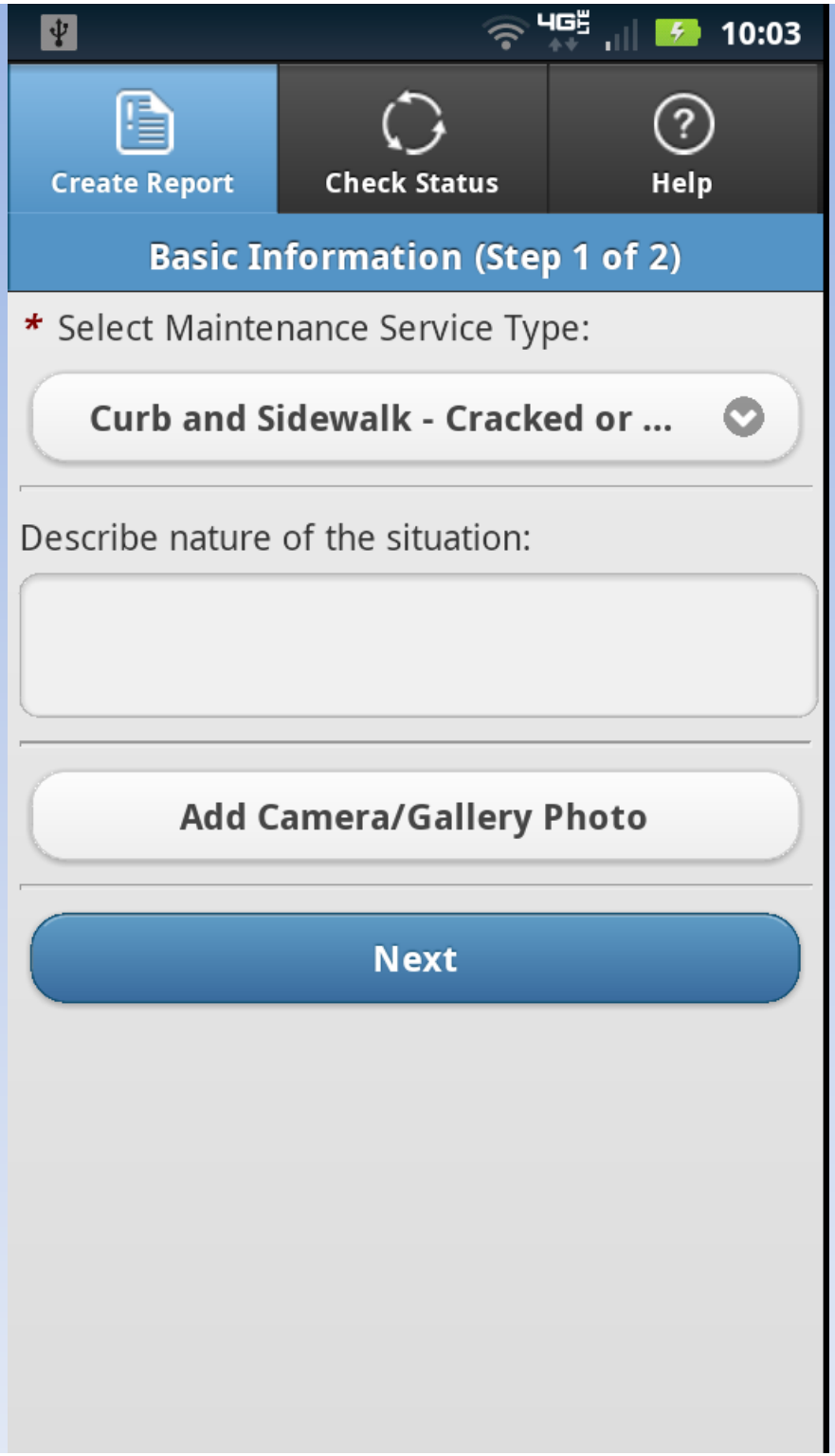

3G
12:44 PM
MSR Mobile
Phone
Messaging
S Note
Internet
Apps

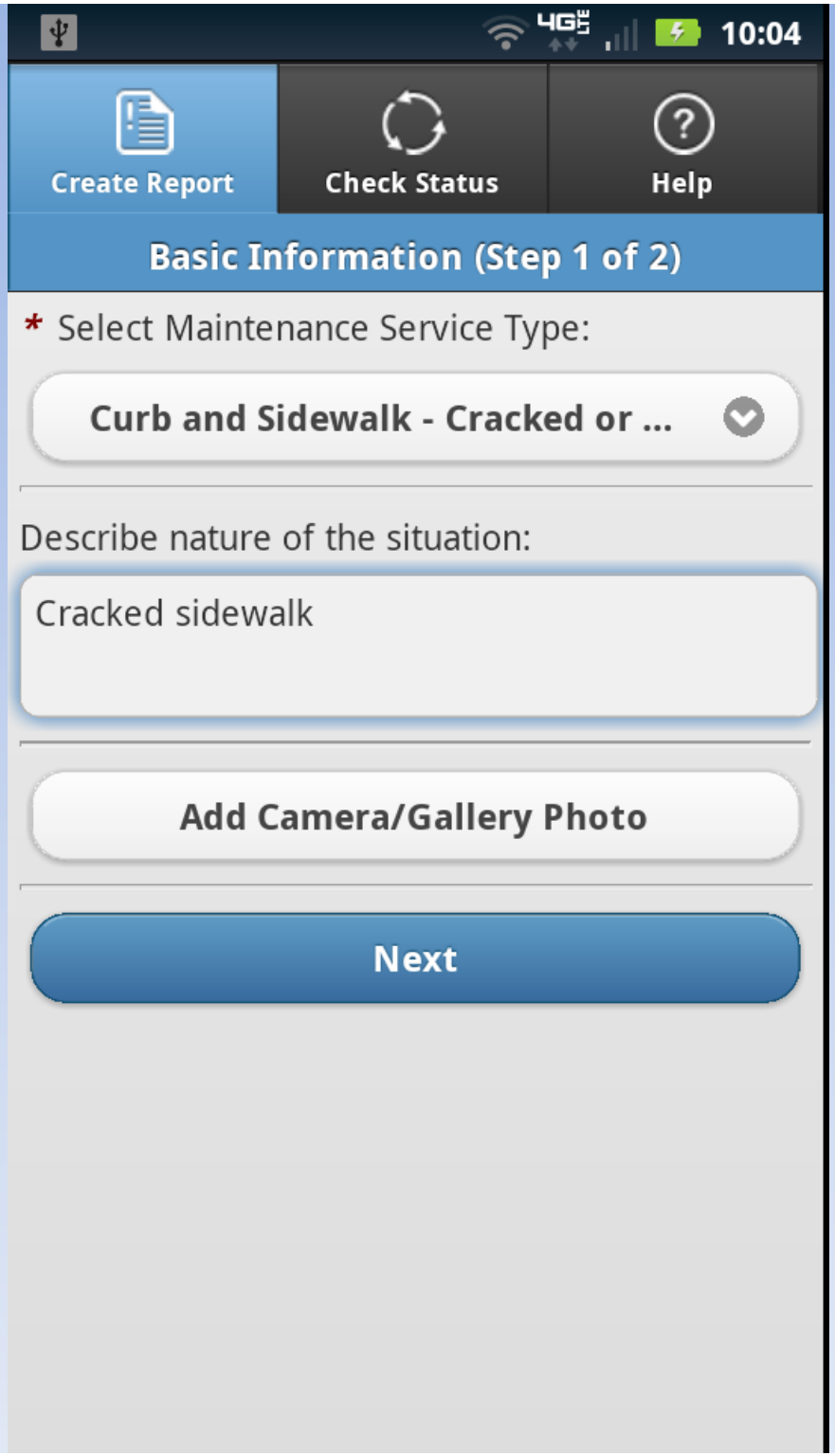

10:02
Create Report
Check Status
Help
Basic Information (Step 1 of 2)
* Select Maintenance Service Type:
Select Situation Type
Warning
Please use this application responsibly.
Do not use while driving, and always pay attention to the road.
Continue

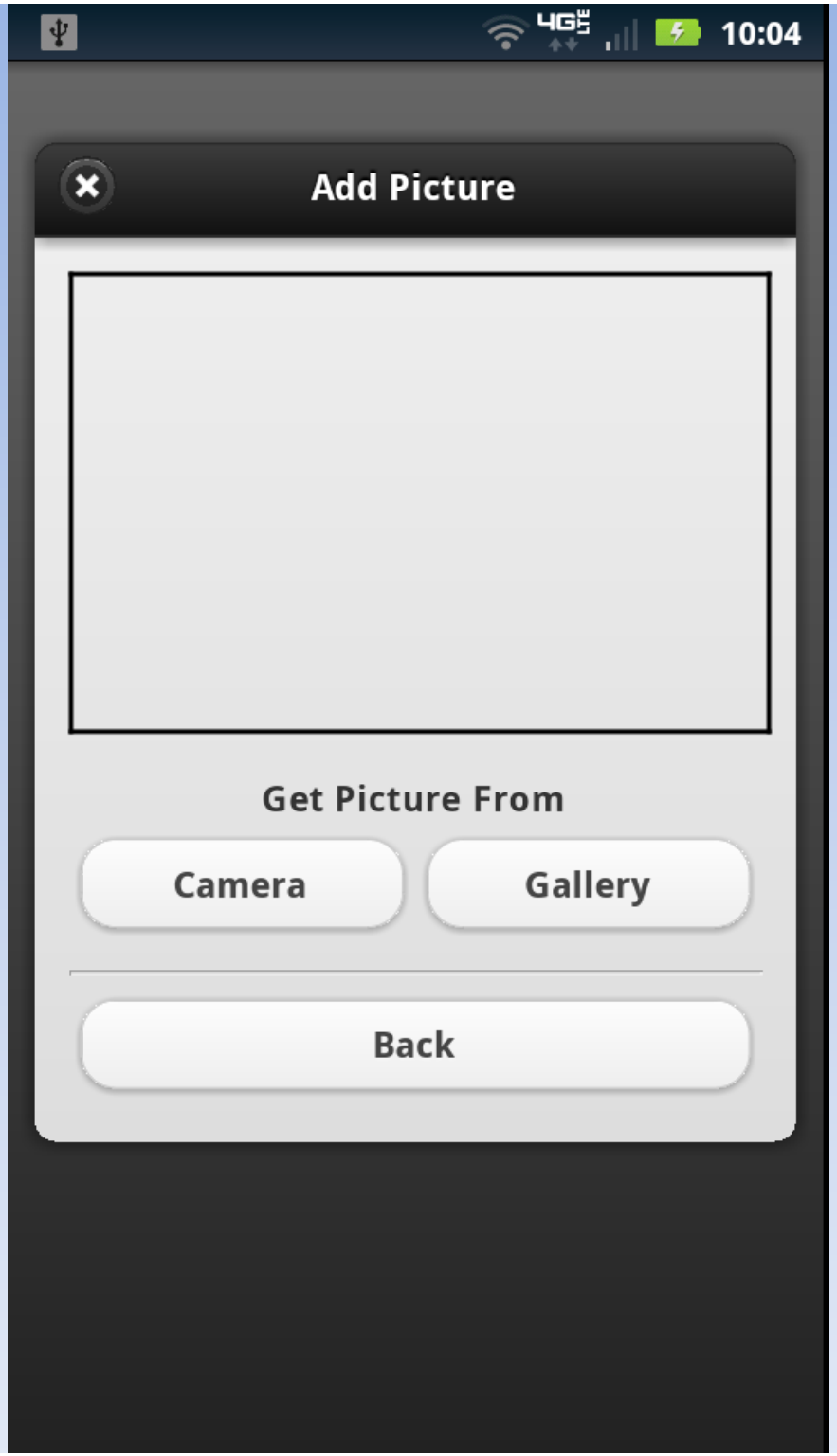

10:02
Create Report
Check Status
Help
Basic Information (Step 1 of 2)
* Select Maintenance Service Type:
Select Situation Type
Demo Application
This is a demo application.
Submitted tickets will not be
responded to.
Continue

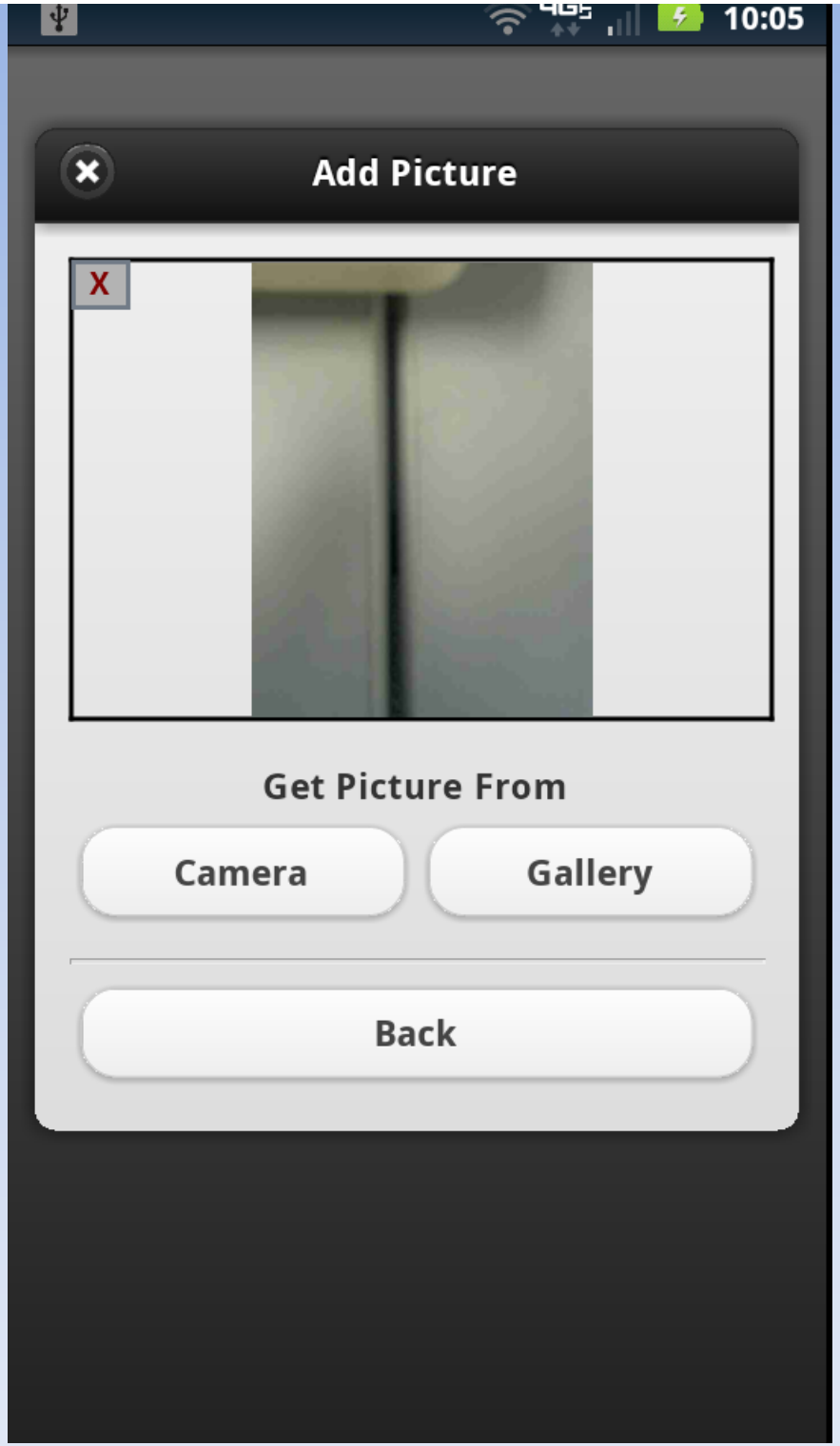

10:02
Create Report
Check Status
Help
Basic Information (Step 1 of 2)
* Select Maintenance Service Type:
Select Situation Type
Describe nature of the situation:
Add Camera/Gallery Photo
Next

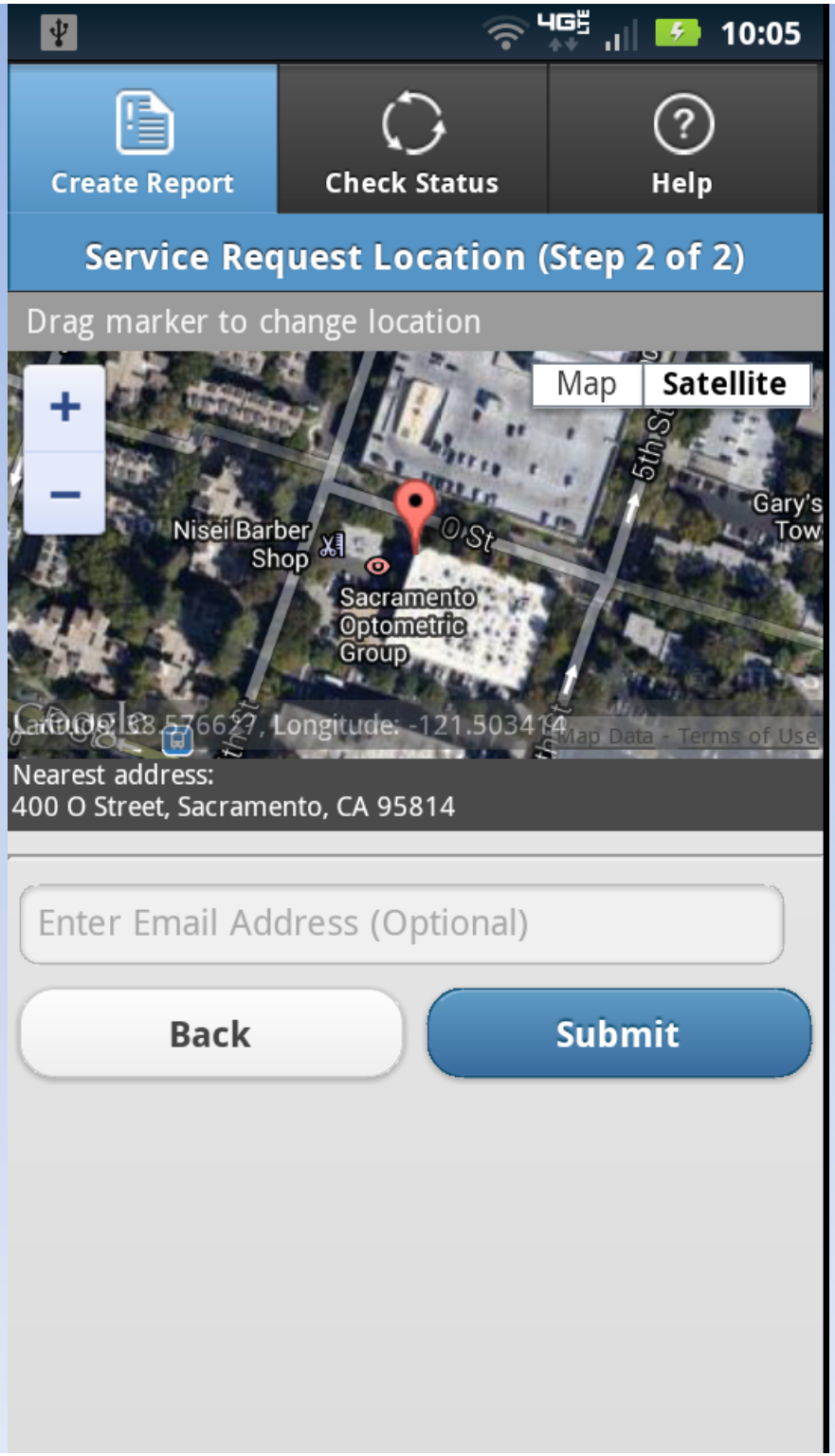

10:03
Create Report
Check Status
Help
Select Situation Type
Adopt-A-Highway
Americans with Disabilities Act
Curb and Sidewalk - Cracked or Broken
Electronic Message Signs
Fencing - Missing or Damaged
Graffiti
Highway Advisory Radio

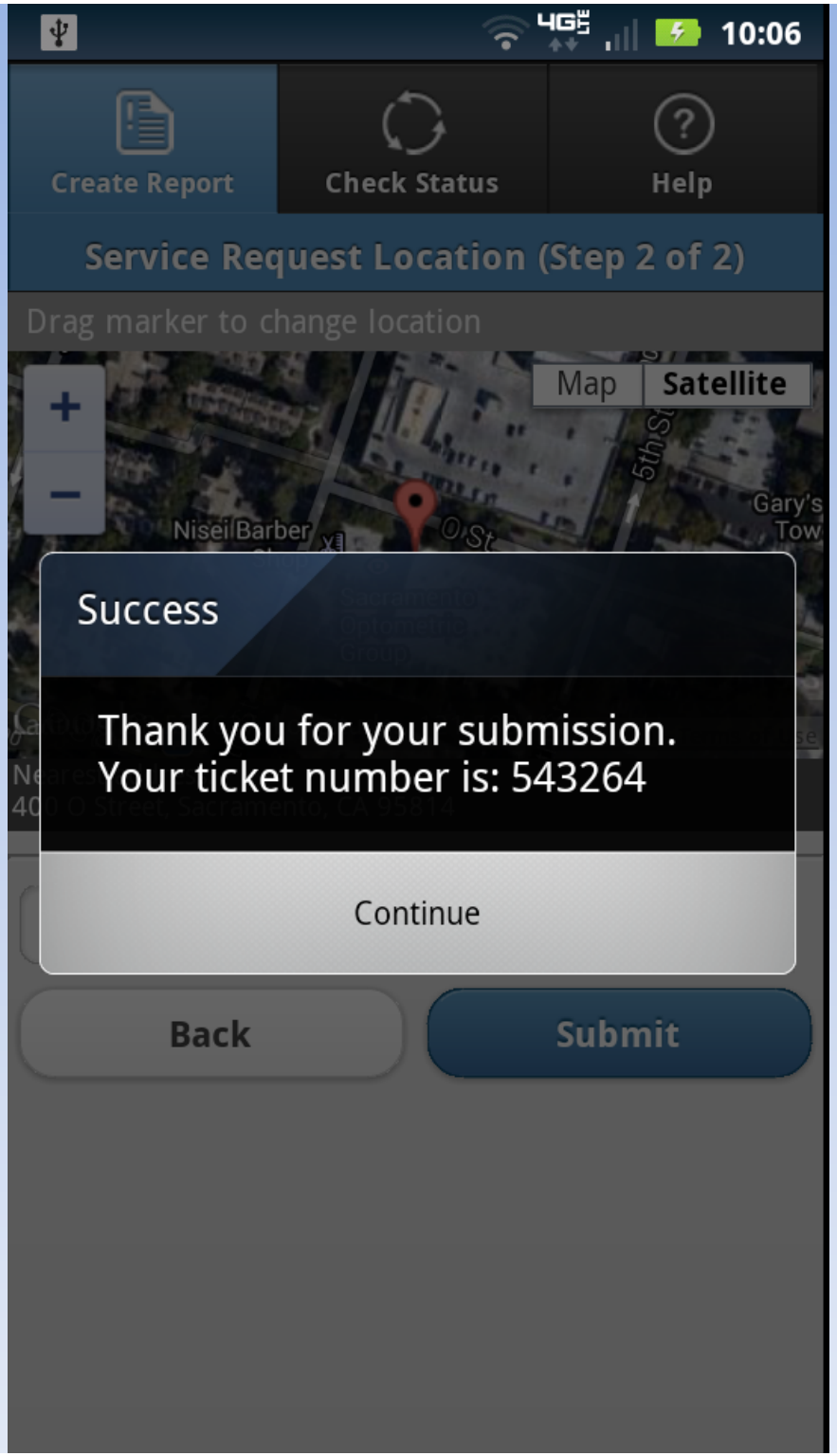

10:03
Create Report
Check Status
Help
Basic Information (Step 1 of 2)
* Select Maintenance Service Type:
Curb and Sidewalk - Cracked or ...
Describe nature of the situation:
Add Camera/Gallery Photo
Next


10:04
Create Report
Check Status
Help
Basic Information (Step 1 of 2)
* Select Maintenance Service Type:
Curb and Sidewalk - Cracked or ...
Describe nature of the situation:
Cracked sidewalk
Add Camera/Gallery Photo
Next


10:04
Add Picture
Get Picture From
Camera
Gallery
Back


10:05
Add Picture
X
Get Picture From
Camera
Gallery
Back


10:05
Create Report
Check Status
Help
Service Request Location (Step 2 of 2)
Drag marker to change location
Map
Satellite
Nisei Barber Shop
O St
5th St
Gary's Tow
Sacramento Optometric Group
Google
Map Data - Terms of Use
Nearest address:
400 O Street, Sacramento, CA 95814
Enter Email Address (Optional)
Back
Submit


10:06
Create Report
Check Status
Help
Service Request Location (Step 2 of 2)
Drag marker to change location
Map
Satellite
Success
Thank you for your submission.
Your ticket number is: 543264
Continue
Back
Submit


3G
11:05 AM
Create Report
Check Status
Help
Ticket#: 543256
Ticket Status: Pending
Submission Date: Tuesday, July 16th 2013
Issue Type: Adopt-A-Highway
Ticket#: 543255
Ticket Status: Pending
Submission Date: Tuesday, July 16th 2013
Issue Type: Americans with Disabilities Act
Ticket#: 543251
Ticket Status: Pending
Submission Date: Tuesday, July 2nd 2013
Issue Type: Americans with Disabilities Act
Ticket#: 543250
Ticket Status: Pending
Submission Date: Tuesday, July 2nd 2013
Issue Type: Americans with Disabilities Act
Ticket#: 543249
Ticket Status: Pending
Submission Date: Tuesday, July 2nd 2013
Issue Type: Adopt-A-Highway