State Transportation Agencies Partner to Deploy and Enhance ShakeCast

L. Turner(1), D. J. Wald(2), K. Lin(3), B. Chiou(4), and D. Slosky(5)

ABSTRACT

The California Department of Transportation (Caltrans) is organizing and leading a three-year Transportation Pooled Fund (TPF) project, Connecting the Dots: Implementing ShakeCast Across Multiple State Departments of Transportation for Rapid Post-Earthquake Response. Ten state Departments of Transportation (DOT)—CA, ID, MO, MS, OK, OR, SC, TX, UT, AND WA—have partnered and combined research funds to pursue implementation and advancement of the U.S. Geological Survey’s (USGS) ShakeCast system. ShakeCast is a software application that automatically retrieves ShakeMap shaking estimates and performs analyses using fragility functions for bridges, buildings, and other structures. The ShakeCast system identifies which facilities are most likely impacted by an earthquake and sends notifications to responders in the minutes after an earthquake. By focusing inspection efforts on the most damage-susceptible facilities in the severely shaken areas, ShakeCast can reduce response time and priorities for bridge inspections in the aftermath of a significant earthquake. The goal of the TPF project is to establish or enhance operational ShakeCast instances for all the partner DOTs, while advancing transportation-focused aspects of the software platform. DOTs are uniquely able to take advantage of the ShakeCast technology in that bridge fragilities can be readily derived from the National Bridge Inventory (NBI). DOTs also share the need for prioritized response strategies given their very large numbers of facilities—over wide areas—that have varying vulnerabilities, many of which could potentially be affected by earthquake shaking. The ten-state TPF project will also explore opportunities for DOT-specific ShakeCast software modifications, for example, for enhanced neighboring-state situational awareness and response coordination as well as for long-term maintenance and operations of their ShakeCast systems.

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The California Department of Transportation (Caltrans) is organizing and leading a three-year Transportation Pooled Fund (TPF) project, Connecting the DOTs: Implementing ShakeCast across Multiple State Departments of Transportation for Rapid Post-Earthquake Response. Ten state Departments of Transportation (DOT)—CA, ID, MO, MS, OK, OR, SC, TX, UT, and WA—have partnered and combined research funds to pursue implementation and advancement of the U.S. Geological Survey’s (USGS) ShakeCast system. ShakeCast is a software application that automatically retrieves ShakeMap shaking estimates and performs analyses using fragility functions for bridges, buildings, and other structures. The ShakeCast system identifies which facilities are most likely impacted by an earthquake and sends notifications to responders in the minutes after an earthquake. By focusing inspection efforts on the most damage-susceptible facilities in the severely shaken areas, ShakeCast can reduce response time and priorities for bridge inspections in the aftermath of a significant earthquake. The goal of the TPF project is to establish or enhance operational ShakeCast instances for all the partner DOTs, while advancing transportation-focused aspects of the software platform. DOTs are uniquely able to take advantage of the ShakeCast technology in that bridge fragilities can be readily derived from the National Bridge Inventory (NBI). DOTs also share the need for prioritized response strategies given their very large numbers of facilities—over wide areas—that have varying vulnerabilities, many of which could potentially be affected by earthquake shaking. The ten-state TPF project will also explore opportunities for DOT-specific ShakeCast software modifications, for example, for enhanced neighboring-state situational awareness and response coordination as well as for long-term maintenance and operations of their ShakeCast systems.

Project Goals

Of all of the current ShakeCast users, the California Department of Transportation (Caltrans)

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perhaps has the greatest exposure of critical infrastructure. Caltrans is responsible for over 25,000 bridges and overpasses in California and operates road management out of 12 Traffic Management Centers (TMCs), which act as nerve centers for these critical lifelines. Caltrans has been working with the U.S. Geological Survey (USGS) over the last 14 years to develop a robust and operational ShakeCast platform. Following a major earthquake, Caltrans faces an array of decision-making challenges. One urgent task is to assess the condition of all bridges and roadway corridors in the highway system. Timely response is important to ensure public safety, aid routing of emergency vehicle traffic, and reestablish critical lifeline routes.

The earlier prototypes and current long-term ShakeCast release (Version 3) have been stably operating at Caltrans since 2007; they have proven to be a valuable tool for Caltrans in post-earthquake response during real events and in scenario planning exercises. ShakeCast sent notifications to Caltrans responders for all earthquakes greater than M4.0 that have resulted in significant ground shaking within California; over 300 events were evaluated over this time period. Though widely felt in the region and reported through the media, the vast majority of these earthquakes did not produce ground shaking strong enough to cause damage to Caltrans structures. A number of events, however, have generated significant shaking and triggered ShakeCast “Potential Impact” notifications: the 2008 M5.4 Chino Hills, 2010 M7.2 Calexico, and 2014 M6.0 Napa earthquakes. For each, ShakeCast generated messages to responders and damage to bridges was observed.

Over the last five years, Washington, Utah, Oregon, Oklahoma, and Nevada also implemented ShakeCast for statewide post-earthquake bridge analyses. These other DOT ShakeCast instances were deployed independently; customized implementation or configuration strategies for each DOT were realized. The wider goal of bringing together additional State DOTs with systematic ShakeCast implementations was recognized and described at the Seventh National Seismic Conference on Bridges and Highways in 2013 [1]. However, allocating resources to do so was not realized until 2017, when the Connecting the DOTs TPF (study number TPF-5(357)) was supported. The three-year TPF project was approved by the Federal Highway Administration (FHWA) in January 2017, and actual implementation of the project began in October 2017. An in-person kickoff workshop was hosted by Caltrans in July 2017, and it is anticipated that annual meetings will be convened to update the participating agency representatives on the status of the project and to provide a forum for information sharing, training and feedback.

This collaborative TPF effort (see Fig. 1) is intended to bring the participating DOTs into full ShakeCast operation for post-earthquake assessment of their state and local bridge inventories. The project is a mechanism to actively engage representatives from state DOTs with common interests in implementing and expanding the application of ShakeCast technologies to improve their emergency response capabilities. The scope of the TPF project comprises two primary focus areas: (1) Provide support for participating DOTs to deploy operational ShakeCast systems. Several technological alternatives exist for deploying ShakeCast depending upon the IT environment and policy requirements of individual DOTs. These options include cloud-based deployments (e.g., Amazon cloud), deployment within an agency’s IT infrastructure, or through a centralized cloud service hosted by the USGS. These and other alternatives will be explored through the project and an operational deployment solution identified for each participating state DOT. Training on ShakeCast administration and structural fragility applications, technical
assistance over the course of the project, and related services will be provided through the USGS.

(2) Develop, modify, and customize ShakeCast features to meet the needs of the state DOTs. Over the course of the project, new and/or modified feature requirements will be identified. The project participants will develop and prioritize these needs, and guide their development implementation by the USGS ShakeCast team. For instance, earthquake-induced landsliding and liquefaction are significant threats to roadways and bridges in many states; with some customization, ShakeCast could include these additional hazards in its analyses and notifications.

![Figure 1](image.png)

Figure 1. Distribution of shaking hazards [3] and state transportation department partners in the TPF. Ten state Departments of Transportation (DOT)—CA, ID, MO, MS, OK, OR, SC, TX, UT, and WA—have partnered with the USGS ShakeCast team.

As of November 2017, two key aspects of the TPF have been underway. First, participating DOTs are working with the USGS to analyze and report on their operational needs including software, security, monitoring, and operational protocols. Second, we are implementing developmental ShakeCast instances for each DOT to begin quality assurance and proper testing of the bridge fragility inventories derived initially from the National Bridge Inventory. The first notable earthquake captured by the ShakeCast TPF system was the M5.3 southern Idaho event on 09/02/2017 and following aftershocks. While there was no observed damage to bridges in Idaho or neighboring Utah, the ShakeCast system generated tailored summary reports for individual DOTs, respectively (Figs. 2 and 3). Most significant earthquakes have shaking that crosses state and other jurisdictional boundaries such that multiple agencies will be viewing the potential impact with different priorities.
Figure 2. Example of the preliminary ShakeCast report for the 9/2/2017 M5.3 southern Idaho earthquake for the Utah DOT. ShakeCast software instance run in demonstration mode at the USGS.
These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.

Figure 3. Example of the preliminary ShakeCast report for the 9/2/2017 M5.3 southern Idaho earthquake for the Idaho DOT. ShakeCast software instance run in demonstration mode at the USGS.
Version 3 (V3) of the ShakeCast software, written primarily in Perl, is the current long-term stable release; it is a robust application that serves most of the needs of our diverse user base. However, a number of aspects of V3 will benefit from updating and there are several new components being added or reengineered. ShakeCast V4, as well as newer versions of USGS’s ShakeMap, “Did You Feel It?”, and PAGER systems, are being reengineered in Python due to its functionality, and near-ubiquity in computer science courses and within academia. The new development has been coined pyCast. While the TPF project will provide ongoing support and expansion of features in the ShakeCast V3 platform, DOT users will have the opportunity to migrate to pyCast over the course of the project if proven to be more suitable.

The reengineering of ShakeCast has given us the opportunity to incorporate more modern technologies into the application. pyCast is open source and implements version control through GitHub; thus, any GitHub user may contribute to the development or submit feature requests in the form of “issues.” Details and availability of the ShakeCast software are available through the ShakeCast GitHub repository [2]. PyCast lowers the overhead in ShakeCast installation by greatly reducing software dependencies. Rather than distributing and installing a heavyweight web server, V4 employs Flask as both the REST API micro-framework and a pure-Python web server. It serves pyCast’s web user interface, which is built on the Angular framework and focuses on reusable and sustainable code. ShakeCast V4 also replaces the bulky MySQL database server with SQLite, a file-based database, which reduces the complexity of the installation process.

Discussion

Over the three-year TPF project, we will also support the implementation of several software and functionality improvements to ShakeCast aimed at DOT concerns. These enhancements will also benefit the more general ShakeCast user base. Companies, lifeline utilities, and other organizations employing ShakeCast recognize the need for long-term operations of the system and that earthquake response is a long-term commitment. However, it is our experience that adjustments to priorities—and changes in staffing and IT support—can result in limited maintenance or even ShakeCast system deactivation. Since damaging earthquakes are so few and far between, an important goal of the TPF is to provide a cost-effective and workable framework for long-term ShakeCast maintenance and operations among the participating DOTs.

As a distributed application, ShakeCast is employed by most users in a cloud computing environment [2]. ShakeCast can be acquired by requesting access to the ShakeCast base image on Amazon Web Services (AWS, Amazon’s cloud service), but our cloud presence requires the accommodation of U.S. Government cloud-computing mandates, which introduces the need for some flexibility. Any significant policy or new cloud implementation requirements will be reported to ShakeCast users via the ShakeCast Newsletter and blog (http://usgs.github.io/shakecast/news). Long-term maintenance and operational support may take the form of software as a service (SAAS) through third-parties or by the USGS. Alternatively, more centralized operations at the national level, for example at the agency level (e.g., FHWA), or even implementation at the regulator level (e.g., the Federal Energy Regulatory Commission, FERC) could be done under the auspices of national critical infrastructure investment. These options are being actively explored.
ShakeCast V4 will incorporate advancements in estimating the likelihood of shaking-induced secondary hazards to bridges and along roadways due to landslides and liquefaction. Oftentimes shaking-induced ground failure is the dominant reason for roadway and bridge closures after earthquakes rather than direct shaking damage [3]. Allstadt et al. [4] describe model testing and improvements to USGS’s near–real-time capability to estimate the spatial distribution of the probability of landslides and liquefaction. These efforts are being made in conjunction with ShakeCast development to ensure full functional compatibility within ShakeCast. For example, a geospatial grid comparable to the ShakeMap shaking estimates (the grid.xml file used by ShakeCast) includes the ground failure probabilities. ShakeCast can access this secondary hazard grid and use it to assign likelihood of landslides and liquefaction at users’ facilities. Like ShakeMap, there are substantial uncertainties associated with such estimates that depend on both degree of the shaking constraints and ground failure model sufficiency at specific locations.

Lastly, some of the DOTs represented (Fig. 1) share state boundaries; both situational awareness and the potential for pre-earthquake planning and post-event mutual aid would benefit from the sharing of ShakeCast assessments. The TPF is thus an important opportunity for working through the software and operational aspects of sharing notifications and inspection priorities across state borders for multiple DOTs. It is anticipated that such shared inventories and alerting arrangements will be useful for ShakeCast users in other sectors.

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References