Earthquake Impacts on Traffic Safety using Crowdsourced and Police Reported Accident Data

William Chupp, Daniel Flynn, Jeffrey McGuire, Sara McBride, Andrew Malwitz, and Robert DeGroot

USGS science for a changing world

U.S. Department of Transportation Volpe Center

Abstract

Recent developments of regional earthquake early warning systems (e.g., ShakeAlert®) have revealed a gap in research about the impacts of earthquakes on moving vehicles and drivers. This research integrated earthquake shaking data, crowdsourced Waze navigation application data, and police crash reports to quantify changes in likelihood of crashes during seismic events. The study includes earthquakes above magnitude 4.0 within the contiguous United States between 2017 and 2023 to align with Waze data availability. An average of the Modified Mercalli Intensity (MMI) measure of shaking from the U.S. Geological Survey's (USGS) ShakeMap raster data product is applied over constant road network geographies across the affected areas. The MMI estimate at locations of accident and other road hazard reports generated by users of the Waze application are used to quantify the frequency of these alerts in earthquake-affected regions. The same process is applied to California Highway Patrol (CAHP) Crash reports. Accident frequency per road mile in different MMI bins are compared visually and using statistical tests before and after earthquakes to similar time periods throughout the previous year.

Most alerts occur in areas where shaking during an earthquake is MMI 4.5 or below across the entire dataset. There are only marginal differences before/after earthquakes between the distributions of MMI at Waze or CAHP alert locations in these low MMI regions. For regions where MMI is higher than 5.5, visual assessment of accident frequencies on a per-road-mile basis show more accident reports during an earthquake than in similar time periods in the previous year. However, the absolute number of reports in those regions is very low, less then ten alerts for some MMI bins, so it is not yet possible to make any conclusions from these results.

Introduction

Research in support of the ShakeAlert earthquake early warning systems revealed a lack of research into the affects of ground shaking on moving vehicles. While there is research on damage risk to infrastructure and potential impacts to road network performance, less is known about the ability for earthquakes to cause crashes on impacted roadways beyond a few well documented cases such as the Loma Prieta and Northridge earthquakes.

Optimization of functionality for early warning systems like ShakeAlert requires an understanding of the impact that earthquakes, and perhaps the warnings themselves, can have on drivers. This research developed methods to study the impact of earthquakes and warning systems on traffic safety through analysis of large traffic datasets including crowdsourced Waze driving application alerts and police reported accident databases.

Since 2017, the US Department of Transportation has cataloged user-generated alerts across the country. The breadth and geographic extent of these alerts can be used to assess the likelihood of crashes occurring under different scenarios. Similarly, police reported crashes provide an official source of accident times and locations across a state. Combined with This research examined distributions of times and locations of Waze and California Highway Patrol accident reports to assess changes in time periods before and after earthquakes.

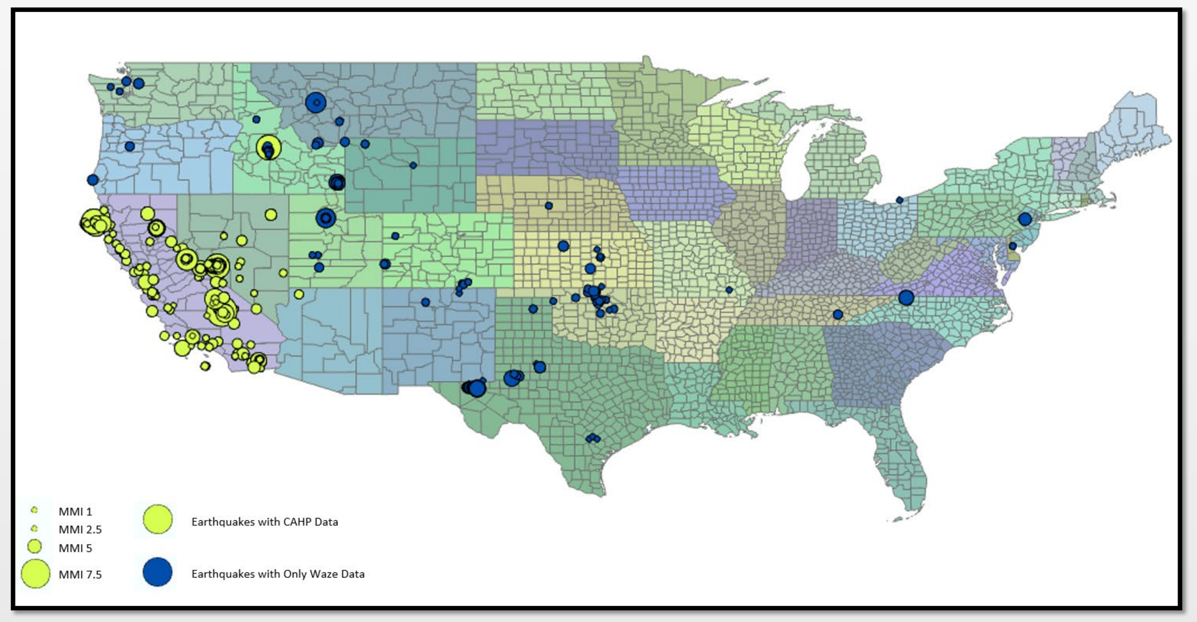
Acknowledgements and Contacts

Thanks to Open Street Map and their roadway data, and the Secure Data Commons team at the USDOT

William Chupp (William.Chupp@dot.gov)
Jeff McGuire (jmcguire@usgs.gov)
Sara McBride (skmcbride@usgs.gov)

Methodology

This study included earthquakes with magnitudes 4.0 and above in the contiguous United States that occurred since the beginning of 2017. This included 412 earthquakes, most of which occurred in California, but there is generally a good distribution across the country.

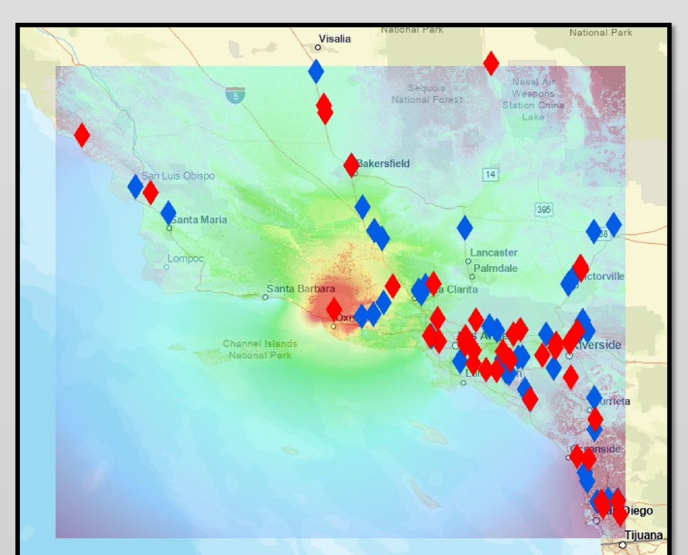


Data Sources:

1. Earthquake shaking data for the full set of earthquakes from USGS's ShakeMap product [Wald et al., 2022]
2. Waze Alert data from 2017 through April 2024
3. California Highway Patrol (CAHP Accident Report data from 2017 through 2023
4. Roadway geometries for earthquake affected regions from Open Street Maps (OSM)

Data Processing:

MMI values at each Waze accident and CAHP were obtained from the MMI raster files from the USGS ShakeMap product at each Waze Alert and CAHP report geographic location (Example on right). Similarly, roadways from OSM were overlayed with the raster data to determine the average amount of shaking that occurred on roadways in the earthquake area.



The resulting dataset contains alerts and accident reports with associated MMI Values for each earthquake, as well as the road networks with associated MMI values. Alerts and accident reports were split into time spans after the earthquake for comparison to similar time bins on the same day of the week for the 1 year prior to the earthquake. The time bins were, 1, 2, and 12 hours after the earthquake, as well as 7 days after the earthquake.

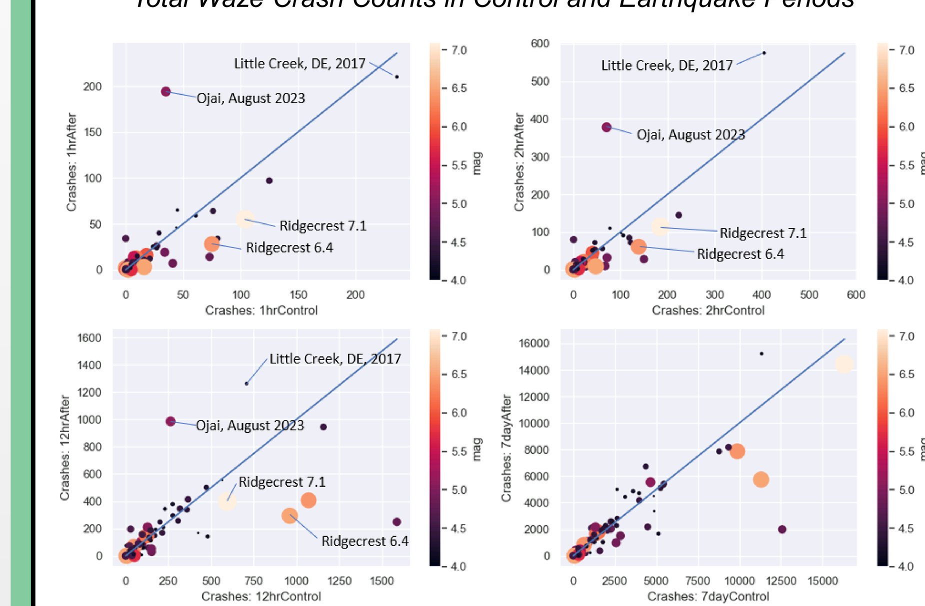
For individual earthquakes, alerts and accident reports were examined 2.5 hours before and 2.5 hours after the earthquake. Trends in MMI distribution across the earthquake timestamp were compared. In specific situations, other datasets were included to understand the sources of any differences in crash frequencies.

Limitations

1. Impossible to verify accident report timestamps and locations.
2. Low numbers of crashes limits statistical power for individual earthquakes.
3. Roadway geometry data assumed static, which may be inaccurate.

Results with Full Dataset

Total Waze Crash Counts in Control and Earthquake Periods



Test Description	Time Bins	p Value
Poisson Means Test of Waze Crash Reports where MMI is less than or equal to 3	1 Hour Bins	0.748
	2 Hour Bins	0.034
	12 Hour Bins	0.788
	7 Day Bins	0.078
Poisson Means Test of CAHP Crash Reports where MMI is less than or equal to 3	1 Hour Bins	0.282
	2 Hour Bins	0.813
	12 Hour Bins	0.215
	7 Day Bins	0.112

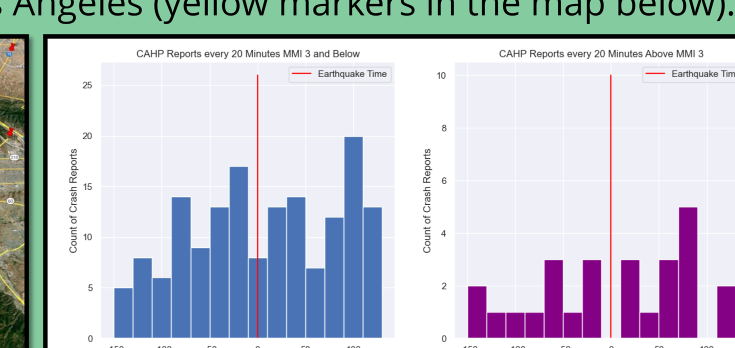
Crash Frequency per Roadway Mile in Range of MMI Bins

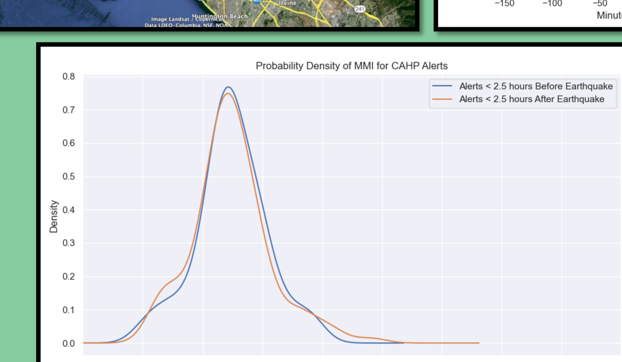
1. No clear pattern or trend between the overall earthquake magnitude and the number of alerts in control or earthquake periods.
2. For MMI values below 3, the trends in frequency of alerts per roadway mile align closely between control and earthquake periods.
4. Poisson Means test examining the rates of Waze and CAHP crashes below MMI 3 showed only marginally significant differences in the 2-hour bin for Waze crashes in control and earthquake-affected periods. This test is commonly used in traffic safety analyses.
5. Poisson tests did not examine the impacts of earthquake alerts or other factors, only alert frequencies in different MMI and time bins.
6. There are isolated cases for some individual earthquakes that may show more affect from either the earthquake or warnings broadcast to wide areas around the epicenter. (See Below)

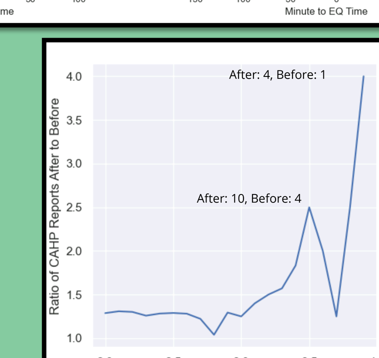
Case Studies for Individual Earthquakes

Ojai Earthquake, August 20, 2023, 2:41 PM

A large hurricane affected the southern California region on the same day as this earthquake. ShakeAlert warnings were broadcast over a large region including much of the Los Angeles Area. There is a possible difference in crash reports before and after the earthquake with a small increase in CAHP Crash reports in the ~2 hours after the earthquake. Ratios (after to before) show an increase in the region of MMI 3 and larger shaking resulting from a slight increase in crashes in the western portion of Los Angeles (yellow markers in the map below).





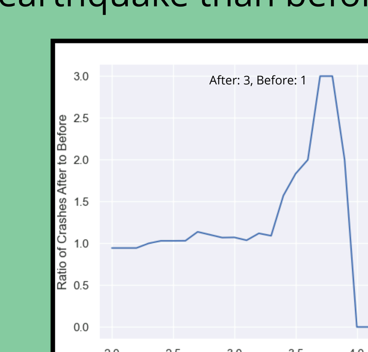


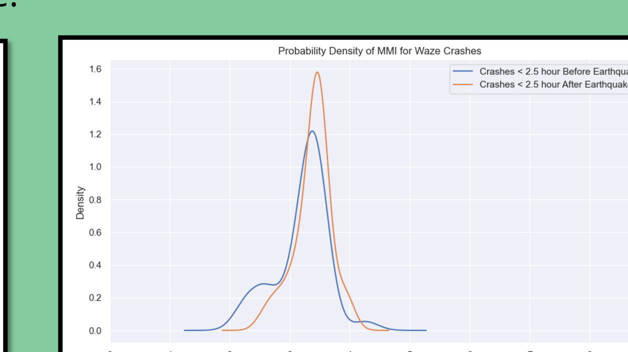
Kolmogorov–Smirnov test used to test differences in MMI distribution of CAHP crashes before and after earthquake gave p value of 0.81.

Key Insight: CAHP crashes are clustered more after the earthquake in areas that received wide area emergency alerts. It is difficult to separate out the effects of the earthquake from the alerting systems.

New Jersey/New York, April 15, 2024

Large metropolitan areas, including New York, Philadelphia, Newark, and some areas of central New England felt this earthquake. This area is not part of the ShakeAlert EEW system. In this case, most roadways affected were close to the epicenter. The ratio of crash reports before and after the earthquake increase above about MMI 3. Reaching a maximum of about two to three times more Waze crash reports in the area of MMI 3.5 - 4.0 shaking after the earthquake than before.





Kolmogorov–Smirnov test used to test differences in MMI distribution before and after earthquake gave p value of 0.022.

Time of Day may have a large impact on these results; 2 hours after the earthquake was peak rush hour period in New York City.