StEER STRUCTURAL EXTREME EVENTS RECONNAISSANCE	**EVENT BRIEFING**	
	Event:	18 March, 2020 Utah, Mw 5.7 Earthquake
	Region:	USA

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Key Lessons

- ❏ This Mw 5.7 earthquake did not cause any injuries or casualties; however, it resulted in damage to buildings and other infrastructure. The mainshock was followed by more than 100 aftershocks.
- ❏ Had the earthquake occurred at a different time of the day, fallen masonry from damaged buildings could have led to severe injuries.
- ❏ There was damage to several historical structures, reiterating the unique challenges of improving seismic response of these types of buildings, while maintaining their cultural value.
- ❏ The most significant damage was experienced by mobile/manufactured homes in the form of foundation sliding and nonstructural component damage.
- ❏ Transportation, electricity, water, and other infrastructure systems were restored in less than a day, suggesting good community resilience to this event.
- ❏ The earthquake caused a Hydrochloric acid leakage of 8,200 gallons at a refinery, forcing it to stop all operations and evacuate personnel. The leakage was later contained.
- ❏ The ongoing COVID-19 pandemic made this a multi-hazard situation and placed additional anxiety and challenges on the residents. On a positive note, some of the COVID-19 preparations helped brace the community for the consequences of an earthquake.

Introduction

On March 18, 2020, at approximately 7:09 am local time, a magnitude 5.7 earthquake, with a depth of 11.7 km, struck 6 km NNE of Magna, Utah (just west of Salt Lake City), USA, as shown in Figure 1 (USGS, 2020a). The epicenter of the earthquake had coordinates of 40.751°N, 112.078°W. The earthquake was followed by more than 100 aftershocks with magnitudes larger than 3.0 (KUTV, 2020). Although not very significant, the earthquake resulted in some damage to buildings and infrastructural systems. Objectives of this earthquake briefing are: 1) to provide details of the 18 March Mw 5.7 Utah Earthquake, 2) to describe damage to buildings and transportation and industrial infrastructure, as well as disruption to the community in terms downtime, and economic losses, and 3) to list key lessons learned.

Figure 1. Epicenter of the Mw 5.7 Utah earthquake (USGS, 2020a)

Hazard Description

This earthquake occurred as a result of normal faulting, i.e., produced by vertical movement as the earth's crust lengthens, near the complex Wasatch fault system in the shallow crust of the North American plate illustrated in Figure 2 (USGS, 2020a). The USGS focal mechanism solution showed that the slip occurred on a moderately dipping fault, striking either to the northwest or to the south-southeast. The earthquake is located in the Intermountain seismic belt, a prominent north-south-trending zone of recorded seismicity in the Intermountain West, including the Wasatch Front urban corridor.

There have been infrequent, moderate-to-large earthquakes in the past originating from the Wasatch Front. There are 26 documented Mw 5+ earthquakes within 250 km of this earthquake in the combined earthquake catalog of the University of Utah Seismograph Stations and USGS, some of them dating back to the late 19th century. The largest recorded earthquake was a Mw 6.6 that took place in March 1934 in the Hansel Valley of the north shore of the Great Salt Lake. In September 1962, a Mw 5.0 earthquake occurred in a very similar location to this earthquake, with strong shaking observed locally. Geologic investigations of the Wasatch fault indicate that the return period of large (Mw ~7) earthquakes near Salt Lake City is 1300 years, with the most recent large earthquake about 1400 years ago.

USGS ShakeMap (Fig. 3) indicates that the Peak Ground Acceleration (PGA) was as high as 0.4g, while the maximum estimated intensity was VIII (USGS, 2020a). This estimate does not seem realistic when compared to the measured accelerations with a peak of 0.044g (Fig. 4), measured at the ground story level of an instrumented 7 story reinforced concrete building (Malhotra, 2020). Although 0.4g is a high estimate for a Mw 5.7 earthquake, one other possible explanation of this discrepancy could be that the location of the building (marked with a red circle in Figure 3) might be in the opposite direction of fault rupture propagation, leading to a reduction in the ground shaking amplitude.

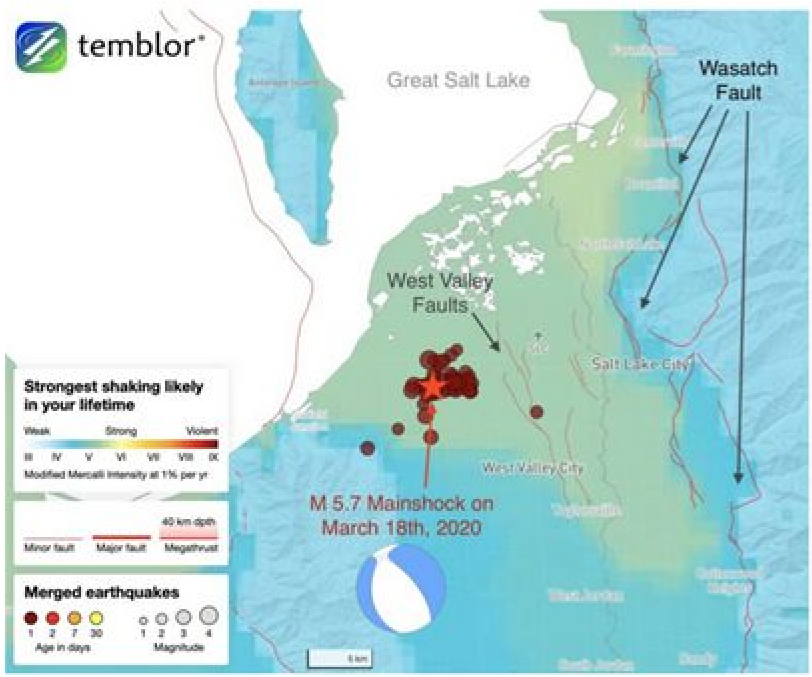
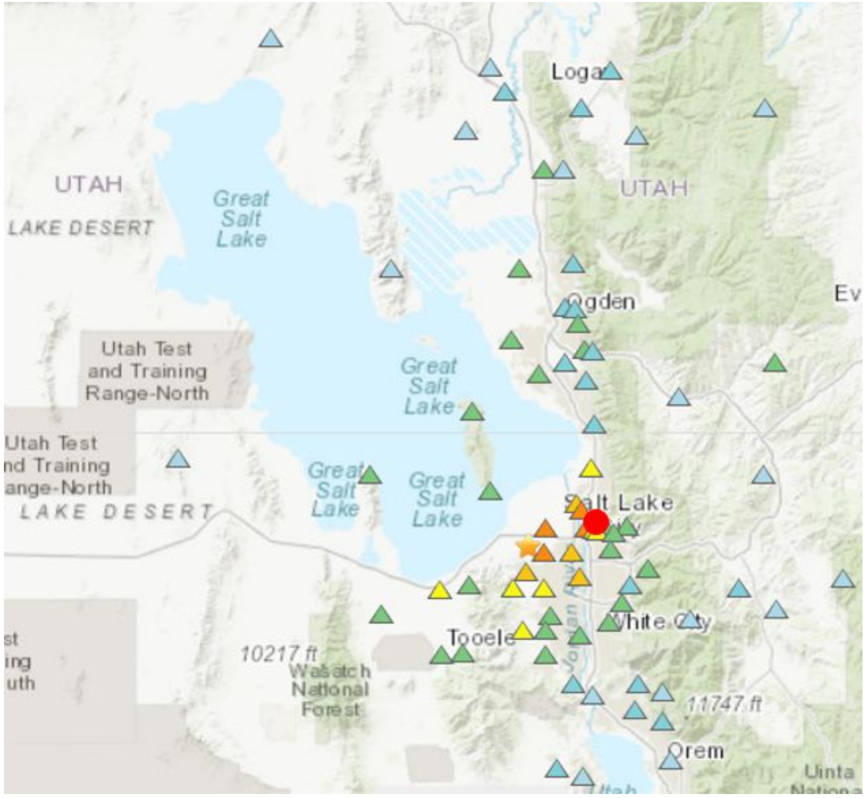


Figure 2. Faults around the epicenter of the Mw 5.7 Utah earthquake (Hobbs, 2020)



PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Figure 3. PGA and intensity estimate from ShakeMap (USGS, 2020a)

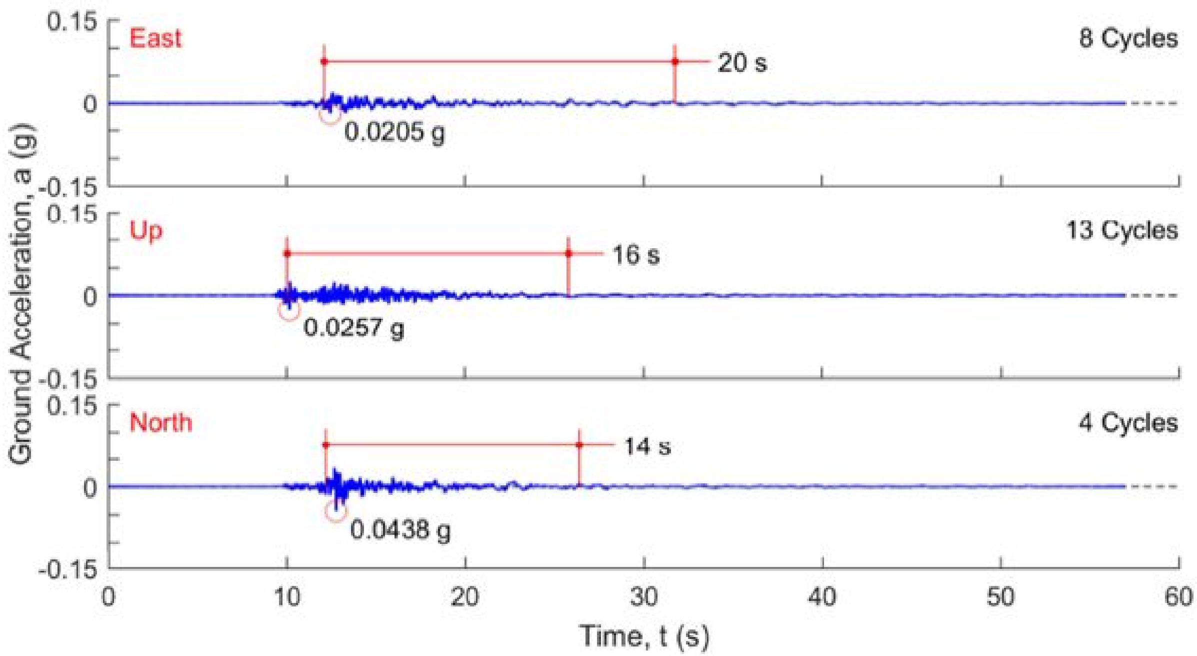


Figure 4. Accelerations measured at the ground story of a 7-story reinforced concrete building (Malhotra, 2020)

Damage to Structures

Although not very significant, the earthquake resulted in some damage to buildings and infrastructural systems. This observed damage is described in the following subsections.

Buildings

Buildings, including historical structures, experienced damage during the earthquake. A commonly observed damage is the out-of-plane failure of the brick veneer walls of wood frame buildings (Fig. 5). A new school building in Herriman, Silver Crest Elementary, experienced similar damage to its front façade, where pieces of masonry fell to the ground (Fig. 6). Such masonry wall and façade failures present a high risk of injury or death due to falling rubble. Furthermore, debris can significantly increase the evacuation time in densely populated areas (Lu et al., 2019). If the earthquake occurred at a different time of day and the schools were not closed due to COVID-19 concerns, fallen masonry in this earthquake could have injured or killed people.

Figure 5. Brick veneer wall damage in Magna (The Salt Lake Tribune, 2020)

Figure 6. Front façade damage experienced in Silver Crest Elementary resulting in masonry debris striking the ground in front of the main entrance (Valley Journals, 2020; Deseret News, 2020)

The University of Utah's Browning Building was closed due to cracks and nonstructural damage, including damage to suspended ceilings. The historic Rio Grande Depot, a brick building constructed in 1910 and housing historical artifacts, sustained minor damage. At the time of the earthquake, the iconic Salt Lake Temple of The Church of Jesus Christ of Latter-day Saints was in the early phases of a four-year upgrade, including a seismic retrofit. The golden Angel Moroni statue of the church was damaged and lost a trumpet (Fig. 7), and some of the temple's smaller spire stones shifted. In West Valley City, 48 mobile/manufactured homes were shifted off their foundations and experienced significant nonstructural utilities and contents damage (Fig. 8).

Figure 7. The statue of Moroni at the top of the Salt Lake temple damaged during the earthquake (The Salt Lake Tribune, 2020)

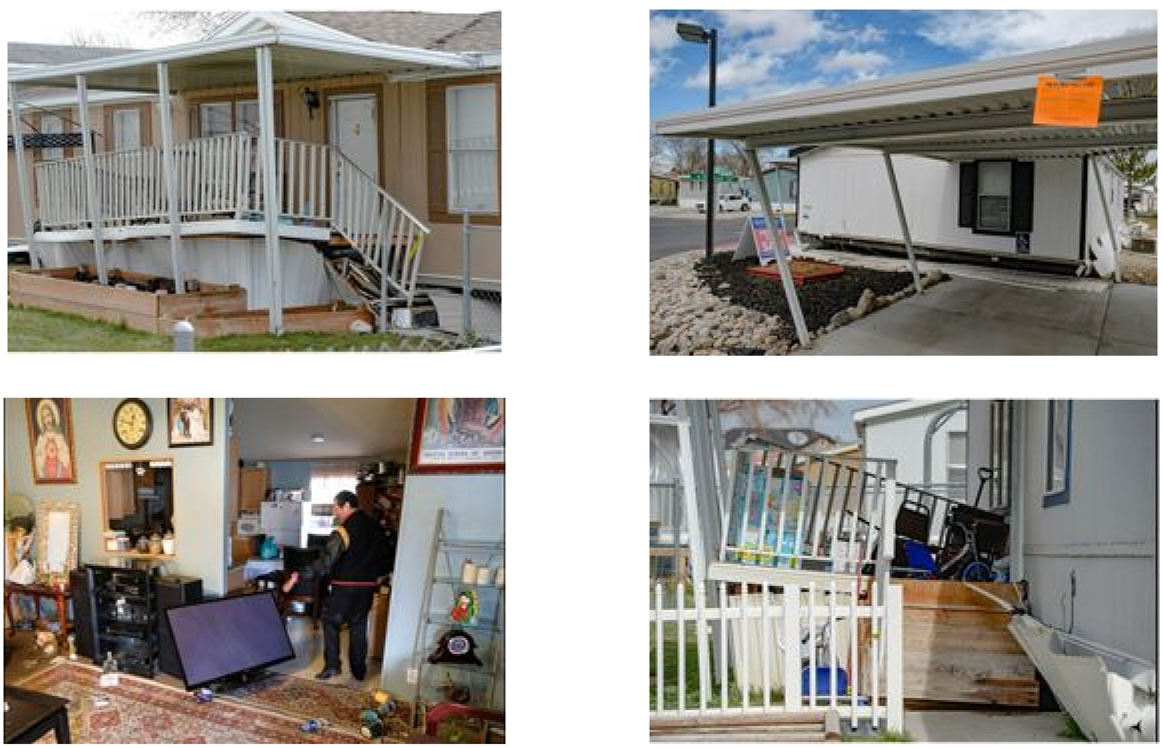


Figure 8. Structural and nonstructural damage experienced by mobile/manufactured homes in West Valley City (The Salt Lake Tribune, 2020)

Transportation Infrastructure

Salt Lake City International Airport, close to the epicenter, was shut down after the earthquake and passengers were evacuated. It reopened almost six hours later after a water line in one of the concourses was fixed. There has not been any major bridge damage, but because of possible structural damage, the Utah Department of Transportation has closed the ramp to the westbound lanes of Interstate 215 at Union Park Boulevard. Front Runner trains did not operate between Murray and Salt Lake City for two hours. All other trains traveled at restricted speeds during the day, lengthening commutes. TRAX train service did not resume until Wednesday (March 18th, 2020) evening. Slow-down and stopping of trains is common around the world after earthquakes. In several countries, including the US, China, Taiwan, Japan, and Turkey, this is performed by automated processes using Earthquake Early Warning (EEW) systems. In some other countries, like Canada, it is pursued as part of protective measures after earthquakes (The Salt Lake Tribune, 2020).

Industrial Systems

The earthquake also caused a Hydrochloric acid leakage of 8,200 gallons at Rio Tinto Kennecott's refinery, forcing it to stop all operations and evacuate personnel. According to the Salt Lake County emergency officials, a chemical plume was released at the refinery and moved toward the Great Salt Lake. The leakage was later contained (ABC4, 2020).

Resilience Aspects and Effects on Community

USGS PAGER tool estimated the fatalities to be "none", "between 1 and 10", and "between 10 and 100" with probabilities of 65%, 30%, and 4%, respectively (Fig. 9). There were no reports of casualties or injuries due to this earthquake. Economic loss was expected to be "less than $1 million", "between $1 million and $10 million", "between $10 million and $100 million", "between $100 million and $1,000 million", and "between $1,000 million and $10,000 million" with probabilities of 4%, 15%, 33%, 32%, and 14%, respectively.

There were power outages in several cities, lasting up to half a day. As previously mentioned, trains, the airport and a bridge were all suspended from service for a period of time. Other than these limited cases, there were no major interruptions in electricity, water, gas, and telecommunication services, indicative of good performance from the perspective of community resilience. The ongoing COVID-19 pandemic introduced additional challenges due to *social distancing* and further anxiety experienced by the residents. On a positive note, Salt Lake Mayor Erin Mendenhall indicated that being prepared for a pandemic meant being prepared for an earthquake in several aspects such as shelter-in-place along with pantries stocked with a couple of weeks' worth of nonperishable foods and well-supplied first aid kits (Hobbs, 2020).

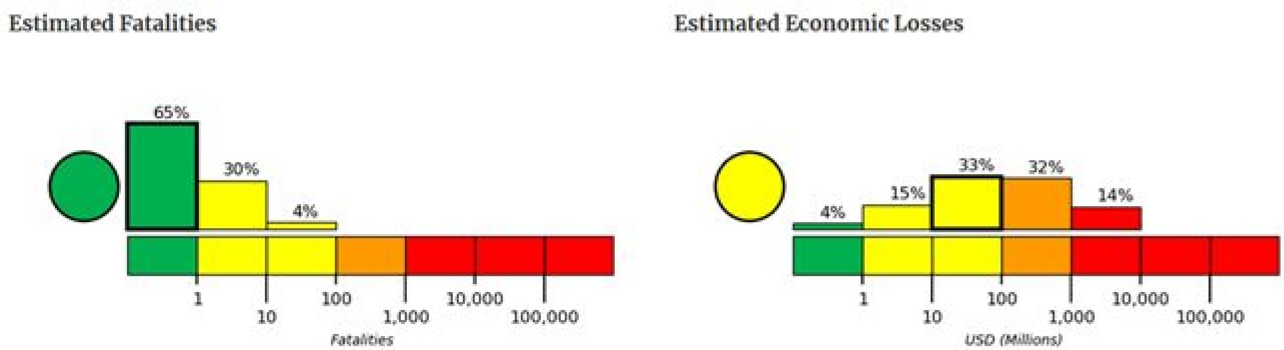


Figure 9. USGS PAGER loss estimates (USGS, 2020a)

Automated Data Collection from News and Social Media Websites

StEER has previously used Natural Language Processing (NLP) to initiate reconnaissance reports in a rapid manner (Tsai et al., 2019). To increase the automated nature of this process and expand the usage of this technique to extract other information related to the consequences of earthquakes and other hazards, an automated data collection process has been developed (Fig. 10). The automatic data collection script used in this process is written in Python and utilizes U.S. Geological Survey Earthquake Hazard Program API (Application Programming Interface) (USGS, 2020b). The program is scheduled to run every day on the server of the PEER (Pacific Earthquake Engineering Research) Center and to query new earthquakes from the USGS API. Only earthquakes that have magnitudes greater than or equal to 5 and USGS PAGER alert levels in either yellow, orange, or red are recorded. When such a new earthquake is detected, the program starts collecting related social media data from Twitter and related news articles from News API (2020). Tweets are collected over a period of two weeks or more using the keyword "earthquake" and the earthquake location name (Utah in this event). Tweets are also collected in local language (English in this case) to capture local changes more precisely. News articles related to the earthquake are collected for a duration of a week or less. The news article data is then used in the automatic text summarization and the social media data is used for extracting information related to the consequences of an earthquake, such as the recovery time.

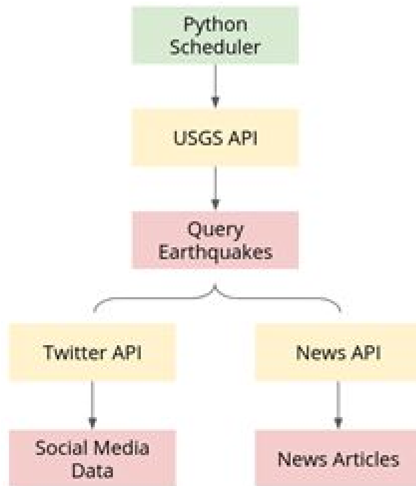


Figure 10. Automatic data collection workflow

In the context of extreme events, recovery time, conceptually illustrated in Figure 11, is the time needed after the extreme event to restore the functionality of a structure, an infrastructure system (e.g. water supply, power grid, or transportation network), or a community to a desired level wherein it can operate or function the same, close to, or better than the condition before the extreme event (Bruneau et al., 2003).

The determination of the recovery time using information from social media (particularly original tweets , i.e. no retweets, cloned, or bot messages) is based on the assumption that certain keywords (e.g. school, office, transportation, or power outage) related to recovery, appear more frequently on the shared posts, tweets, etc., right after an earthquake occurs and the frequency of these words reduce as time passes. Using this assumption, the time between the occurrence of the earthquake and when these frequencies reduce to pre-earthquake levels is used as a measure of recovery time. Here, this exercise was conducted for four words in Figure 12, namely, “earthquake,” “electricity,” “building,” and “damage.” It is observed that the frequency of these four words reduces to normal levels (especially clear in the plot for the word “earthquake”) within 24 hours consistent with the identified one-day recovery time from other sources of information. The word electricity reduces to normal levels in 14 hours consistent with the timeline over which power was restored. The second peaks in some plots are thought to correspond to the occurrence of aftershocks.

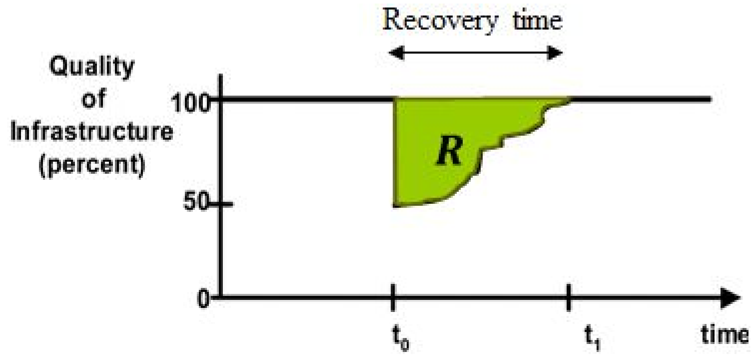


Figure 11. Conceptual illustration of recovery time (Bruneau et al., 2003)

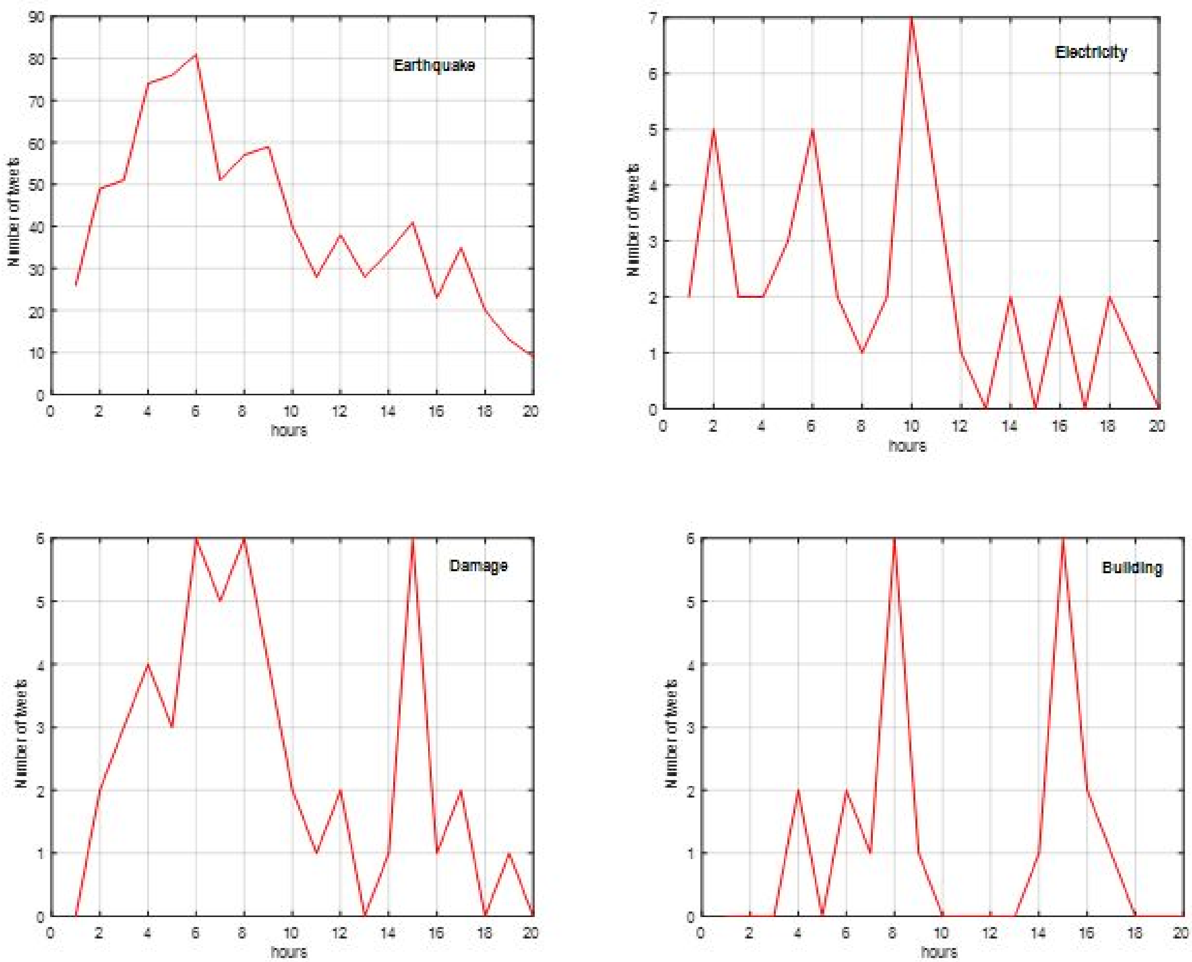


Figure 12. Variation of tweets with different keywords over time: (from upper left clockwise) earthquake, electricity, damage, building

StEER Response Strategy

StEER's present response to this earthquake consists of this Event Briefing, compiling information from various websites, news channels and USGS. The briefing does not include detailed field investigations. This earthquake event would traditionally warrant a Preliminary Virtual Reconnaissance Report (PVRR) but is documented herein by an Event Briefing consistent with "StEER Response to COVID-19" (released on March 20, 2020, https://www.steer.network/copy-of-response-alert).

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