Documenting the Impact of Lifeline Service Disruptions on Healthcare System Performance Following Earthquakes Since 2000:

A Reconnaissance Report Analysis

Katherine Pedersen

A thesis

submitted in partial fulfillment of the

requirement of the degree of

Master of Urban Planning

Master of Public Health

University of Washington

2020

Committee:

Nicole Errett

Himanshu Grover

Youngjun Choe

Program's Authorized to Offer Degree:

Department of Urban Design and Planning

Department of Health Services

University of Washington

Abstract

Documenting the Impact of Lifeline Service Disruptions on Healthcare System Performance Following Earthquakes Since 2000:

A Reconnaissance Report Analysis

Katherine Pedersen

Chair of the Supervisory Committee:

Nicole Errett

Department of Environmental and Occupational Health Sciences

&

Himanshu Grover

Department of Urban Design and Planning

Earthquakes impact millions of people worldwide, leading to an increased need for an effective and efficient healthcare response. Due to their heavy reliance on external lifeline services, hospitals are particularly vulnerable to decreased functionality post-earthquake when they are needed most. This research assesses if and how reconnaissance reporting has covered the impacts lifeline service disruptions have had on healthcare system performance for earthquakes magnitude 6.0 and greater since 2000. Utilizing content analysis methods, 104 publicly available post-earthquake reconnaissance reports covering 50 earthquake events were assessed for information on lifeline service impacts, overall functionality, and evacuations of area hospitals and healthcare systems. This research found that lifeline service disruptions can impact hospital and healthcare system functionality, and hospital and healthcare system evacuations occurred the majority of the time for included earthquake events. This research highlights the lack of consistent and high quality reporting of lifeline service disruptions to hospital and healthcare system performance post-earthquake. Due to this lack of reported information, a number of recommendations on critical research gaps around data quality and standardization to better prepare for healthcare impacts following future earthquake events are proposed.

Table of Contents

List of Figures and Tables

Introduction

Post-disaster healthcare system functionality is an essential component of community resilience. Hurricane Katrina, a category five storm, made landfall in the Gulf of Mexico in August 2005. This seminal event highlighted the lack of preparedness within the US healthcare system. Katrina is estimated to have killed 1,300 people and displaced over one million people to surrounding states (Rodríguez & Aguirre, 2006). The New Orleans healthcare system was not inexperienced with hurricanes, and many healthcare workers expressed confidence in their ability to weather this storm like they had many others in the past (Fink, 2013). However, this event was not like previous events (Fink, 2013). A lack of planning at the corporate (healthcare system), state, and federal levels left hospital administrators stranded with high acuity patients and insufficient information on when help would arrive (Fink, 2013). This ultimately resulted in the death of numerous people allegedly assisted by medical staff, due to the horrendous conditions within the hospital, or by natural causes (Fink, 2013). In the years following Hurricane Katrina - an event with advance notice - the US healthcare system has still been observed to be unprepared to respond to the medical needs of thousands of people, both immediately after an event and in the months that follow, as seen in the aftermaths of Hurricane Maria, Hurricane Irma, Hurricane Harvey, among others (Parmar et al., 2013; Shultz & Galea, 2017).

Earthquakes are estimated to have been the cause of 1.87 million deaths globally in the 20th century (Doocy et al., 2013). Depending on local codes, standards, and regulations, earthquakes can result in a high number of casualties which increases the burden on local and regional emergency and medical services. While healthcare services may be needed most in the aftermath of a disaster, hospitals are vulnerable to disruptions to functionality (Al-Shaqsi et al., 2013, p.; Santarsiero et al., 2018; Schultz et al., 2003; World Health Organization, 2006).

Of particular concern, damage to primary and redundant lifeline delivery systems can lead to a complete shutdown of hospital services (Achour et al., 2011, 2014; Kirsch et al., 2010; Mitrani-Reiser et al., 2012; Myrtle et al., 2005; Nagata et al., 2017; Yavari et al., 2010). For example, during the Kumamoto earthquakes, loss of both power and water forced several hospitals to evacuate over 1,000 patients overnight (Nagata et al., 2017). As such, hospital vulnerability is increased by its heavy reliance on external utilities (Achour et al., 2014). The loss of one of these services, such as power, water, or communications, can have a large impact on hospital functionality following an earthquake event (Dueñas-Osorio & Kwasinski, 2012; Myrtle et al., 2005; Yavari et al., 2010). Alternative sources are commonly used by hospitals as a backup when faced with a utility disruption (Achour et al., 2014; Mitrani-Reiser et al., 2012). However, these have been shown to fail due to damage sustained during the event, thus rendering them inoperable when they are needed the most (Achour et al., 2014; Al-Shaqsi et al., 2013). During the 2011 magnitude 6.3 Christchurch Earthquake, the backup generator system at Christchurch Hospital was damaged as a result of the shaking and was reported as unreliable in the immediate aftermath of the earthquake (Ardagh et al., 2012).

Hospitals' heavy reliance on lifeline services to maintain full functionality is further complicated due to the interdependent nature of modern lifeline services (Kuwata & Takada, 2007). As one system fails (e.g., power) the effects cascade down throughout the network causing catastrophic failures throughout the hospital system (Rinaldi et al., 2001). This can result in the complete loss of functionality of a hospital with minimal structural damage (Kuwata & Takada, 2007).

This research will describe how the impacts of lifeline service disruptions on healthcare system operations have been reported in reconnaissance reports following major earthquakes since 2000. Using documents developed for reporting reconnaissance work conducted following major global earthquakes (magnitude >6.0), this research aims to describe the types of information about healthcare and hospital system disruption included in reconnaissance reporting following major earthquakes. This research will address the following research questions:

1. Are lifeline service, evacuation, and operation impacts to hospitals described in healthcare-related reconnaissance reporting following major earthquakes?
2. Are lifeline service disruptions reported to impact hospital operations in the immediate aftermath of major earthquakes?

To begin to unpack this complex relationship between hospital functionality and lifeline service disruptions, this research will review the existing literature on how earthquakes impact hospitals and healthcare systems, the vulnerability of lifeline system interdependencies, outline existing frameworks for measuring hospital functionality, and end with a discussion on current reconnaissance efforts in earthquake research and response. It will outline a mixed methods approach to documenting the coverage of lifeline service impacts to hospital and healthcare system functionality in reconnaissance reports since January 1, 2000 and report the findings. It will end with a discussion on the significant lack of information on this topic included in post-earthquake reconnaissance reporting and propose recommendations on how to better cover past earthquake events in order to be better prepared in the future.

Literature Review

Hospitals in Earthquakes

Many hospitals in the US are not prepared to manage a large scale surge of patients following a disaster, as several are already at or beyond capacity on any given day. (Parmar et al., 2013). Quick and efficient rescue and emergency care are important to prevent increased mortality following an earthquake (Doocy et al., 2013). However, this is only an option when hospitals are prepared and able to remain open in the immediate aftermath of the event. In most seismic regions, building codes have increased the structural protections for critical facilities, including hospitals (Mitrani-Reiser et al., 2012). California has the most robust seismic building code requirements in the United States (Mitrani-Reiser et al., 2012; Myrtle et al., 2005; Yavari et al., 2010). However, vulnerabilities remain. For example, damage experienced during the 2019 6.3 foreshock in Ridgecrest, California contributed to the decision to evacuate all patients to surrounding hospitals, even though the building met local seismic standards ("Ridgecrest Hospital's Quake Damage Prompts Questions About State Seismic Standards," 2019).

Hospital and healthcare performance has been widely researched in order to better prepare for future events(Achour et al., 2011, 2014; Al-Shaqsi et al., 2013; Ardagh et al., 2012; Favier et al., 2017; Kirsch et al., 2010; Mitrani-Reiser et al., 2012; Nagata et al., 2017; Santarsiero et al., 2018; Vasquez et al., 2017). This research has focused on response following an individual event, description of service delivery failures, assessment of system vulnerabilities, and recommendation of steps for improvement. One common focus of these studies is the impact of non-structural damage, including lifeline service disruptions, on healthcare system functionality.

Community lifelines are defined by the Federal Emergency Management Agency (FEMA) as "A lifeline that enables the continuous operation of critical government and business functions and [are] essential to human health and safety or economic security." (Federal Emergency Management Agency, 2020). This includes services such as, water, energy (i.e., gas and power), communications, health and medical, among other services (Federal Emergency Management Agency, 2020).

The disruption of lifelines to healthcare delivery systems (i.e., healthcare system), defined as "the organization of people, institutions, and resources to deliver health care services to meet the health needs of a target population, whether a single-provider practice or a large health care system" (Piña et al., 2015), has been found in many studies as detrimental to hospital functionality following numerous earthquake events. Following the 2011 magnitude 6.3 Christchurch, New Zealand earthquake, Christchurch Hospital immediately lost municipal power. However, due to damage caused by the shaking, their backup generators were unable to provide consistent power for several hours, leaving many critical services, such as the intensive care unit (ICU) and emergency department (ED) without electricity (Ardagh et al., 2012). Following the 2010 magnitude 8.8 Maule, Chile earthquake, all surveyed governmental hospitals in the Bio-Bio province lost communications, municipal power, and water for several days (Kirsch et al., 2010; Mitrani-Reiser et al., 2012). And, following the 2015 magnitude 8.3 Illapel, Chile earthquake, a number of hospitals lost municipal power, many indicated they experienced issues with communication networks, and one hospital reported water loss (Favier et al., 2017).

Achour et al. (2014) identified the three major challenges faced by healthcare systems regarding their heavy reliance on lifeline services as: 1) the "vulnerability of infrastructure to natural hazards 2) the "low performance of alternative sources"; and 3) a "lack of consideration of healthcare utility supplies in resilience codes and legislations" (p. 5). The authors go on to discuss how the healthcare system's risk of lifeline service disruptions is compounded by critical lifeline infrastructure's (e.g., power substations, water treatment plants, and cellular towers) risk from natural hazards (Achour et al., 2014). Backup systems for critical lifeline services are recommended by the World Health Organization (WHO) and the Pan American Health Organization for all hospitals (Pan-American Health Organization, 2000). However, depending on the magnitude of the ground acceleration during an earthquake and any subsequent aftershocks, there can be extensive damage that renders any redundant systems unusable (Achour et al., 2014; Al-Shaqsi et al., 2013; Ardagh et al., 2012). Conversely, other researchers have shown the success of redundant systems in maintaining functionality in prior earthquakes (Favier et al., 2017; Mitrani-Reiser et al., 2012; Vasquez et al., 2017). Achour et al. (2014) also highlighted the lack of integration of critical lifeline infrastructure and the healthcare system in planning efforts, codes, and legislation, as the majority of the emphasis has been placed on structural factors. They report that only the state of California and the UK have outlined general suggestions and recommendations to improve lifeline service/utility resilience (Achour et al., 2014). These findings highlight the need to focus research efforts on non-structural impacts to healthcare system functionality, and more specifically, lifeline service disruptions.

Lifeline service disruptions have the potential for widespread impacts to healthcare service availability. Following prior disasters, such disruptions have motivated the evacuation of hospitals. For example, following the Northridge California earthquake, five of the six hospitals that fully evacuated decided to do so because non-structural damage, such as water damage and loss of electrical power, made adequate patient care impossible (Schultz et al., 2003). Additionally, McGinty et al. (2017) found utility disruptions were the most common determinants of evacuation following Hurricane Sandy (McGinty et al., 2017). Furthermore, Bagaria et al. (2009) found that non-structural damage, including lifeline service disruptions, resulted in the evacuation of at least 26 hospitals (Bagaria et al., 2009).

Critical Infrastructure Interdependencies

As highlighted by Achour et al. (2014), the healthcare system is highly dependent on a complex system of lifeline services, many of which are highly interdependent on one other. Interdependencies were introduced as an inherent risk to lifeline services and infrastructures in the 1997 report to the President of the United States by the U.S. President's Commission on Critical Infrastructure Protection (PCCIP) (Rinaldi et al., 2001). The PCCIP defined infrastructure as "a network of independent, mostly privately-owned, man-made systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services" (Staff et al., 1997, p. 3). They highlighted eight critical infrastructure systems which, if damaged, could have debilitating impacts to the US: telecommunications, electric power systems, natural gas and oil, banking and finance, transportation, water supply systems, government services, and emergency services (Staff et al., 1997). Currently, the US Department of Homeland Security has outlined 16 critical infrastructure systems which are "vital to the United States and their incapacitation or destruction would have debilitating effects on security, national economic security, national public health or safety, or any combination thereof" (*Critical Infrastructure Sectors*, 2020). Sectors included in this classification are: communications, emergency services, energy, healthcare and public health, information technology, water, and wastewater systems, among others (*Critical Infrastructure Sectors*, 2020).

Interdependencies between critical systems are not always known or easily identified. Interdependence can be in the form of an infrastructure system being dependent upon another system (i.e., unidirectional), or two systems can be interdependent of each other (i.e., bidirectional) (Rinaldi et al., 2001). Rinaldi et al. (2001) established a set of six "dimensions" which they recommend when determining interdependencies that exist within various infrastructure systems: type of failure, infrastructure characteristics, state of operation, types of interdependencies, environment, and coupling and response behavior. This framework has been widely used in the research of infrastructure interdependencies (Kakderi et al., 2011; Kjølle et al., 2012; Utne et al., 2011), including a few studies on lifeline service disruptions and recovery times following an earthquake (Cimellaro et al., 2014; Dueñas-Osorio & Kwasinski, 2012).

The more complex the interdependency, the harder it is to fully comprehend and understand the vulnerabilities that exist within the system (Kakderi et al., 2011; Rinaldi et al., 2001). One shock, such as an earthquake, can either result in a common cause failure or a cascading failure on a variety of infrastructure systems (Kakderi et al., 2011). A cascading failure is when a disruption in one infrastructure results in the failure and subsequent disruption of another infrastructure system (Rinaldi et al., 2001). A common cause failure is where one event (or cause) leads to the failure of multiple infrastructures at once (Rinaldi et al., 2001). These failures can reach beyond the initially impacted geographical region due to the national and international interconnectedness of these systems (Cimellaro et al., 2014; Dueñas-Osorio & Kwasinski, 2012; Rinaldi et al., 2001). Hospitals rely on a variety of other systems to function (Achour et al., 2011, 2014), which creates an interdependent relationship between healthcare and external lifeline services, provided by both public and private entities (Rinaldi et al., 2001).

Types of Interdependencies

Rinaldi et al. (2001) defined four types of interdependencies, physical, cyber, logical, and geographic (Kakderi et al., 2011; Rinaldi et al., 2001). Physical interdependencies are when two or more infrastructures depend on the material output(s) of the other (Rinaldi et al., 2001). For example, in the case of hospital lifeline requirements for service delivery, there are a number of systems within the hospital which are critical for patient care and are reliant on the consistent supply of multiple private lifeline services in order to function (i.e., power, water, or gas). If both the primary and secondary sources fail for one of these services, such as power, the delivery of another service, such as water, to some internal systems will also fail, and vice versa. (figure 1) This is also an example of a cascading failure.

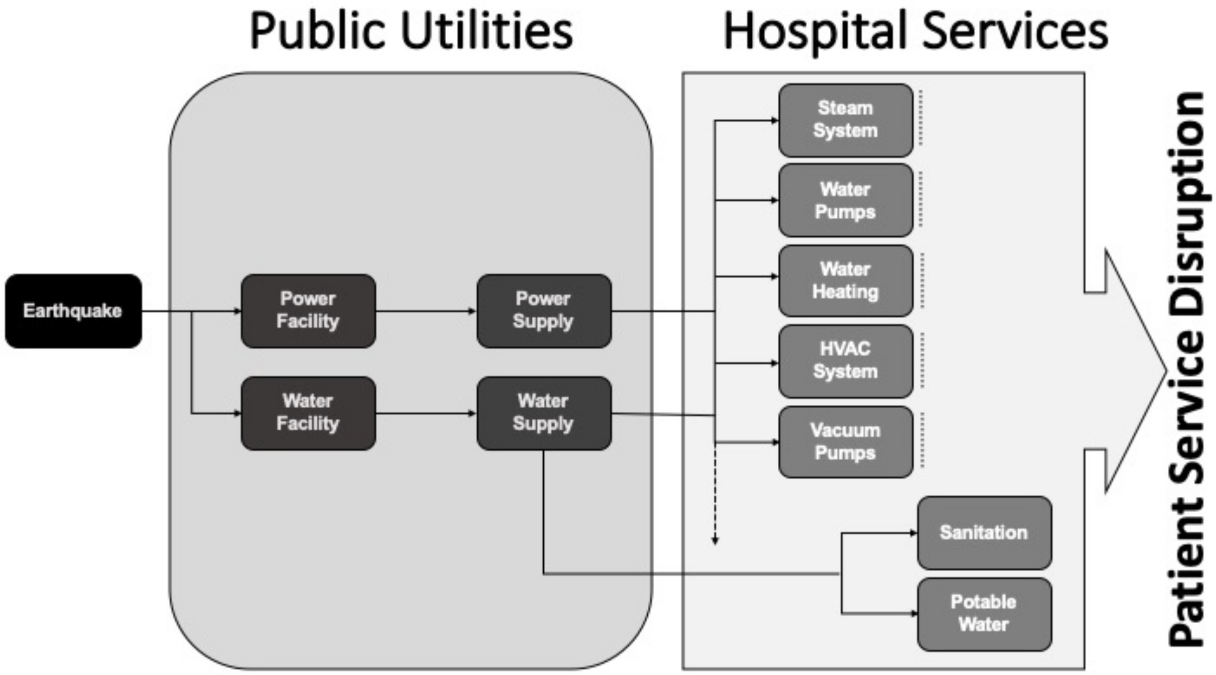

Figure 1: Conceptual Framework of Power and Water Service Interdependencies within a Hospital Environment

Cyber interdependency is when one system is dependent on information that is transmitted through information infrastructures (Rinaldi et al., 2001). This is an evolving type of interdependency due to the rapidly changing dependency on new technologies, automatization, and computing processes. Geographic interdependencies are when systems are interdependent solely based on their geographic location. The vulnerability of this type of interdependency is when a single event, such as an earthquake, impacts a large geographical area and then affects all systems within the area (Rinaldi et al., 2001).

Logical interdependency is when the state of one system is dependent on another by some other mechanism beyond physical, cyber, or geographic (Kakderi et al., 2011; Rinaldi et al., 2001). After the February 2010 magnitude 8.8 Offshore Maule, Chile, Earthquake, Dueñas-Osorio and Kwasinski researched how physical infrastructure restoration after a natural-hazard induced disaster was impacted by interdependencies (Dueñas-Osorio & Kwasinski, 2012). They found minimal physical interdependency between the water and power systems, even with a large lag in water restoration seen in many impacted communities. However, after exploring possible logical interdependencies at the city level, power supply showed coupling with the restoration of water. The coordination of repairs of broken water pipelines was dependent on power and telecommunications, which was not clearly shown by the raw restoration curves developed by their initial analysis. Other regional utilities also showed logical coupling with water systems, highlighting the high dependency water systems had on other utilities (Dueñas-Osorio & Kwasinski, 2012).

Methods for Interdependency Simulation

Kakderi et al. (2011) relies heavily on the concepts developed by Renalidi et al. (2001) in order to compile a comprehensive list of the available methodologies to assess vulnerabilities of interdependent systems, also known as "System of Systems", to seismic events (Kakderi et al., 2011). They outline five models which can be used in these assessments: Physics-based models, nodal analysis models, agent-based models, stocks-and-flows models, and network models (Kakderi et al., 2011). Two will be covered below.

Physics-based models, which explore the interaction among critical infrastructure systems on a more theoretical basis, use fault tree analysis or geographic information systems (GIS) analysis to measure simple models with interdependencies categorized as interaction terms (Kakderi et al., 2011). However, this type of methodology is limited in its ability to assess vulnerability and functionality loss due to its theoretical and over simplified nature (Kakderi et al., 2011). One notable study used a physics-based model to develop a methodology to measure seismic risk to critical infrastructure systems in relation to hospitals (Kuwata & Takada, 2007). The results of this study highlighted the flexibility of physics-based models to measure risk probabilities of lifeline service failure for a number of Japanese hospitals after five different earthquake scenarios. However, this study had numerous limitations, such as the assumption by Kuwata and Takada that back-up utility systems would function properly following each earthquake. This may be an oversimplification of the complex nature of hospital lifeline relationships and the sufficiency of redundancies that exist within the system. Additionally, the findings remained untested and are theoretical in nature (Kuwata & Takada, 2007).

Another available methodology highlighted by Kakderi et al. (2011) are stock-and-flow models, which are based on economic theory and Input-Output models. This methodology assumes that the level of economic dependency is the same as the level of physical dependency, with financial capital as the measured outcome (Kakderi et al., 2011). This type of model is used to simulate potential cascading impacts, rather than as a forecasting model (Kakderi et al., 2011). Utne et al. (2011) used a similar model in order to develop methods to use Risk and Vulnerability Analysis (RVA) to assess existing critical infrastructure interdependencies (Utne et al., 2011). While RVA has been widely used, it has been limited to assessments of individual critical infrastructures. Here, the authors propose an approach to adapt RVA for multiple infrastructures in order to better understand interdependencies and their vulnerability to cascading failures (Utne et al., 2011). Their work highlighted the numerous stakeholders that are invested in critical infrastructure. These stakeholders may have differing priorities, which can impact risk perception and the possibility of successfully reducing risk (Utne et al., 2011). The privatization of many U.S utilities has limited available information on mitigation and preparedness practices, resulting in an incomplete picture of how each system relies on others, locally, nationally, or even internationally. While lifeline service disruptions could lead to catastrophic outcomes for individual hospitals, the potential for impacts on the regional healthcare system may be more profound and requires additional exploration.

Measuring Healthcare System Functionality

There have been many systems proposed to measure or predict healthcare system functionality in the immediate aftermath of a disaster (Jacques et al., 2014; Kuwata & Takada, 2007; Myrtle et al., 2005; Porter & Ramer, 2012; Yavari et al., 2010). Many of these studies built off of the original classification of non-structural hospital systems and components developed by Myrtle et al (2005). With a classification established, researchers began to develop probabilistic and predictive models in order to measure hospital performance and functionality in the immediate aftermath of a large scale earthquake (C. C. Jacques et al., 2014; Yavari et al., 2010). While other researchers have focused on estimating downtime of any type of critical facility (Porter & Ramer, 2012), Mieler and Mitrani-Reiser (2018) have provided a comprehensive summary of the available research on earthquake-induced loss of functionality in buildings and summarized future research needs.

Systems Classification

Myrtle et al. (2005) provided a foundational classification of hospital systems and highlighted how the impact of non-structural damages, such as disruptions to lifeline systems and loss of functionality of specific hospital devices, impacts overall hospital functionality. They conducted a three part study: 1) they developed a list of non-structural, essential services which was reviewed by California Hospital Building Safety Board and compared to an existing hospital for completeness; 2) they analyzed damage reports and survey responses to non-structural systems following the 1994 Northridge earthquake and the 1995 Hanshin-Awaji earthquake which led to the creation of a survey which was sent to hospital administrators to see what hospital systems were impacted and what individuals felt were critically needed systems following an earthquake; 3) they interviewed 200 hospital personnel who had experienced a past earthquake to gain insight into what systems, tools, and treatment components were vital to maintain hospital functionality and provide care following an earthquake (Myrtle et al., 2005).

A number of important findings resulted from each part of this study. During the first part of the analysis, the nonstructural system level impacts/disruptions of both the Northridge and Hanshin-Awaji earthquake was assessed showing a large impact during both earthquakes (Myrtle et al., 2005). Based on the surveys, lifeline service disruptions, both primary and secondary, were found to have had a large impact on hospital functionality immediately following the Kocaeli earthquake, and for the Chi-Chi earthquake for many days and weeks afterwards. Finally, based on the interviews, water and power were mentioned the most as critical systems for hospital functionality, closely followed by telecommunications (Myrtle et al., 2005). These findings classify essential non-structural components within a hospital and give a baseline of which systems should be protected in earthquake mitigation efforts. Additionally, these systems should be prioritized for data gathering in reconnaissance efforts to better understand their impact on hospital and healthcare system functionality.

Probabilistic and Predictive Modeling

Yavari et al. (2010) utilized many of the findings from Myrtle et al. (2005) to create a tool to estimate post-earthquake hospital functionality based on structural, non-structural, lifelines, and personnel factors. Statistical analysis of data on hospital impacts (structural, non-structural, lifelines, and personnel factors) following previous California earthquakes was used to develop a predictive model of hospital functionality. This model was then applied to two possible earthquake scenarios in Los Angeles County. The model made additional adjustments for the impact that loss of external lifeline services would have on hospital performance levels (Yavari et al., 2010).

The results from their simulations showed that even when it was assumed that there was no loss of external lifelines, there was still a large portion of hospitals which would have decreased functionality (Yavari et al., 2010). By removing the assumption about external lifeline disruption, the results showed minimal material changes in functionally except for in a few hospitals which would have a significant decrease in functionality. The authors stressed that one key limitation of this study was large gaps within the data on post-earthquake hospital functionality and lifeline service outages at hospital sites. Furthermore, Yavari et al. (2010) identified the influence external lifelines have on hospital functionality as a significant research need.

The fault-tree analysis (FTA) method was first developed in the 1960's for the United States Air Force as a way to study potential failures within the Minuteman Missile launch control system

(Lee et al., 1985). It is a widely used technique by a variety of disciplines in order to model cascading failures within a system through a series of "AND," "OR," and various other gates resulting in the probability of a final outcome (Lambert, 1975; Lee et al., 1985; Ruijters & Stoelinga, 2015). There are two major steps in FTA: 1) the construction of the fault tree and 2) its evaluation. The evaluation can be quantitative, qualitative, or a combination of both (Lambert, 1975). Jacques et al. (2014) performed both of these steps for their research and then applied the results to their proposed resilience metric.

Jacques et al. (2014) utilized FTA in order to measure the functionality of critical hospital services while accounting for "staff, structure, and stuff" as contributing factors. They found that failures of critical infrastructure systems (i.e., power, water, and communication) had the greatest impact on hospital functionality. This was coupled with other non-structural damage, such as partition walls and cladding. Additionally, they found that overall there was minimal structural damage and thus this did not impact the functionality significantly (Jacques et al., 2014). These findings further emphasize the need for future research on the impact of lifeline service disruptions on healthcare systems globally.

Future Research Needs: Hospital Functionality Following Earthquakes

Mieler and Mitrani-Reiser (2018) compiled a comprehensive overview of the available literature on functionality loss assessment of buildings following earthquakes. They cover a number of studies outlined above within their overview (Achour et al., 2011; Jacques et al., 2014; Mitrani-Reiser et al., 2012; Myrtle et al., 2005; Porter & Ramer, 2012; Rinaldi et al., 2001). However, most importantly, they outline next steps and future research needs in the area of building functionality following earthquakes. They identified three primary needs for future research: 1) collecting better data after earthquakes; 2) refining and validating analytical models for predicting functionality loss and downtime, and 3) developing sociotechnical models that are capable of assessing multiscale earthquake impacts (Mieler & Mitrani-Reiser, 2018).

Mieler and Mitrani-Reiser (2018) first stressed the importance of gathering better data following earthquake events. They indicated that there is an abundance of information on physical damage to specific building components with few linkages to how this impacts overall functionality or downtime. This would be best accomplished through the use of standardized data collection platforms and protocols, which have yet to be developed. As these platforms and protocols are developed, they need to include information on overall recovery, restoration of lifeline services, and changes to the building placarding in order to provide a more comprehensive story, through data, of real-time events (Mieler & Mitrani-Reiser, 2018).

The authors also indicated a need for improved analytical models for predicting functionality loss and downtime, which account for the complexities and interdependencies of modern building components, systems, human factors, and community services (e.g., housing, transportation) (Mieler & Mitrani-Reiser, 2018). In order to develop accurate and increasingly complex models, focus needs to be placed on collecting standardized, high quality data during reconnaissance efforts.

Earthquake Reconnaissance Reporting

Earthquake reconnaissance efforts have been undertaken since the 17th century, with the field investigation of the 1627 magnitude 6.8 Gargano Region, Italy earthquake (Robin Spence, 2014). However, it was not until the Great Neapolitan Earthquake in 1857 that the first principles of observational seismology were laid out by Robert Mallet (Robin Spence, 2014). UNESCO dominated earthquake reconnaissance for 20 years in the late 20th century, using multi-disciplinary teams composed of both engineers and scientists (Robin Spence, 2014). Today, several international groups coordinate reconnaissance efforts, including the Earthquake Engineering Research Institute (EERI) based in the US and Earthquake Engineering Field Investigation Team (EEFIT) based in the United Kingdom (Robin Spence, 2014).

Previous reconnaissance efforts have increased understanding about earthquakes' impacts on structures, non-structural components, and communities (Reitherman, 1997). Building off Robert Mallet's seminal work, there is a growing body of knowledge on the increased damage suffered by "non-engineered" structures, many of which are domestic buildings and historical structures. In fact, these damages commonly have dedicated sections within reconnaissance reports (Robin Spence, 2014).

While reconnaissance efforts have experienced scientific and logistical advances, lack of funding, organizational difficulties, and extensive delays in the integration of field observations into design practice remain (Robin Spence, 2014). Advances in technology have led to web-accessible databases which are being used for statistical model development and testing (Robin Spence, 2014) However, the lack of standards for current data gathering endeavors remains a significant challenge (de la Llera et al., 2017; Robin Spence, 2014). One study which assessed all data gathered following the 2010 magnitude 8.8 Maule, Chile earthquake, found that the inconsistencies in data granularity and accuracy made comparisons between even similar structures inaccurate. (de la Llera et al., 2017).

Earthquake Engineering Research Institute: Learning from Earthquakes Program

EERI was founded in 1949 and has conducted earthquake reconnaissance efforts in the U.S. and abroad ever since (Robin Spence, 2014). Following the 1971 magnitude 6.5 San Fernando earthquake, EERI's Learning from Earthquakes (LFE) program was developed and formalized in 1973 (Robin Spence, 2014). LFE strives to "accelerate and increase learning from earthquake-induced disasters that affect the natural, built, social and political environments worldwide" (Earthquake Engineering Research Institute, 2016). In order to fulfill this mission, they conduct a number of earthquake response efforts: Establishing a virtual clearinghouse website which consolidates reconnaissance efforts by numerous entities into a single database; Activating the Virtual Earthquake Response Team (VERT) which reports out available information from news and social media within the first few days following an event, including a section on healthcare and hospital impacts; Sending EERI reconnaissance teams to investigate earthquakes; Coordinating international reconnaissance teams; and participating in physical clearinghouses (i.e., a physical space where field investigators can gather and share information, findings, and coordinate efforts) within the U.S. (Earthquake Engineering Research Institute, 2016). LFE has supported over 80 reconnaissance efforts and has archived available information for over 300 earthquakes, dating back to the 1971 San Fernando, California earthquake, worldwide (Earthquake Engineering Research Institute, 2016).

Methods

This research utilized a mixed methods content analysis of publicly available earthquake reconnaissance documents.

Documents selected for analysis met the following inclusion criteria:

1. Document was published and available on the Earthquake Engineering Research Institute (EERI) Learning from Earthquakes (LFE) Reconnaissance Archive.
2. Main earthquake event occurred on or after January 1, 2000.
3. Magnitude of the main event was greater to or equal to 6.0 on the Richter scale. According to Pacific Northwest Seismic Network, earthquakes that are 6.0 on the Richter scale are capable of being *“[d]estructive. Damage slight in specifically designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures.”* (Pacific Northwest Seismic Network, n.d.).
4. Document was a formal written report, publication, or EERI Newsletter story, not a PowerPoint, news article, movie, or audio file.
5. Document was available in English.
6. Document was about the immediate effects of the studied event(s), not prior event or recovery.
7. Using a keyword search, available reports must have included the word “Hospital”, “Health”, or “Medical.” If a document was unsearchable, due to age of document, scanning quality, or document type, then a visual scan was conducted for keywords.

8. Text including keyword(s) must have discussed damage, functionality, response, or evacuation. Text that discusses geological aspects of the event, shaking at hospital locations, or number of casualties sent to facilities was excluded.

When two similar documents were available from the same group (i.e., multiple published versions) then the document with the most recent publication date was used. If the link on the LFE website did not work, attempts were made to locate the report on the websites of the reporting group.

Table 1 describes available and included events and documents.

	Number
Events	
Reported	325
After 2000	151
Magnitude 6.0 or Greater	127
Documents for Relevant Earthquakes	
Available	506
Included in Analysis (After keyword search)	104

Table 1: LFE Reconnaissance Archive on February 5, 2020

Each document that met the above criteria (n=104) was saved as a PDF.

Each document which met the above outlined criteria was reviewed and assigned attributional codes (i.e., event information). If the document had a section on hospitals or healthcare, the whole section was included. In addition, a keyword search (Search words: “health”, “hospital”, and "medical") was then used to identify relevant sections of the report. Each paragraph that included a keyword search result was read to determine if it discussed damage, functionality, response, or evacuation of an individual hospital or the healthcare system. Report sections that did not discuss any of these elements were excluded. Examples of excluded sections included those which discussed: shaking intensities at hospital locations, geological impacts on hospital sites, and the number of casualties sent to local area hospitals.

Included text was coded leveraging a conventional content analysis method, where coding categories are derived directly from the text (Hsieh & Shannon, 2005). First, text was read and reread to identify the types of issues discussed in reports. Then, a series of coding questions were developed to determine if reconnaissance reports included specific information about lifeline service interruptions relevant to the research questions (Appendix B). A corresponding qualitative codebook (Appendix A) was then developed to capture relevant sections of the report that answered the specific coding questions. A single coder coded the text using the qualitative codebook (Appendix A) in NVivo 12.6.0 software (released November 2019)

Examples used in the codebook were updated for clarity during the coding process and any changes to code interpretation resulted in the re-coding of previous documents for consistency. The coded text was then reviewed and used to provide discrete (ordinal and binary) responses by report to coding question by the same coder. Microsoft Excel version 16.37 (released April 2020) was used to manage these responses and to calculate descriptive statistics. RStudio version 1.2.5033 (released December 2019) was used to calculate additional statistics.

Text was coded to determine if the discussion of lifeline services was at the hospital level, meaning a discussion about a single hospital unit, or the healthcare system level, meaning when the discussion was about two or more healthcare units. Descriptive statistics, such as number, percentages, and standard deviations, were calculated by reports, events, and reporting groups. Additionally, the number of times specific issues, such as lifeline service disruptions, types of damage, or evacuation, were mentioned were compiled and reported. Notably, as this research endeavored to assess if reports included information about lifeline system disruptions (not if those lifeline service disruptions resulted in damage), text was coded if it reported lifeline service interruptions regardless of impact. (Appendix D)

Results

Only 20.6% of all available reports met inclusion criteria (n = 104, total available = 506), covering 50 earthquake events, meaning that they had any mention or discussion of health system impacts. The average magnitude at the event level was magnitude 7.2, with 14% (n = 7) reporting that there were multiple events within the series. There was an average of 172 days between the earthquake event and the publication of the reconnaissance report. However, there were 10 reports that took over a year to reach publication and one which took 1559 days (Table 2).

Statistic	Number
Event Level	
Events (n)	50
Magnitude [mean(sd)]	magnitude 7.2 (0.785)
Report Level	
Reports (n)	104
Time Lapse to Report Publication [mean(sd)]	172 days (268)

Table 2: Descriptive Statistics

EERI authored 41% (n = 43) of the analyzed documents, with the next largest reporting group being university based research groups (15%, n = 16). Additionally, both EERI and university based research groups had the best coverage based on category, with discussions on all areas of interest. EERI had the highest proportion of reports covering all categories, with hospital evacuation being the highest at 48% (n = 12) and lifeline performance next at 46% (n = 16) (Table 3).

Reporting Group	Reports n (%)	Lifeline Performance n (%)	Functionality HCS n (%)	Functionality H n (%)	Functionality Both n (%)	Evacuation HCS n (%)	Evacuation H n (%)	Evacuation Both n (%)
Total	**104**	**35 (34)**	**57 (55)**	**68 (65)**	**29 (27)**	**10 (10)**	**25 (24)**	**4 (4)**
EERI	43 (41)	16 (46)[1]	24 (44)	26 (38)	11 (38)	9 (90)	12 (48)	3 (75)
EEFIT	13 (13)	2 (6)	6 (11)	12 (18)	5 (17)	0	7 (28)	0
GEER	8 (8)	3 (9)	3 (5)	7 (10)	3 (10)	0	2 (8)	0
StEER	2 (2)	1 (3)	1 (2)	1 (1)	1 (3)	0	1 (4)	0
University Based Research Group[2]	16 (15)	5 (14)	10 (18)	9 (13)	3 (10)	1 (10)	3 (12)	1 (25)
Governmental Group	8 (8)	3 (9)	7 (12)	3 (4)	3 (10)	0	0	0
Private Entity	1 (1)	1 (3)	0	1 (7)	0	0	0	0
Other - Engineering	9 (9)	2 (6)	5 (9)	5 (7)	2 (7)	0	0	0
Other	4 (4)	2 (6)	1 (2)	4 (6)	1 (2)	0	2 (8)	0

[1] Percentage calculated within category, not based on total number of reports within full analysis
[2] This group is defined as research groups which are affiliated with a university or university based lab/institute. They did not report participating in reconnaissance activities with other formal groups (e.g., EERI or GEER).

Table 3: Issue Discussion by Reporting Group (HCS: Healthcare system; H: Hospital)

The majority of events (n = 27, 54%) only had one relevant report available to analyze. The average event magnitude remained consistent for events which had one, two, and three relevant reports analyzed, at a magnitude 7.0. This increases to magnitude 7.5 for events which had four relevant reports, and magnitude 7.9 which has six. There was only one event (Indian Ocean, magnitude 9.3) which had five relevant reports (Table 4).

Reports n	Events n (%)	Magnitude mean(sd)
1	27 (54)	7.0 (0.68)
2	8 (16)	7.0 (0.63)
3	6 (12)	7.0 (0.71)
4	5 (10)	7.5 (0.92)
5	1 (2)	9.3 (NA)
6	3 (6)	7.9 (1.01)

Table 4: Number of Reports per Event

34% of the analyzed reports discussed lifeline system performance at either the hospital or healthcare system level (n = 35) (Table 5). This covered 42% of the reported events (n = 21) (Table 7). The most common lifeline service mentioned at the report level was power at 27% (report: n = 28), followed by potable water at 16% (report: n = 17). This trend was consistent with discussions on secondary (or backup) systems, which were only discussed in 17% of the analyzed reports (n = 18). Power was the most common secondary system discussed (n = 15, 14%), and potable water was second (n = 7, 7%) (Table 5).

Topic	Primary n (%)	Secondary n (%)
Lifeline performance at both the hospital and healthcare system level	**35 (34)**	**18 (17)**
Power	28 (27)	15 (14)
Potable Water	17 (16)	7 (7)
Sewer	4 (4)	0 (0)
Communications	10 (10)	2 (2)
Gas	3 (3)	1 (1)

Table 5: Lifeline Systems Mentioned within Reports

63% of reports discussed post-earthquake functionality at the hospital level (n = 68), and 54% at healthcare system level (n = 57). The most common type of damage discussed at both the hospital and healthcare system level was non-structural damage (healthcare system [n = 19, 18%], hospital [n = 42, 40%]), closely followed by structural damage (healthcare system [n = 16, 15%], Hospital [n = 38, 37%]) (Table 6).

Lifeline impacts were only accounted for in 10% (n = 10) of the analyzed reports at both the hospital and healthcare system level. Evacuation was mentioned in the majority of reports discussing impacts at the hospital level (n = 66, 63%). However, only a third of these included lifeline impacts when discussing evacuation (n = 22), which only accounted for 21% of the analyzed reports (Table 6). Only one report specifically indicated that the evacuation was due to the failure of backup lifeline services (Haiti, magnitude 7.0, power failure). Most discussion lacked specifics into the reasoning behind evacuation decisions.

Topic	Healthcare System n (%)	Hospital n (%)
Total	**57 (55)**	**68 (65)**
Functionality	56 (54)	66 (63)
Structural	16 (15)	38 (37)
Non-Structural	19 (18)	42 (40)
Lifeline	10 (10)	10 (10)
Evacuation	10 (10)	66 (63)
Lifeline	4 (4)	22 (21)

Table 6: Functionality and Evacuation Issues Mentioned within Reports

However, the coverage of lifeline system impacts was higher when the data was analyzed at the event level, meaning more events had at least some coverage of lifeline system impacts within at least one of the available reports analyzed. The most common lifeline service mentioned at the event level was power (n = 16, 32%), followed by potable water (n = 11, 22%). This was consistent with discussions on secondary systems, which were discussed by 26% of the analyzed reports at the event level (n = 13). Power was the most common secondary system discussed (n = 11, 22%), and potable water was second (n = 6, 12%) (Table 7).

Topic	Primary n (%)	Secondary n (%)
Lifeline performance at both the hospital and healthcare system level	**21 (42)**	**13 (26)**
Power	16 (32)	11 (22)
Potable Water	11 (22)	6 (12)
Sewer	3 (6)	0 (0)
Communications	8 (16)	2 (4)
Gas	3 (6)	1 (2)

Table 7: Lifeline Systems Mentioned by Event

74% of the events had discussion on earthquake impacts to functionality at the hospital level (n = 37), and 64% at healthcare system level (n = 32). The most common type of damage discussed at both the hospital and healthcare system level was non-structural damage (healthcare system [n = 17, 34%], hospital [n = 28, 56%]), closely followed by structural damage (healthcare system [n = 13, 26%], hospital [n = 22, 44%]) (Table 7).

Lifeline impacts were only covered in a small portion of events (healthcare system [n = 7, 14%], Hospital [n = 8, 16%]). 74% of events had some discussion about evacuation at the hospital level (n = 37), however only 14% of these included lifeline impacts when discussing evacuation (n = 7) (Table 7).

Topic	Healthcare System n (%)	Hospital n (%)
Total	**33 (66)**	**37 (74)**
Functionality	32 (64)	37 (74)
Structural	13 (26)	22 (44)
Non-Structural	17 (34)	28 (56)
Lifeline	7 (14)	8 (16)
Evacuation	8 (16)	37 (74)
Lifeline	4 (8)	17 (34)

Table 8: Functionality and Evacuation Issues Mentioned by Event

Discussion

Despite prior calls for consistent data gathering tools and increased focus on non-structural impacts, and more specifically lifeline service disruptions, following earthquakes, these findings indicate that there is a significant underreporting of hospital and healthcare-related information in reconnaissance reports. While lifeline services have been previously described as critical for hospital functionality and healthcare system operations following major earthquakes, the majority of reports reviewed included limited or no information about healthcare- or hospital-system specific impacts from lifeline service disruption or if such disruptions impacted evacuation decision-making. Only 10% of included reports, covering less than 20% of included events, had any discussion on lifeline service impacts to hospitals or the healthcare system.

These findings indicate the need for additional lifeline service reporting in earthquake reconnaissance in relation to healthcare systems, as well as data collection standards to improve data quality and capacity to learn from and across earthquakes. Additional research is necessary to develop standardized reporting tools and better understand the human-factors of evacuation decision-making following no-notice events. Here I will discuss these needs, as well as limitations to this work.

Lifeline Service Reporting

These findings indicate that there is an overall lack of hospital or healthcare system specific data on lifeline service disruptions. 34% of reports indicated that there was some type of lifeline service disruption when discussing hospital or healthcare system impacts. However, only 10%

specified if or how these disruptions impacted functionality, and only one report specified that the evacuation of a single hospital was due to the loss of a lifeline service (both primary and secondary power). Numerous researchers have stressed that lifeline service disruptions are a large contributing factor to hospital functionality decreases following earthquakes and that additional data is needed to improve models and mitigation measures (Achour et al., 2011, 2014; Ardagh et al., 2012; Mieler & Mitrani-Reiser, 2018; Myrtle et al., 2005; Yavari et al., 2010). Yet, these findings indicate that this information is either not consistently gathered or reported. While many reconnaissance documents reported on lifeline service disruptions at the community level, due to the redundancies in many hospital systems for these external services, it is not possible to assess if and how these disruptions impacted hospital and healthcare system functionality without more specific information.

As outlined by Achour et al. (2014), there are a number of ways to reduce hospital vulnerabilities to external lifeline services, including increasing the resilience of the primary lifeline service infrastructure, improving the performance of alternative systems, and integrating lifeline service resilience measures into local codes. However, the financial requirements to increase existing infrastructure resilience to earthquakes is unattainable by many communities (Achour et al., 2014). This is further complicated by the fact that many lifeline service providers are owned and operated by private companies, especially in the U.S. (Rinaldi et al., 2001). Private companies have different financial priorities and obligations to shareholders than a publicly provided service (Rinaldi et al., 2001). The unlikely probability of widespread improvements to infrastructure moves the focus onto improving the performance of backup systems and integrating lifeline service resiliency into local codes, as stressed by Achour et al. (2014). However, only 18 (17%)

analyzed reports made any mention of the performance of backup systems. This lack of available data leads to an inability to assess backup system performance across different earthquakes and over time.

Data Quality

Written, free-form reconnaissance reports allow for the ability to provide contextual information about the earthquake. However, the lack of a standardized reporting system, even within reports developed by a single reporting group, decreases the ability to gather a sufficient amount of data necessary to learn from and across earthquakes. Prior research has demonstrated that even data available for a single earthquake event can be variable, leading to inconsistent decisions made during response and recovery (de la Llera et al., 2017). Moreover, improving the quality of available reconnaissance data was a future need indicated by the EERI LFE contributions report published in 2004 (EERI, 2004). Yet, these findings indicate there is still opportunity for improvement on standardizing data gathering efforts in order to improve quality. There were large variations in lifeline system discussion between the various reporting groups. Many events only had 1-3 available reports which covered the healthcare system and hospital impacts. Furthermore, quality, quantity, or saturation of discussion was not considered in this analysis (i.e., a report with one mention was counted the same as one with 100). This diminished the ability to glean key information about specific impacts to healthcare- or hospital-systems.

Beyond the lack of a standardized method of reporting, analyzed reconnaissance reports lacked content about hospital and healthcare system impacts. Only 104 reports (20.6%), of the available 506 reports covering events that met the criteria for this research (i.e., after December 31, 1999 with a magnitude of 6.0 or greater), included information about hospital and healthcare system performance.

Recommendations

These findings indicate there are several steps that can be taken to improve post-earthquake reconnaissance efforts. In particular, I recommend: 1) Developing standardized reporting tools in order to gather better quality and more consistent data based on the literature and 2) Conducting research about the role of lifeline service interruption in evacuation decision-making for no-notice events.

Standardized Reporting Tools

The need for a standardized reporting system for building performance has been previously described (de la Llera et al., 2017; Mieler & Mitrani-Reiser, 2018; Mitrani-Reiser et al., 2012; Myrtle et al., 2005). These findings also indicate the need for hospital specific reporting tools, such as the Johns Hopkins University/Earthquake Engineering Research Institute Hospital Impact Survey which was tested following the 2010 magnitude 8.8 earthquake that struck Chile (Mitrani-Reiser et al., 2012) , that collect information on the myriad of non-structural components necessary for hospital and healthcare system functionality. The Johns Hopkins University/Earthquake Engineering Research Institute Hospital Impact Survey, although hospital specific and very robust, may be an unrealistic tool to use to measure lifeline service impacts to functionality at the healthcare system level. When it was tested in Chile, each survey took approximately 1 hour to complete and required the assistance by a knowledgeable hospital administrator (Mitrani-Reiser et al., 2012). This may not always be possible when working with all facilities at the healthcare system level, and simplified tools may be more practical for system-wide reconnaissance activities.

While significant progress has been made to improve building codes and reduce structural impacts following earthquakes, additional attention must be paid to non-structural impacts, including lifeline service disruptions. Comprehensive lists of systems perceived by hospital administrators as most critical following an extreme event have been previously described, and include: piping systems (i.e., water, medical gases, suction, and steam), electrical, communications, medical monitors/ventilators/defibrillators, HVAC, and suspended ceilings/fire sprinklers (Myrtle et al., 2005). I recommend inclusion of information about impacts to systems on this list when developing standardized reconnaissance tools to increase understanding of hospital functionality across earthquakes.

Human Factors of Evacuation for No-Notice Events

While reports covering 74% of the analyzed events indicated that some or all hospitals evacuated following the earthquake, the literature on hospital decision-making following no-notice events, like earthquakes, is sparse. Prior research following disasters has shown that lifeline service disruptions are important influencing factors in evacuation decision-making (Bagaria et al., 2009; McGinty et al., 2017; Schultz et al., 2003). Additional information about decision-making following non-notice events can improve model development and, ultimately, the understanding about lifeline service impacts to hospital functionality and healthcare system operations.

Limitations

While attempts were made to minimize limitations through study design, several remain. During the filtering process of the available reports there were a number of broken links. Every effort was made to check the link and search for the report, however many of them were skipped. The types of documents available within the EERI LFE archive could be systematically different from documents which are not included within their archive. Additionally, documents were qualitatively coded by a single individual which may decrease reliability of results.

Moreover, native data files may have additional information that was collected about hospital and healthcare impacts that were not included in written reports. This research focused only on published and publicly available reconnaissance reports, rather than other available information, such as data files or other healthcare system studies. The use of a convenience sample could limit the findings to what others felt important to share, including their own bias, rather than the whole picture of post-earthquake hospital and healthcare system functionality.

Most importantly, there was not enough data to explore the impacts of earthquake magnitude on lifeline service performance at the hospital or healthcare systems level fully. This contributed to the inability to explore the impacts of lifeline service interdependencies, cascading failures, and how they impact overall hospital and healthcare system functionality following earthquakes.

Conclusion

Previous research has highlighted the impacts lifeline service disruptions have on healthcare system functionality following earthquakes (Achour et al., 2011, 2014; Kirsch et al., 2010; Mitrani-Reiser et al., 2012; Myrtle et al., 2005; Nagata et al., 2017; Yavari et al., 2010). The use of post-earthquake reconnaissance reporting is one way to improve the understanding of how lifeline service disruptions impact hospital and healthcare functionality. This research contributes to these efforts in the following ways: 1) It quantified the severe underreporting of hospital and healthcare system discussions in post-earthquake reconnaissance efforts especially coverage of lifeline service impacts. 2) It highlighted the inconsistent coverage of key issues around lifeline disruption, functionality, and evacuation between reconnaissance reporting groups. 3) Finally, it confirmed that non-structural damage is the main issue discussed during reporting's of hospital and healthcare system functionality.

However, this research highlights the large gaps that still exist in post-earthquake reconnaissance reporting on hospital and healthcare system functionality, regardless of coverage of lifeline service disruptions. Because of the lack of data and inconsistent reporting techniques, two recommendations have been made: 1) developing standardized reporting tools and 2) additional research on the human-factors of evacuation decision-making following no-notice events. These efforts will contribute to post-earthquake healthcare resilience and increase our ability to respond to community needs when they are needed most.

Appendix A: Qualitative Codebook

Code / (Sub code)	When to apply	Notes	Example
Disruption	Apply when discussing any type of utility/lifeline service disruption to individual hospitals or the healthcare system as a whole.	This will include all utilities which will be sub coded. This will also include hospital and healthcare system level information which will be coded separately. Coded text must be specifically discussing disruptions to the hospital or healthcare system, not just a general statement about a communitywide disruption.	The hospital experienced power and water service disruption follow the earthquake event
(Disruption - Power)	Apply when discussing a power disruption to individual hospitals or the healthcare system as a whole.	Include discussion on any descriptive information available in the report. Include both primary and secondary service disruptions.	
(Disruption - Potable Water)	Apply when discussing a potable water disruption to individual hospitals or the healthcare system as a whole.	Include discussion on any descriptive information available in the report. Include both primary and secondary service disruptions.	
(Disruption - Waste Water)	Apply when discussing a wastewater disruption to individual hospitals or the healthcare system as a whole.	Include discussion on any descriptive information available in the report. Include both primary and secondary service disruptions.	
(Disruption - Communications)	Apply when discussing a communications disruption to individual hospitals or the healthcare system as a whole.	Include discussion on any descriptive information available in the report. Include both primary and secondary service disruptions. This includes telecommunications and internet access if discussed.	
(Disruption - Gas)	Apply when discussing a gas disruption to an individual hospital or the healthcare system as a whole.	Include discussion on any descriptive information available in the report. Include both primary and secondary service disruptions. This does not include medical gases such as oxygen.	
(Disruption - Length of Disruption)	Apply when discussing the length of lifeline service disruption to individual hospitals or the healthcare system as a whole.		

Code / (Sub code)	When to apply	Notes	Example
Hospital level	Apply when discussing earthquake impacts to individual hospitals.		Hospital "x" suffered structural and non-structural damage as a result of the earthquake.
Healthcare System Level	Apply when discussing earthquake impacts to the healthcare system as a whole or multiple hospitals all at once.		16 of 25 hospitals were impacted by the earthquake. The healthcare system was severely affected by this event.
Evacuation	Apply when discussing hospital evacuation	This will include individual and community level information which will be coded separately	
(Hospital Evacuation - Utilities)	Apply when discussing hospital evacuation due specifically to utility/lifeline service disruptions		This hospital had to evacuate because it lost both primary and secondary power
(Hospital Evacuation - Structural)	Apply when discussing hospital evacuation due specifically to structural damage		This hospital had to evacuate because there was too much structural damage and it was unsafe to remain inside the building
(Hospital Evacuation - Non-Structural)	Apply when discussing hospital evacuation due specifically to non-structural damage	This includes medical equipment, medical gas, and internal utility issues (i.e. burst pipes).	
(Hospital Evacuation - Secondary Hazard)	Apply when discussing hospital evacuation due specifically to a secondary hazard		Tsunami, landslide, liquefaction, or aftershocks
Operations	Apply when discussing operations and ability to provide safe and effective care by individual hospitals or the healthcare system as a whole following the earthquake event	This will include individual and community level information which will be coded separately. Include all types of damage as they will be sub coded. Apply to text that discusses the lack of damage as well.	
(Operations - Utility Functionality)	Apply when discussing functionality and damage of and due specifically to utility/lifeline services		
(Operations - Structural Functionality)	Apply when discussing functionality and damage of and due specifically to the physical structure		
(Operations - Non-Structural Functionality)	Apply when discussing functionality and damage of and due specifically to non-structural aspects		

Code / (Sub code)	When to apply	Notes	Example
(Operations - Secondary Hazard)	Apply when discussing functionality and damage of and due specifically to secondary hazards		Tsunami, landslide, or aftershocks
Preparedness	Apply when discussing hospital or healthcare system mitigation, preparedness, response, and recovery.	The timeline, i.e. pre or post-event, will be sub coded.	
(Preparedness - Pre-event Mitigation)	Apply when discussing hospital or healthcare system preparedness or mitigation practices prior to the event.		
(Preparedness - Post-event Response)	Apply when discussing hospital or healthcare system response practices after the event.	This includes lessons learned and preparedness recommendations for the future.	
Reporting Group	Apply to the entire document based on what type of reporting agency created the report.	If there are multiple reporting agencies, code for the first one listed	EERI, GEER, EEFIT, Private, University
EERI			
GEER			
EEFIT			
Private Entity			
Academic Group			
Governmental Group			
Other			
Other - Engineering			

Appendix B: Quantitative Codebook

Variable Name	Order[1]	Question	Possible Answers	Notes	Question Type
Standard Questions					
Location	P	What is the primary location for this report?	*Country* *Region (ex. Indian Ocean)*	Indicate the region when multiple countries were impacted and covered within the reports.	Text
Multiple_Events	P	Were there multiple earthquake events covered in this report?	1 (Yes) 0 (No)		Binary - Mutually Exclusive
Magnitude	P	What was the magnitude of the reported event?	Ex. 6.4	If multiple events, record the main event recorded by report. If not specified, then use the largest magnitude in series.	Numeric
Event_Date	P	What was the date of the earthquake event?	*YYYY/MM/DD* *NA (Unknown)*	If over multiple days, record the day of the main event if specified by report. If not specified, then choose the first date.	Date
Report_Date	P	What was the date the report was published?	*YYYY/MM/DD* *NA (Unknown)*	If the date indicated on the report is only month and year, assign it to the 1st day of the month.	Date

[1] Key: P = Parent Question, C = Child Question - The question appearance is conditioned on the response to the parent question, G = Grandchild Question - The question appearance is conditioned on the response to the child questions.

Variable Name	Order	Question	Possible Answers	Notes	Question Type
Reporting_Group	P	What is the name of the agency/group/corporation that authored the report?	Ex. EERI	If multiple groups are mentioned, record the group mentioned first. Only use the keywords used in the qualitative coding (i.e. EERI, GEER, Academic Group, Other - Engineering, etc.).	Text - Mutually Exclusive
Developed_Nation_Status	P	Is this country classified as a developed nation by the UN according to the 2019 World Economic Situation and Prospects report?[2]	1 (Yes) 0 (No)		Binary - Mutually Exclusive
Lifeline Disruption					
Power_Disrupt	P	Was the primary power disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: electricity	Binary - Mutually Exclusive
BU_Power	C	Was the secondary/backup power disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: electricity This question is dependent on the results from the question above. This includes the lack of a backup system.	Binary - Mutually Exclusive
PotWater_Disrupt	P	Was the primary potable water disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: fresh water, treated water, sweet water	Binary - Mutually Exclusive
BU_PotWater	C	Was the secondary/backup potable water disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: fresh water, treated water, sweet water This question is dependent on the results from the question above. This includes the lack of a backup system.	Binary - Mutually Exclusive

[2] (United Nations, 2019)

Variable Name	Order	Question	Possible Answers	Notes	Question Type
WasteWater_Disrupt	P	Was the primary wastewater disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: sewer, sewage	Binary - Mutually Exclusive
BU_WasteWater	C	Was the secondary/backup wastewater disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: sewer, sewage This question is dependent on the results from the question above. This includes the lack of a backup system.	Binary - Mutually Exclusive
Comm_Disrupt	P	Was the primary communication system disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: telecommunications, internet	Binary - Mutually Exclusive
BU_Comm	C	Was the secondary/backup communication system disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Other acceptable terms: telecommunications, internet This question is dependent on the results from the question above. This includes the lack of a backup system.	Binary - Mutually Exclusive
Gas_Disrupt	P	Was the primary gas disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	Does not include medical gas, such as oxygen. Only include municipal gas utilities provided via an outside line from an off-site source.	Binary - Mutually Exclusive
BU_Gas	C	Was the secondary/backup gas disrupted to any local healthcare facilities?	1 (Yes) 0 (No) NA (Unknown)	This question is dependent on the results from the question above. This includes the lack of a backup system.	Binary - Mutually Exclusive
Length_Disrupt	P	What was the maximum length of disruption discussed within the report?	Ex. 6	Several = 3, couple = 2, 0 = < 24 hours	Number

Variable Name	**Order**	**Question**	**Possible Answers**	**Notes**	**Question Type**
Healthcare System Functionality					
HCS_Functionality	P	What is the stated functionality of the healthcare system following the earthquake event mentioned in the report?	0 (No decrease in functionality) 1 (Minimal loss of functionality) 2 (Significant decrease in functionality) 3 (Complete loss of functionality) NA (Unknown)	Damage can include both lifeline service disruption, non-structural damage, and structural damage. If more than one hospital is discussed, then mark the most common level of functionality. Only mark 3 when a complete loss of function or completely destroyed is mentioned in the text.	Categorical - Mutually Exclusive
HCS_Damage_Structural	P	Was there any indicated structural damage following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)	If no mention of type of damage at all, mark NA.	Binary - Mutually Exclusive
HCS_Damage_Non-Structural	P	Was there any indicated non-structural damage following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)	If no mention of type of damage at all, mark NA.	Binary - Mutually Exclusive
HCS_Damage_Lifeline	P	Was there any indicated lifeline damage following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)	If no mention of type of damage at all, mark NA.	Binary - Mutually Exclusive

Variable Name	Order	Question	Possible Answers	Notes	Question Type
HCS_Damage_Lifeline_LV	C	If yes, what was the stated level of lifeline damage that occurred to the healthcare system following the earthquake event?	0 (No damage or negligible damage to internal lifelines occurs.) 1 (Minor damage is observed.) 2 (Damage affects hospital operations.) 3 (Evacuation of staff and patients is required.) NA (Unknown)[3]	This question is dependent on the results from the question above.	Categorical - Mutually Exclusive

[3] 0 (No damage or negligible damage to internal lifelines occurs. Power, water supply, and other utilities are available), 1 (Minor damage is observed. Power and water are available, possibly from standby sources. Damage can be repaired during the time period that backup systems are used), 2 (Damage affects hospital operations. Damage includes loss of emergency generators, local pipe breaks, and damage to the facility water reservoir), 3 (Evacuation of staff and patients is required. Major flooding from pipe breaks, long term power or water outage, spreading of hazardous materials due to container breaks, and contamination of water may be observed)(Yavari et al., 2010)

Variable Name	Order	Question	Possible Answers	Notes	Question Type
Hospital Functionality					
H_Functionality	P	What is the stated functionality of the individual hospital(s) following the earthquake event mentioned in the report?	0 (No decrease in functionality) 1 (Minimal loss of functionality) 2 (Significant decrease in functionality) 3 (Complete loss of functionality) NA (Unknown)	Damage can include both lifeline service disruption, non-structural damage, and structural damage. If more than one hospital is discussed, then mark the most common level of functionality. Only mark 3 when a complete loss of function, completely destroyed, or fully evacuated for more than 24 hours is mentioned in the text.	Categorical - Mutually Exclusive
H_Functionality_Majority	C	Was there a majority of hospitals that had the same functionality rating?	1 (Yes) 0 (No) NA (Not applicable)	This question is dependent on the results from the question above. This question should only be answered when more than one individual hospital is discussed.	Binary - Mutually Exclusive
H_Damage_Structural	P	Was there any indicated structural damage following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)	If no mention of type of damage at all, mark NA.	Binary - Mutually Exclusive
H_Damage_Non-Structural	P	Was there any indicated non-structural damage following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)	If no mention of type of damage at all, mark NA.	Binary - Mutually Exclusive
H_Damage_Lifeline	P	Was there any indicated lifeline damage following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)	If no mention of type of damage at all, mark NA.	Binary - Mutually Exclusive

Variable Name	Order	Question	Possible Answers	Notes	Question Type
H_Damage_Lifeline_LV	C	If yes, what was the stated level of lifeline damage that occurred to the hospital(s) following the earthquake event?	0 (No damage or negligible damage to internal lifelines occurs.) 1 (Minor damage is observed.) 2 (Damage affects hospital operations.) 3 (Evacuation of staff and patients is required.) NA (Unknown)[4]	This question is dependent on the results from the question above.	Categorical - Mutually Exclusive
H_Damage_Lifeline_LV_Majority	G	Was there a majority of healthcare facilities that had the same lifeline damage rating?	1 (Yes) 0 (No) NA (Not applicable)	This question is dependent on the results from the question above.	Binary - Mutually Exclusive
Healthcare System - Evacuation					
HCS_Evacuation_Status	P	Were there any indicated evacuations of healthcare facilities following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)		Binary - Mutually Exclusive

[4] 0 (No damage or negligible damage to internal lifelines occurs. Power, water supply, and other utilities are available), 1 (Minor damage is observed. Power and water are available, possibly from standby sources. Damage can be repaired during the time period that backup systems are used), 2 (Damage affects hospital operations. Damage includes loss of emergency generators, local pipe breaks, and damage to the facility water reservoir), 3 (Evacuatio n of staff and patients is required. Major flooding from pipe breaks, long term power or water outage, spreading of hazardous materials due to container breaks, and contamination of water may be observed)(Yavari et al., 2010)

Variable Name	Order	Question	Possible Answers	Notes	Question Type
HCS_Evacuation_Status_LV	C	If yes, what was the stated level/proportion of evacuations of healthcare facilities following the earthquake event mentioned in the report?	0 (Only partial evacuation. This includes wings and departments within a facility. All healthcare facilities remained open) 1 (Full evacuation) NA (Unknown)	This question is dependent on the results from the question above.	Binary - Mutually Exclusive
HCS_Evacuation_Lifelines	C	Was it indicated that evacuations were due to lifeline service disruptions?	1 (Yes) 0 (No) NA (Unknown)	This question is dependent on the results from the question above. This includes any indication that lifeline service disruption led to evacuation, even if there were additional factors (i.e. non-structural or structural damage as well) that led to the evacuation. Lifeline service disruption must be mentioned as a reason. If another reason for evacuation is indicated and there is no mention of a lifeline service disruption, then mark "no". If no indication into why the evacuation happened mark NA.	Binary - Mutually Exclusive
HCS_Evacuation_Lifelines_Specific	G	Which lifeline service disruption was indicated in the report as leading to evacuation?	Ex. Power NA (Unknown)	Only use the keywords used in the lifeline disruption section (i.e. Power, PotWater, Waste, etc.).	Text - Mutually Exclusive
Hospital - Evacuation					
H_Evacuation_Status	P	Were there any indicated evacuations of hospital(s) following the earthquake event mentioned in the report?	1 (Yes) 0 (No) NA (Unknown)		Binary - Mutually Exclusive

Variable Name	Order	Question	Possible Answers	Notes	Question Type
H_Evacuation_Status_LV	C	If yes, what was the stated level/proportion of evacuations of hospital(s) following the earthquake event mentioned in the report?	0 (Only partial evacuation. This includes wings and departments within a facility. All healthcare facilities remained open) 1 (Full evacuation) NA (Unknown)	This question is dependent on the results from the question above.	Binary - Mutually Exclusive
H_Evacuation_Lifelines	C	Was it indicated that evacuations were due to lifeline service disruptions?	1 (Yes) 0 (No) NA (Unknown)	This question is dependent on the results from the question above. This includes any indication that lifeline service disruption led to evacuation, even if there were additional factors (i.e. non-structural or structural damage as well) that led to the evacuation. Lifeline service disruption must be mentioned as a reason. If another reason for evacuation is indicated and there is no mention of a lifeline service disruption, then mark "no". If no indication into why the evacuation happened mark NA.	Binary - Mutually Exclusive
H_Evacuation_Lifelines_Specific	G	Which lifeline service disruption was indicated in the report as leading to evacuation?	Ex. Power NA (Unknown)	Only use the keywords used in the lifeline disruption section (i.e. Power, PotWater, Waste, etc.).	Text - Mutually Exclusive

Appendix C: Reports Included in Analysis

Event Name	Event Date	Magnitude	Country
Ridgecrest Earthquake Sequence, California	July 04, 2019	6.4, 7.1	United States
Anchorage, Alaska	November 30, 2018	7	United States
Palu, Indonesia	September 28, 2018	7.5	Indonesia
Halabjah, Iran	November 12, 2017	7.3	Iran
Chiapas, Mexico	September 08, 2017	8.1	Mexico
Pidie Jaya, Aceh, Indonesia	December 07, 2016	6.5	Indonesia
Central Italy	August 24, 2016	6.2, 5.4, 5.9, 6.5	Italy
Musine, Ecuador	April 16, 2016	7.8	Ecuador
Kumamoto, Japan	April 15, 2016	7	Japan
Southern Taiwan Earthquake	February 05, 2016	6.4	Taiwan
Northeastern Afghanistan Earthquake	October 26, 2015	7.5	Afghanistan, Pakistan
Illapel, Chile	September 16, 2015	8.3	Chile
Gorkha, Nepal	April 25, 2015	7.8	Nepal
South Napa, California	August 24, 2014	6	USA
Cephalonia, Greece	January 26, 2014	6.0, 6.1	Greece
Lushan County, China	April 20, 2013	6.6	China
Champerico, Guatemala	November 07, 2012	7.4	Guatemala
Hojancha, Costa Rica	September 05, 2012	7.6	Costa Rica

Event Name	Event Date	Magnitude	Country
Varzaghan-Ahar, Iran	August 11, 2012	6.3, 6.4	Iran
Ometepec, Mexico	March 20, 2012	7.4	Mexico
Eastern Turkey	October 23, 2011	7.1	Turkey
Sikkim	September 18, 2011	6.9	Bhutan, India, Nepal
Tohoku Japan	March 11, 2011	9	Japan
Christchurch, New Zealand	February 22, 2011	6.3	New Zealand
Canterbury, New Zealand	September 04, 2010	7.1	New Zealand
Taiwan	March 04, 2010	6.2	Taiwan
Maule, Chile (offshore)	February 27, 2010	8.8	Chile
Haiti	January 12, 2010	7	Haiti
Eureka	January 10, 2010	6.5	USA
Padang, Indonesia	September 30, 2009	7.6	Indonesia
L'Aquila, Italy	April 06, 2009	6.3	Italy
Southern Sumatra	September 12, 2007	8.5	Indonesia
Near Central Coast, Peru	August 15, 2007	8	Peru
Western Sumatra, Indonesia	March 06, 2007	6.4	Indonesia
Taiwan	December 26, 2006	7.1	Taiwan
Island of Hawaii	October 15, 2006	6.7	USA
Java	May 26, 2006	6.3	Indonesia
Kashmir	October 08, 2005	7.6	India, Pakistan
Tarapaca	June 13, 2005	7.8	Chile

Event Name	Event Date	Magnitude	Country
Sumatra-Andaman Islands and Indian Ocean Tsunami	December 26, 2004	9	India, Indonesia, Maldives, Si
Santiago del Estero Province	September 07, 2004	6.4	Argentina
Bam (Southeastern Iran)	December 26, 2003	6.6	Iran
Southwestern Siberia	September 27, 2003	7.3	Russia
Boumerdes (Northern Algeria)	May 21, 2003	6.8	Algeria
Bingöl	May 01, 2003	6.4	Turkey
Sumatra	November 02, 2002	7.4	Indonesia
Southern Peru	June 23, 2001	8.4	Peru
Nisqually, Washington	February 28, 2001	6.8	USA
Central Sulawesi	May 04, 2000	7.4	Indonesia

Appendix D: Dataset

File Name	Location	Multiple_Events	Magnitude	Event_Date	Report_Date	Days Lapsed	Reporting_Group	Developed_Nation_Status
000504_Indonesia_EERI.pdf	Indonesia	0	6.5	5/4/00			EERI	0
010228_USA_UniversityOfWashington.pdf	USA	0	6.8	2/28/01	3/1/01	1.00	Academic Group	1
010623_Peru_EERI.pdf	Peru	0	8.3	6/23/01	11/1/01	131.00	EERI	0
021102_Indonesia_EERI.pdf	Indonesia	0	7.4	11/2/02	2/1/03	91.00	EERI	0
030501_Turkey_BU.pdf	Turkey	0	6.4	5/1/03	5/30/03	29.00	Academic Group	0
030501_Turkey_EERI.pdf			6.4	5/1/03	7/1/03	61.00	EERI	0
030501_Turkey_EERI_2.pdf			6.4	5/1/03	6/1/03	31.00	EERI	0
030501_Turkey_KOERI.pdf			6.4	5/1/03			Academic Group	0
030521_Algeria_EERI.pdf	Algeria	0	6.8	5/21/03	10/1/03	133.00	EERI	0
030927_Siberia_EERI.pdf	Siberia	0	7.3	9/27/03	12/1/03	65.00	EERI	0
031226_Iran_EERI.pdf	Iran	0	6.6	12/26/03	4/1/04	97.00	EERI	0
040907_Argentina_EERI.pdf	Argentina	0	6.4	9/7/04	10/1/04	24.00	EERI	0
041226_IndianOcean_EEFIT.pdf	Indian Ocean	0	9.3	12/26/04	2/1/06	402.00	EEFIT	0
041226_IndianOcean_EERI_2.pdf			9.3	12/26/04	4/1/05	96.00	EERI	0
041226_IndianOcean_EERI_3.pdf			9.3	12/26/04	7/1/05	187.00	EERI	0

File Name	Location	Multiple_Events	Magnitude	Event_Date	Report_Date	Days Lapsed	Reporting_Group	Developed_Nation_Status
041226_IndianOcean_EERI.pdf			9.3	12/26/04	5/1/05	126.00	EERI	0
041226_IndianOcean_IITK.pdf			9.3	12/26/04			Academic Group	0
050613_Chile_DU.pdf	Chile	0	7.8	6/13/05			Academic Group	0
051008_Pakistan_EEFIT.pdf	Pakistan	0	7.6	10/8/05	7/1/08	997.00	EEFIT	0
051008_Pakistan_EERI.pdf			7.6	10/8/05	2/1/06	116.00	EERI	0
051008_Pakistan_EERI_2.pdf			7.6	10/8/05	12/1/05	54.00	EERI	0
060527_Indonesia_BAPPENAS.pdf	Indonesia	0	6.3	5/27/06	6/14/06	18.00	Governmental Group	0
061015_USA_EERI.pdf	USA	1	6.7	10/15/06	12/1/06	47.00	EERI	1
061015_USA_RMS.pdf			6.7	10/16/06			Other	1
061226_Taiwan_EERI.pdf	Taiwan	0	7.1	12/26/06			Other - Engineering	0
070306_Indonesia_EERI.pdf	Indonesia	1	6.4	3/6/07	5/1/07	56.00	EERI	0
070912_Indonesia_EERI.pdf	Indonesia	1	8.4	9/12/07	11/1/07	50.00	EERI	0
070919_Peru_CISMID.pdf	Peru	0	8	8/15/07	8/24/07	9.00	Academic Group	0
070919_Peru_EEFIT.pdf			8	8/15/07			EEFIT	0
070919_Peru_EERI.pdf			8	8/15/07	10/1/07	47.00	EERI	0
070919_Peru_OCHA.pdf			8	8/15/07	8/18/07	3.00	Governmental Group	0
090406_Italy_EEFIT.pdf	Italy	0	6.2	4/6/09			EEFIT	1
090406_Italy_NHC.pdf			6.2	4/6/09	10/1/09	178.00	Academic Group	1

File Name	Location	Multiple_Events	Magnitude	Event_Date	Report_Date	Days Lapsed	Reporting_Group	Developed_Nation_Status
090930_Indonesia_EEFIT.pdf	Indonesia	0	7.6	9/30/09	12/1/09	62.00	EEFIT	0
090930_Indonesia_EERI.pdf			7.6	9/30/09	12/1/09	62.00	EERI	0
100110_USA_EERI.pdf	USA	0	6.5	1/9/10	3/1/10	51.00	EERI	1
100112_Haiti_EEFIT.pdf	Haiti	0	7	1/12/10			EEFIT	0
100112_Haiti_EERI_2.pdf			7	1/12/10	4/1/10	79.00	EERI	0
100112_Haiti_EERI_3.pdf			7	1/12/10	5/1/10	109.00	EERI	0
100112_Haiti_EERI.pdf			7	1/12/10	11/1/10	293.00	EERI	0
100112_Haiti_MRP.pdf			7	1/12/10			Other - Engineering	0
100112_Haiti_USGS.pdf			7	1/12/10	2/23/10	42.00	Governmental Group	0
100227_Chile_EEFIT.pdf	Chile	0	8.8	2/27/10			EEFIT	0
100227_Chile_EERI_2.pdf			8.8	2/27/10	11/1/10	247.00	EERI	0
100227_Chile_EERI.pdf			8.8	2/27/10	6/1/10	94.00	EERI	0
100227_Chile_GEER.pdf			8.8	2/27/10	5/25/10	87.00	GEER	0
100304_Taiwan_EERI.pdf	Taiwan	0	6.4	3/4/10	5/1/10	58.00	EERI	0
100404_Baja_EERI_2.pdf	Baja	0	7.2	4/4/10	7/1/10	88.00	EERI	0
100404_Baja_EERI.pdf			7.2	4/4/10	10/1/10	180.00	EERI	0
100404_Baja_USCD_2.pdf			7.2	4/4/10			Academic Group	0
100903_NZ_EERI.pdf	New Zealand	0	7.1	9/4/10	11/1/10	58.00	EERI	1

File Name	Location	Multiple_Events	Magnitude	Event_Date	Report_Date	Days Lapsed	Reporting_Group	Developed_Nation_Status
110222_NZ_EEFIT.pdf	New Zealand	0	6.3	2/22/11	6/1/11	99.00	EEFIT	1
110222_NZ_EERI.pdf			6.3	2/22/11	5/1/10	-297.00	EERI	1
110222_NZ_GEER.pdf			6.3	2/22/11	8/15/11	174.00	GEER	1
110311_Japan_EEFIT.pdf	Japan	0	9	3/11/11			EEFIT	1
110311_Japan_EERI_2.pdf			9	3/11/11	1/1/12	296.00	EERI	1
110311_Japan_EERI_3.pdf			9	3/11/11	8/1/11	143.00	EERI	1
110311_Japan_EERI.pdf			9	3/11/11	9/1/11	174.00	EERI	1
110311_Japan_G&E.pdf			9	3/11/11	6/25/12	472.00	Other - Engineering	1
110311_Japan_PEER.pdf			9	3/11/11			Academic Group	1
110918_Nepal/India_EERI.pdf	Nepal-India	0	6.9	9/18/11	1/1/12	105.00	EERI	0
110918_Nepal/India_NICEE.pdf			6.9	9/18/11			Other - Engineering	0
110918_Nepal/India_tRGoB.pdf			6.9	9/18/11	10/24/11	36.00	Governmental Group	0
111023_Turkey_BU.pdf	Turkey	0	7.2	10/23/11			Academic Group	0
111023_Turkey_EERI.pdf			7.2	10/23/11	4/1/12	161.00	EERI	0
111023_Turkey_IIEES.pdf			7.2	10/23/11	11/30/11	38.00	Other - Engineering	0
111023_Turkey_Other.pdf			7.2	10/23/11			Academic Group	0
120320_Mexico_EERI.pdf	Mexico	0	7.4	3/20/12	5/1/12	42.00	EERI	0
120905_CostaRica_RSN.pdf	Costa Rica	0	7.6	9/5/12			Academic Group	0

File Name	Location	Multiple_Events	Magnitude	Event_Date	Report_Date	Days Lapsed	Reporting_Group	Developed_Nation_Status
120911_Iran_IASPEI.pdf	Iran	1	6.4	8/11/12			Other - Engineering	0
120911_Iran_IIEES.pdf			6.4	8/11/12			Other - Engineering	0
121107_Guatemala_EERI.pdf	Guatemala	0	7.4	11/7/12			EERI	0
130420_China_EERI.pdf	China	0	6.6	4/20/13	9/1/13	134.00	EERI	0
130420_China_Other.pdf			6.6	4/20/13			Governmental Group	0
140126_Greece_GEER.pdf	Greece	1	6.1	1/26/14	6/6/14	131.00	GEER	1
140824_USA_EERI.pdf	USA	0	6	8/14/14	10/1/14	48.00	EERI	1
140824_USA_FEMA.pdf			6	8/14/14	2/1/15	171.00	Governmental Group	1
140824_USA_Other.pdf			6	8/14/14			Other	1
150425_Nepal_CEDIM.pdf	Nepal	0	7.8	4/25/15	4/27/15	2.00	Academic Group	0
150425_Nepal_EEFIT.pdf			7.8	4/25/15	8/1/19	1559.00	EEFIT	0
150425_Nepal_EERI.pdf			7.8	4/25/15	5/1/16	372.00	EERI	0
150425_Nepal_HFG.pdf			7.8	4/25/15	4/21/16	362.00	Other	0
150425_Nepal_Other_2.pdf			7.8	4/25/15	1/9/17	625.00	Academic Group	0
150425_Nepal_Other.pdf			7.8	4/25/15	1/9/17	625.00	Academic Group	0
150916_Chile_CIGIDEN.pdf	Chile	0	8.3	9/16/15			Other	0
151026_Pakistan/Afghanistan_OCHA.pdf	Afghanistan	0	7.5	10/26/15	10/28/15	2.00	Governmental Group	0
160206_Taiwan_GEER.pdf	Taiwan	0	6.3	2/6/16	7/14/16	159.00	GEER	0

File Name	Location	Multiple_Events	Magnitude	Event_Date	Report_Date	Days Lapsed	Reporting_Group	Developed_Nation_Status
160416_Equador_EEFIT.pdf	Equador	0	7.8	4/16/16	9/1/18	868.00	EEFIT	0
160416_Equador_EERI.pdf			7.8	4/16/16	10/1/16	168.00	EERI	0
160416_Equador_GEER.pdf			7.8	4/16/16	10/14/16	181.00	GEER	0
160414_Japan_EEFIT.pdf	Japan	1	7.1	4/14/16			EEFIT	1
160414_Japan_Private.pdf			7.1	4/14/16	4/29/16	15.00	Private Entity	1
160414_Japan_TCLEE.pdf			7.1	4/14/16	5/7/17	388.00	Other - Engineering	1
160414_Japan_UniversityOfTokyo.pdf			7.1	4/14/16	4/24/16	10.00	Academic Group	1
160824_Italy_EEFIT.pdf	Italy	0	6.2	8/24/16	5/1/19	980.00	EEFIT	1
161207_Indonesia_EERI.pdf	Indonesia	0	6.5	12/7/16	5/1/17	145.00	EERI	0
170907_Mexico_Miyamoto.pdf	Mexico	0	8.1	9/7/17			Other - Engineering	0
170919_Mexico_GEER.pdf			8.1	9/7/17			GEER	0
171112_Iran_EERI.pdf	Iran	0	7.3	11/12/17	2/1/18	81.00	EERI	0
180928_Indonesia_EuropeanCommission.pdf	Indonesia	0	7.5	9/28/18	10/1/18	3.00	Governmental Group	0
181130_USA_GEER.pdf	USA	0	7	11/30/18			GEER	1
181130_USA_StEER.pdf			7	11/30/18	12/6/18	6.00	StEER	1
190704_USA_GEER.pdf	USA	1	7.1	7/5/19	8/1/19	27.00	GEER	1
190704_USA_StEER.pdf			7.1	7/5/19	7/8/19	3.00	StEER	1

File Name	Disruption	Power_Disrupt	BU_Power	PotWater_Disrupt	BU_PotWater	WasteWater_Disrupt	BU_WasteWater	Comm_Disrupt	BU_Comm	Gas_Disrupt	BU_Gas	Length-Disrupt
000504_Indonesia_EERI.pdf												
010228_USA_UniversityOfWashington.pdf	1							1				
010623_Peru_EERI.pdf												
021102_Indonesia_EERI.pdf												
030501_Turkey_BU.pdf	1	1		0		0		1				5
030501_Turkey_EERI.pdf	1	1		0		0		1				5
030501_Turkey_EERI_2.pdf												
030501_Turkey_KOERI.pdf												
030521_Algeria_EERI.pdf												
030927_Siberia_EERI.pdf	1			1								
031226_Iran_EERI.pdf												
040907_Argentina_EERI.pdf												
041226_IndianOcean_EEFIT.pdf												
041226_IndianOcean_EERI_2.pdf												

File Name	Disruption	Power_Disrupt	BU_Power	PotWater_Disrupt	BU_PotWater	WasteWater_Disrupt	BU_WasteWater	Comm_Disrupt	BU_Comm	Gas_Disrupt	BU_Gas	Length-Disrupt
041226_IndianOcean_EERI_3.pdf												
041226_IndianOcean_EERI.pdf												
041226_IndianOcean_IITK.pdf												
050613_Chile_DU.pdf												
051008_Pakistan_EEFIT.pdf												
051008_Pakistan_EERI.pdf												
051008_Pakistan_EERI_2.pdf												
060527_Indonesia_BAPPENAS.pdf												
061015_USA_EERI.pdf	1	1	0									
061015_USA_RMS.pdf												
061226_Taiwan_EERI.pdf												
070306_Indonesia_EERI.pdf												
070912_Indonesia_EERI.pdf												
070919_Peru_CISMID.pdf												
070919_Peru_EEFIT.pdf												
070919_Peru_EERI.pdf	1	1	0	1				1				

File Name	Disruption	Power_Disrupt	BU_Power	PotWater_Disrupt	BU_PotWater	WasteWater_Disrupt	BU_WasteWater	Comm_Disrupt	BU_Comm	Gas_Disrupt	BU_Gas	Length-Disrupt
070919_Peru_OCHA.pdf	1	1		1		1						
090406_Italy_EEFIT.pdf												
090406_Italy_NHC.pdf												
090930_Indonesia_EEFIT.pdf	1	1	0	1	0			1	0			10
090930_Indonesia_EERI.pdf	1	1	0	1	0							
100110_USA_EERI.pdf	1			0	1							
100112_Haiti_EEFIT.pdf												
100112_Haiti_EERI_2.pdf												
100112_Haiti_EERI_3.pdf	1	1		1		1						
100112_Haiti_EERI.pdf	1	1										
100112_Haiti_MRP.pdf												
100112_Haiti_USGS.pdf												
100227_Chile_EEFIT.pdf												
100227_Chile_EERI_2.pdf	1											
100227_Chile_EERI.pdf	1	1	0	1	0			1	1			3
100227_Chile_GEER.pdf												

File Name	Disruption	Power_Disrupt	BU_Power	PotWater_Disrupt	BU_PotWater	WasteWater_Disrupt	BU_WasteWater	Comm_Disrupt	BU_Comm	Gas_Disrupt	BU_Gas	Length-Disrupt
100304_Taiwan_EERI.pdf												
100404_Baja_EERI_2.pdf												
100404_Baja_EERI.pdf	1	1	0									
100404_Baja_USCD_2.pdf												
100903_NZ_EERI.pdf	1	1	0									0
110222_NZ_EEFIT.pdf												
110222_NZ_EERI.pdf	1	1	1									
110222_NZ_GEER.pdf	1									1	0	
110311_Japan_EEFIT.pdf												
110311_Japan_EERI_2.pdf												
110311_Japan_EERI_3.pdf												
110311_Japan_EERI.pdf												
110311_Japan_G&E.pdf	1			1	0							
110311_Japan_PEER.pdf												
110918_Nepal/India_EERI.pdf												
110918_Nepal/India_NICEE.pdf												

File Name	Disruption	Power_Disrupt	BU_Power	PotWater_Disrupt	BU_PotWater	WasteWater_Disrupt	BU_WasteWater	Comm_Disrupt	BU_Comm	Gas_Disrupt	BU_Gas	Length-Disrupt
110918_Nepal/India_tRGoB.pdf												
111023_Turkey_BU.pdf												
111023_Turkey_EERI.pdf												
111023_Turkey_IIEES.pdf												
111023_Turkey_Other.pdf												
120320_Mexico_EERI.pdf												
120905_CostaRica_RSN.pdf												
120911_Iran_IASPEI.pdf												
120911_Iran_IIEES.pdf												
121107_Guatemala_EERI.pdf												
130420_China_EERI.pdf												
130420_China_Other.pdf												
140126_Greece_GEER.pdf												
140824_USA_EERI.pdf	1	1	0									
140824_USA_FEMA.pdf	1	1	0	1	1							0
140824_USA_Other.pdf	1	1	0									

File Name	Disruption	Power_Disrupt	BU_Power	PotWater_Disrupt	BU_PotWater	WasteWater_Disrupt	BU_WasteWater	Comm_Disrupt	BU_Comm	Gas_Disrupt	BU_Gas	Length-Disrupt
150425_Nepal_CEDIM.pdf	1	1										
150425_Nepal_EEFIT.pdf												
150425_Nepal_EERI.pdf	1	1	0	1	0			0				7
150425_Nepal_HFG.pdf	1	1		1								
150425_Nepal_Other_2.pdf	1	1	0	1				0				
150425_Nepal_Other.pdf	1	1		1								
150916_Chile_CIGIDEN.pdf												
151026_Pakistan/Afghanistan_OCHA.pdf												
160206_Taiwan_GEER.pdf												
160416_Equador_EEFIT.pdf												
160416_Equador_EERI.pdf												
160416_Equador_GEER.pdf	1	1										
160414_Japan_EEFIT.pdf												
160414_Japan_Private.pdf	1	1	0									5
160414_Japan_TCLEE.pdf	1	1		1						1		
160414_Japan_UniversityOfTokyo.pdf												

File Name	Disruption	Power_Disrupt	BU_Power	PotWater_Disrupt	BU_PotWater	WasteWater_Disrupt	BU_WasteWater	Comm_Disrupt	BU_Comm	Gas_Disrupt	BU_Gas	Length-Disrupt
160824_Italy_EEFIT.pdf	1							0				
161207_Indonesia_EERI.pdf												
170907_Mexico_Miyamoto.pdf												
170919_Mexico_GEER.pdf												
171112_Iran_EERI.pdf	1	1										
180928_Indonesia_EuropeanCommission.pdf	1	1						1				
181130_USA_GEER.pdf	1	1	0									
181130_USA_StEER.pdf	1	1								1		
190704_USA_GEER.pdf												
190704_USA_StEER.pdf												

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
000504_Indonesia_EERI.pdf	1	2												
010228_USA_UniversityOfWashington.pdf	1	1	0	1										
010623_Peru_EERI.pdf	1	2	1	1										
021102_Indonesia_EERI.pdf														
030501_Turkey_BU.pdf	1	2												
030501_Turkey_EERI.pdf														
030501_Turkey_EERI_2.pdf							1	1						
030501_Turkey_KOERI.pdf							1	2		1				
030521_Algeria_EERI.pdf	1	2					1	3						
030927_Siberia_EERI.pdf	1	3												
031226_Iran_EERI.pdf							1	3	1	1				
040907_Argentina_EERI.pdf							1	3						
041226_IndianOcean_EEFIT.pdf	1	2					1	2	1					
041226_IndianOcean_EERI_2.pdf	1	2												

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
041226_IndianOcean_EERI_3.pdf	1	2												
041226_IndianOcean_EERI.pdf	1	2												
041226_IndianOcean_IITK.pdf	1	2												
050613_Chile_DU.pdf	1	1												
051008_Pakistan_EEFIT.pdf	1	3												
051008_Pakistan_EERI.pdf	1	3					1	3	1	1	1			
051008_Pakistan_EERI_2.pdf	1	2	1											
060527_Indonesia_BAPPENAS.pdf	1	2												
061015_USA_EERI.pdf	1	2		1			1	2	1		1			
061015_USA_RMS.pdf							1	2			1			
061226_Taiwan_EERI.pdf	1	1	1	1	0									
070306_Indonesia_EERI.pdf														
070912_Indonesia_EERI.pdf	1			1			1	3			1			
070919_Peru_CISMID.pdf	1	2												

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
070919_Peru_EEFIT.pdf							1	2	0					
070919_Peru_EERI.pdf							1	2	0	1	1			
070919_Peru_OCHA.pdf	1	2			1	2	1	2						
090406_Italy_EEFIT.pdf							1	3		1	1			
090406_Italy_NHC.pdf							1	3		1				
090930_Indonesia_EEFIT.pdf	1	2					1	2	0	1	1	1	2	
090930_Indonesia_EERI.pdf	1	2					1	2		1	1	1	1	
100110_USA_EERI.pdf							1	0		0	1	0		
100112_Haiti_EEFIT.pdf							1	2	0					
100112_Haiti_EERI_2.pdf	1	2					1	3		1				
100112_Haiti_EERI_3.pdf	1	2		1	1	3	1	3		1				
100112_Haiti_EERI.pdf	1	2												
100112_Haiti_MRP.pdf							1	3		1				
100112_Haiti_USGS.pdf	1	2					1	2	1	1	1			
100227_Chile_EEFIT.pdf							1	2	0					

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
100227_Chile_EERI_2.pdf	1	2	1	1	1	2								
100227_Chile_EERI.pdf	1	2	1	1	1	2	1	2	0	1	1			
100227_Chile_GEER.pdf	1	2					1	1		1	1			
100304_Taiwan_EERI.pdf	1	1		1										
100404_Baja_EERI_2.pdf							1	2			1			
100404_Baja_EERI.pdf							1	2		0	1	1	1	
100404_Baja_USCD_2.pdf							1		1	0	1			
100903_NZ_EERI.pdf	1	0					1	0			1			
110222_NZ_EEFIT.pdf							1	0	1	1				
110222_NZ_EERI.pdf							1	1	1	1	1			
110222_NZ_GEER.pdf														
110311_Japan_EEFIT.pdf	1	2					1	3			1			
110311_Japan_EERI_2.pdf							1	2	0		1			
110311_Japan_EERI_3.pdf	1	3												
110311_Japan_EERI.pdf														

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
110311_Japan_G&E.pdf														
110311_Japan_PEER.pdf	1	2		1	1	3								
110918_Nepal/India_EERI.pdf	1	2	1	1										
110918_Nepal/India_NICEE.pdf	1	2												
110918_Nepal/India_tRGoB.pdf	1	0												
111023_Turkey_BU.pdf	1	1	0				1	1						
111023_Turkey_EERI.pdf							1	2	0		1			
111023_Turkey_IIEES.pdf	1	1					1	2						
111023_Turkey_Other.pdf	1	2		1										
120320_Mexico_EERI.pdf							1	1	0	1	1			
120905_CostaRica_RSN.pdf							1	2						
120911_Iran_IASPEI.pdf	1	2					1	3	1	1	1			
120911_Iran_IIEES.pdf							1	3	0	0	1			
121107_Guatemala_EERI.pdf	1	2	1				1	3	1	1	1			
130420_China_EERI.pdf							1	1						

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
130420_China_Other.pdf	1	1												
140126_Greece_GEER.pdf							1	3						
140824_USA_EERI.pdf							1	1		1	1			
140824_USA_FEMA.pdf	1	1	0	1			1	1	1	1	1	1	1	1
140824_USA_Other.pdf							1	1		1	1			
150425_Nepal_CEDIM.pdf							1	3						
150425_Nepal_EEFIT.pdf	1	2	1				1	3		1				
150425_Nepal_EERI.pdf	1	2	1	1	1	2								
150425_Nepal_HFG.pdf							1	3						
150425_Nepal_Other_2.pdf	1	2			1	3	1	3		1	1	1	1	
150425_Nepal_Other.pdf	1	3			1	3	1	3	1	1				
150916_Chile_CIGIDEN.pdf	1	1		1			1	2			1			
151026_Pakistan/Afghanistan_OCHA.pdf	1	0	0											
160206_Taiwan_GEER.pdf							1	0			1			

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
160416_Equador_EEFIT.pdf							1	2		1	1			
160416_Equador_EERI.pdf	1	2	1	1			1	3	0	1	1			
160416_Equador_GEER.pdf	1	2	1	1			1	3		1	1	1	2	
160414_Japan_EEFIT.pdf	1	2		1			1	3			1			
160414_Japan_Private.pdf							1	1		1	1	1	1	
160414_Japan_TCLEE.pdf	1	1	1		1									
160414_Japan_UniversityOfTokyo.pdf							1			1	1			
160824_Italy_EEFIT.pdf							1	2		1	1			
161207_Indonesia_EERI.pdf							1	3						
170907_Mexico_Miyamoto.pdf							1	2		1	1			
170919_Mexico_GEER.pdf	1	2					1	2						
171112_Iran_EERI.pdf							1	3			1			
180928_Indonesia_EuropeanCommission.pdf														
181130_USA_GEER.pdf							1	1			1	1	0	

File Name	HCS	HCS_Functionality2	HCS_Damage_Structural	HCS_Damage_Non-Structural	HCS_Damage_Lifeline	HCS_Damage_Lifeline_LV	H	H_Functionality	H_Functionality_Majority	H_Damage_Structural	H_Damage_Non-Structural	H_Damage_Lifeline	H_Damage_Lifeline_LV	H_Damage_Lifeline_LV_Majority
181130_USA_StEER.pdf	1	1		1			1	2	0	1	1	1	1	
190704_USA_GEER.pdf							1	3		0	1			
190704_USA_StEER.pdf														

File Name	HCS_Evacuation_Status	HCS_Evacuation_Status_LV	HCS_Evacuation_Lifelines	HCS_Evacuation_Lifelines_Specific	H_Evacuation_Status	H_Evacuation_Status_LV	H_Evacuation_Lifelines	H_Evacuation_Lifelines_Specific
000504_Indonesia_EERI.pdf								
010228_USA_UniversityOfWashington.pdf								
010623_Peru_EERI.pdf								
021102_Indonesia_EERI.pdf					1	1		
030501_Turkey_BU.pdf					1	1	0	
030501_Turkey_EERI.pdf					1	1	0	
030501_Turkey_EERI_2.pdf								
030501_Turkey_KOERI.pdf								
030521_Algeria_EERI.pdf								
030927_Siberia_EERI.pdf								
031226_Iran_EERI.pdf								
040907_Argentina_EERI.pdf								
041226_IndianOcean_EEFIT.pdf								
041226_IndianOcean_EERI_2.pdf								
041226_IndianOcean_EERI_3.pdf								
041226_IndianOcean_EERI.pdf								
041226_IndianOcean_IITK.pdf								
050613_Chile_DU.pdf								
051008_Pakistan_EEFIT.pdf								
051008_Pakistan_EERI.pdf					1	1	0	
051008_Pakistan_EERI_2.pdf								

File Name	HCS_Evacuation_Status	HCS_Evacuation_Status_LV	HCS_Evacuation_Lifelines	HCS_Evacuation_Lifelines_Specific	H_Evacuation_Status	H_Evacuation_Status_LV	H_Evacuation_Lifelines	H_Evacuation_Lifelines_Specific
060527_Indonesia_BAPPENAS.pdf								
061015_USA_EERI.pdf					1	1	0	
061015_USA_RMS.pdf					1	1		
061226_Taiwan_EERI.pdf								
070306_Indonesia_EERI.pdf	1	1						
070912_Indonesia_EERI.pdf								
070919_Peru_CISMID.pdf								
070919_Peru_EEFIT.pdf					1	1		
070919_Peru_EERI.pdf					1	1	0	
070919_Peru_OCHA.pdf								
090406_Italy_EEFIT.pdf					1	1	0	
090406_Italy_NHC.pdf								
090930_Indonesia_EEFIT.pdf					1	1		
090930_Indonesia_EERI.pdf								
100110_USA_EERI.pdf								
100112_Haiti_EEFIT.pdf								
100112_Haiti_EERI_2.pdf								
100112_Haiti_EERI_3.pdf	1	1	0					
100112_Haiti_EERI.pdf								
100112_Haiti_MRP.pdf								
100112_Haiti_USGS.pdf								
100227_Chile_EEFIT.pdf								

File Name	HCS_Evacuation_Status	HCS_Evacuation_Status_LV	HCS_Evacuation_Lifelines	HCS_Evacuation_Lifelines_Specific	H_Evacuation_Status	H_Evacuation_Status_LV	H_Evacuation_Lifelines	H_Evacuation_Lifelines_Specific
100227_Chile_EERI_2.pdf	1	1						
100227_Chile_EERI.pdf	1	1			1	1	0	
100227_Chile_GEER.pdf								
100304_Taiwan_EERI.pdf								
100404_Baja_EERI_2.pdf					1	0	0	
100404_Baja_EERI.pdf	1	1	0		1	0	0	
100404_Baja_USCD_2.pdf					1	0	0	
100903_NZ_EERI.pdf								
110222_NZ_EEFIT.pdf								
110222_NZ_EERI.pdf					1	0	1	
110222_NZ_GEER.pdf								
110311_Japan_EEFIT.pdf					1	1	0	
110311_Japan_EERI_2.pdf								
110311_Japan_EERI_3.pdf								
110311_Japan_EERI.pdf	1	1						
110311_Japan_G&E.pdf								
110311_Japan_PEER.pdf								
110918_Nepal/India_EERI.pdf								
110918_Nepal/India_NICEE.pdf								
110918_Nepal/India_tRGoB.pdf								
111023_Turkey_BU.pdf								
111023_Turkey_EERI.pdf								
111023_Turkey_IIEES.pdf								

File Name	HCS_Evacuation_Status	HCS_Evacuation_Status_LV	HCS_Evacuation_Lifelines	HCS_Evacuation_Lifelines_Specific	H_Evacuation_Status	H_Evacuation_Status_LV	H_Evacuation_Lifelines	H_Evacuation_Lifelines_Specific
111023_Turkey_Other.pdf								
120320_Mexico_EERI.pdf					1	1	0	
120905_CostaRica_RSN.pdf								
120911_Iran_IASPEI.pdf								
120911_Iran_IIEES.pdf								
121107_Guatemala_EERI.pdf	1	1	0					
130420_China_EERI.pdf								
130420_China_Other.pdf								
140126_Greece_GEER.pdf					1	1	0	
140824_USA_EERI.pdf								
140824_USA_FEMA.pdf								
140824_USA_Other.pdf								
150425_Nepal_CEDIM.pdf								
150425_Nepal_EEFIT.pdf					1	1	0	
150425_Nepal_EERI.pdf	1	1						
150425_Nepal_HFG.pdf								
150425_Nepal_Other_2.pdf	1	1			1	1	0	
150425_Nepal_Other.pdf								
150916_Chile_CIGIDEN.pdf					1	1	0	
151026_Pakistan/Afghanistan_OCHA.pdf								
160206_Taiwan_GEER.pdf								
160416_Equador_EEFIT.pdf								
160416_Equador_EERI.pdf	1	1	0		1	1	0	

File Name	HCS_Evacuation_Status	HCS_Evacuation_Status_LV	HCS_Evacuation_Lifelines	HCS_Evacuation_Lifelines_Specific	H_Evacuation_Status	H_Evacuation_Status_LV	H_Evacuation_Lifelines	H_Evacuation_Lifelines_Specific
160416_Equador_GEER.pdf					1	1	0	
160414_Japan_EEFIT.pdf					1	1	0	
160414_Japan_Private.pdf								
160414_Japan_TCLEE.pdf								
160414_Japan_UniversityOfTokyo.pdf								
160824_Italy_EEFIT.pdf					1	1		
161207_Indonesia_EERI.pdf					1	1	0	
170907_Mexico_Miyamoto.pdf								
170919_Mexico_GEER.pdf								
171112_Iran_EERI.pdf								
180928_Indonesia_EuropeanCommission.pdf								
181130_USA_GEER.pdf								
181130_USA_StEER.pdf								
190704_USA_GEER.pdf								
190704_USA_StEER.pdf					1	1	0	

Appendix E: R Code

```
library(MASS)
library(pander)
library(Hmisc)

data <- read.csv("Dataset.csv", header = TRUE)

data$HCS_Functionality2 <- factor(data$HCS_Functionality2)
data$H_Functionality <- factor(data$H_Functionality)

disruption_reported <- mean(data$Magnitude[data$Event.Level==1], na.rm = TRUE)
disruption_reported_min <- min(data$Magnitude[data$Event.Level==1], na.rm = TRUE)
disruption_reported_max <- max(data$Magnitude[data$Event.Level==1], na.rm = TRUE)
disruption_reported_sd <- sd(data$Magnitude[data$Event.Level==1], na.rm = TRUE)

Lifeline_disruption_reported <- mean(data$Magnitude[data$HCS_Damage_Lifeline == 1|
data$H_Damage_Lifeline == 1], na.rm = TRUE)
Lifeline_disruption_reported_sd <- sd(data$Magnitude[data$HCS_Damage_Lifeline == 1|
data$H_Damage_Lifeline == 1], na.rm = TRUE)
Lifeline_disruption_reported_min <- min(data$Magnitude[data$HCS_Damage_Lifeline == 1|
data$H_Damage_Lifeline == 1], na.rm = TRUE)
Lifeline_disruption_reported_max <- max(data$Magnitude[data$HCS_Damage_Lifeline == 1|
data$H_Damage_Lifeline == 1], na.rm = TRUE)

Healthcaresystem_functionality <- mean(data$HCS_Damage_Lifeline_LV, na.rm = TRUE)
Healthcaresystem_functionality_sd <- sd(data$HCS_Damage_Lifeline_LV, na.rm = TRUE)

Hospital_functionality <- mean(data$H_Damage_Lifeline_LV, na.rm = TRUE)
Hospital_functionality_sd <- sd(data$H_Damage_Lifeline_LV, na.rm = TRUE)
```

```
Time_laspe <- mean(data$Days.Lapsed, na.rm = TRUE)
Time_laspe_sd <- sd(data$Days.Lapsed, na.rm = TRUE)

Report_number_1 <- mean(data$Magnitude[data$Number_Reports == 1], na.rm = TRUE)
Report_number_1_sd <- sd(data$Magnitude[data$Number_Reports == 1], na.rm = TRUE)
Report_number_2 <- mean(data$Magnitude[data$Number_Reports == 2], na.rm = TRUE)
Report_number_2_sd <- sd(data$Magnitude[data$Number_Reports == 2], na.rm = TRUE)
Report_number_3 <- mean(data$Magnitude[data$Number_Reports == 3], na.rm = TRUE)
Report_number_3_sd <- sd(data$Magnitude[data$Number_Reports == 3], na.rm = TRUE)
Report_number_4 <- mean(data$Magnitude[data$Number_Reports == 4], na.rm = TRUE)
Report_number_4_sd <- sd(data$Magnitude[data$Number_Reports == 4], na.rm = TRUE)
Report_number_5 <- mean(data$Magnitude[data$Number_Reports == 5], na.rm = TRUE)
Report_number_5_sd <- sd(data$Magnitude[data$Number_Reports == 5], na.rm = TRUE)
Report_number_6 <- mean(data$Magnitude[data$Number_Reports == 6], na.rm = TRUE)
Report_number_6_sd <- sd(data$Magnitude[data$Number_Reports == 6], na.rm = TRUE)
```

Works Cited

Achour, N., Miyajima, M., Kitaura, M., & Price, A. (2011). Earthquake-Induced Structural and Nonstructural Damage in Hospitals. *Earthquake Spectra*, *27*(3), 617–634. https://doi.org/10.1193/1.3604815

Achour, N., Miyajima, M., Pascale, F., & D.F. Price, A. (2014). Hospital resilience to natural hazards: Classification and performance of utilities. *Disaster Prevention and Management: An International Journal*, *23*(1), 40–52. https://doi.org/10.1108/DPM-03-2013-0057

Al-Shaqsi, S., Gauld, R., Lovell, S., McBride, D., Al-Kashmiri, A., & Al-Harthy, A. (2013). Challenges of the New Zealand healthcare disaster preparedness prior to the Canterbury earthquakes: A qualitative analysis. *The New Zealand Medical Journal*, *126*(1371), 9–18.

Ardagh, M. W., Richardson, S. K., Robinson, V., Than, M., Gee, P., Henderson, S., Khodaverdi, L., McKie, J., Robertson, G., Schroeder, P. P., & Deely, J. M. (2012). The initial health-system response to the earthquake in Christchurch, New Zealand, in February, 2011. *The Lancet*, *379*(9831), 2109–2115. https://doi.org/10.1016/S0140-6736(12)60313-4

Bagaria, J., Heggie, C., Abrahams, J., & Murray, V. (2009). Evacuation and Sheltering of Hospitals in Emergencies: A Review of International Experience. *Prehospital and Disaster Medicine*, *24*(5), 461–467. https://doi.org/10.1017/S1049023X00007329

Cimellaro, G. P., Solari, D., & Bruneau, M. (2014). Physical infrastructure interdependency and regional resilience index after the 2011 Tohoku Earthquake in Japan: INFRASTRUCTURE INTERDEPENDENCY AND REGIONAL RESILIENCE INDEX. *Earthquake Engineering & Structural Dynamics*, *43*(12), 1763–1784. https://doi.org/10.1002/eqe.2422

Critical Infrastructure Sectors. (2020, March 24). [Governmental]. Official Website of the Department of Homeland Security. https://www.cisa.gov/critical-infrastructure-sectors

de la Llera, J. C., Rivera, F., Mitrani-Reiser, J., Jünemann, R., Fortuño, C., Ríos, M., Hube, M., Santa María, H., & Cienfuegos, R. (2017). Data collection after the 2010 Maule earthquake in Chile. *Bulletin of Earthquake Engineering*, *15*(2), 555–588. https://doi.org/10.1007/s10518-016-9918-3

Doocy, S., Daniels, A., Packer, C., Dick, A., & Kirsch, T. D. (2013). The Human Impact of Earthquakes: A Historical Review of Events 1980-2009 and Systematic Literature Review. *PLoS Currents*. https://doi.org/10.1371/currents.dis.67bd14fe457f1db0b5433a8ee20fb833

Dueñas-Osorio, L., & Kwasinski, A. (2012). Quantification of Lifeline System Interdependencies after the 27 February 2010 M_w 8.8 Offshore Maule, Chile, Earthquake. *Earthquake Spectra*, *28*(S1), S581–S603. https://doi.org/10.1193/1.4000054

Earthquake Engineering Research Institute. (2016). *About*. EERI Learning From Earthquakes. http://www.learningfromearthquakes.org/about

EERI. (2004). *The EERI Learning from Earthquakes Program: A Brief Synopsis of Major Contributions* (No. 2005–03; p. 31). EERI. http://www.learningfromearthquakes.org/images/Resources-and-Publications/Report_LFE_Contributions.pdf

Favier, P., Rivera, F., Poulos, A., Vásquez G., J., de la Llera, J., & Mitrani-Reiser, J. (2017). *Impact on Chilean Hospitals Following the 2015 Illapel Earthquake*.

Federal Emergency Management Agency. (2020, March 27). *Community Lifelines* [Governmental]. FEMA.Gov. https://www.fema.gov/lifelines

Jacques, C. C., McIntosh, J., Giovinazzi, S., Kirsch, T. D., Wilson, T., & Mitrani-Reiser, J. (2014). Resilience of the Canterbury Hospital System to the 2011 Christchurch Earthquake. *Earthquake Spectra*, *30*(1), 533–554. https://doi.org/10.1193/032013EQS074M

Kakderi, K., Argyroudis, S., & Pitilakis, K. (2011). State-of-the-art literature review of methodologies to assess the vulnerability of a “system of systems.” *Report, Aristotle University of Thessaloniki*.

Kirsch, T. D., Mitrani-Reiser, J., Bissell, R., Sauer, L. M., Mahoney, M., Holmes, W. T., Santa Cruz, N., & de la Maza, F. (2010). Impact on Hospital Functions Following the 2010 Chilean Earthquake. *Disaster Medicine and Public Health Preparedness*, *4*(2), 122–128. https://doi.org/10.1001/dmphp.4.2.122

Kjølle, G. H., Utne, I. B., & Gjerde, O. (2012). Risk analysis of critical infrastructures emphasizing electricity supply and interdependencies. *Reliability Engineering & System Safety*, *105*, 80–89. https://doi.org/10.1016/j.ress.2012.02.006

Kuwata, Y., & Takada, S. (2007). *Seismic risk assessment of lifeline considering hospital functions*.

Lambert, H. E. (1975). *Fault trees for decision making in systems analysis* (UCRL--51829, 4169124). https://doi.org/10.2172/4169124

Lee, W. S., Grosh, D. L., Tillman, F. A., & Lie, C. H. (1985). Fault Tree Analysis, Methods, and Applications ߝ A Review. *IEEE Transactions on Reliability*, *R-34*(3), 194–203. https://doi.org/10.1109/TR.1985.5222114

McGinty, M. D., Burke, T. A., Resnick, B., Barnett, D. J., Smith, K. C., & Rutkow, L. (2017). Decision Processes and Determinants of Hospital Evacuation and Shelter-in-Place During Hurricane Sandy: *Journal of Public Health Management and Practice*, *23*(1), 29–36. https://doi.org/10.1097/PHH.0000000000000404

Mieler, M. W., & Mitrani-Reiser, J. (2018). Review of the State of the Art in Assessing Earthquake-Induced Loss of Functionality in Buildings. *Journal of Structural Engineering*, *144*(3), 04017218. https://doi.org/10.1061/(ASCE)ST.1943-541X.0001959

Mitrani-Reiser, J., Mahoney, M., Holmes, W. T., de la Llera, J. C., Bissell, R., & Kirsch, T. (2012). A Functional Loss Assessment of a Hospital System in the Bío-Bío Province. *Earthquake Spectra*, *28*(S1), S473–S502. https://doi.org/10.1193/1.4000044

Myrtle, R. C., Masri, S. F., Nigbor, R. L., & Caffrey, J. P. (2005). Classification and Prioritization of Essential Systems in Hospitals under Extreme Events. *Earthquake Spectra*, *21*(3), 779–802. https://doi.org/10.1193/1.1988338

Nagata, T., Himeno, S., Himeno, A., Hasegawa, M., Lefor, A. K., Hashizume, M., Maehara, Y., & Ishii, M. (2017). Successful Hospital Evacuation After the Kumamoto Earthquakes, Japan, 2016. *Disaster Medicine and Public Health Preparedness*, *11*(5), 517–521. https://doi.org/10.1017/dmp.2016.180

Pacific Northwest Seismic Network. (n.d.). *Magnitude/Intensity*. Pacific Northwest Seismic Network. Retrieved April 29, 2020, from https://pnsn.org/outreach/about-earthquakes/magnitude-intensity

Pan-American Health Organization. (2000). *Principles of disaster mitigation in health facilities*. Pan American Health Organization [u.a.

Parmar, P., Arii, M., & Kayden, S. (2013). Learning From Japan: Strengthening US Emergency Care And Disaster Response. *Health Affairs*, *32*(12), 2172–2178. https://doi.org/10.1377/hlthaff.2013.0704

Piña, I. L., Cohen, P. D., Larson, D. B., Marion, L. N., Sills, M. R., Solberg, L. I., & Zerzan, J. (2015). A Framework for Describing Health Care Delivery Organizations and Systems. *American Journal of Public Health*, *105*(4), 670–679. https://doi.org/10.2105/AJPH.2014.301926

Porter, K., & Ramer, K. (2012). Estimating earthquake-induced failure probability and downtime of critical facilities. *Journal of Business Continuity & Emergency Planning*, *5*(4), 352–364. bth.

Reitherman, R. (1997). Contributions of Earthquake Reconnaissance to Improved Understanding of the Seismic Behavior of Nonstructural Components. *Proceedings of Structures Congress XV, Portland, OR*, 645–651.

Ridgecrest Hospital's Quake Damage Prompts Questions About State Seismic Standards. (2019, August 4). *CBS Local: San Francisco Bay Area*. https://sanfrancisco.cbslocal.com/2019/08/04/ridgecrest-hospital-quake-damage-seismic-standards/

Rinaldi, S. M., Peerenboom, J. P., & Kelly, T. K. (2001). Identifying, understanding, and analyzing critical infrastructure interdependencies. *IEEE Control Systems*, *21*(6), 11–25. https://doi.org/10.1109/37.969131

Robin Spence, A. (2014). The Full-Scale Laboratory: The Practice of Post-Earthquake Reconnaissance Missions and Their Contribution to Earthquake Engineering. In *Perspectives on european earthquake engineering and seismology: Volume 1* (Vol. 34, p. 52). Springer.

Ruijters, E., & Stoelinga, M. (2015). Fault tree analysis: A survey of the state-of-the-art in modeling, analysis and tools. *Computer Science Review*, *15–16*, 29–62. https://doi.org/10.1016/j.cosrev.2015.03.001

Santarsiero, G., Di Sarno, L., Giovinazzi, S., Masi, A., Cosenza, E., & Biondi, S. (2018).

Performance of the healthcare facilities during the 2016–2017 Central Italy seismic sequence. *Bulletin of Earthquake Engineering*. https://doi.org/10.1007/s10518-018-0330-z

Schultz, C. H., Koenig, K. L., & Lewis, R. J. (2003). Implications of Hospital Evacuation after the Northridge, California, Earthquake. *New England Journal of Medicine*, *348*(14), 1349–1355. https://doi.org/10.1056/NEJMsa021807

Staff, G. P. O., States, U., & Protection, U. S. P. C. on C. I. (1997). *Critical Foundations: Protecting America's Infrastructures: The Report of the President's Commission on Critical Infrastructure Protection*. The Commission. https://books.google.com/books?id=fFsay6uMwNkC

United Nations. (2019). *World Economic Situation and Prospects 2019*. UN. https://doi.org/10.18356/a97d12e3-en

Utne, I. B., Hokstad, P., & Vatn, J. (2011). A method for risk modeling of interdependencies in critical infrastructures. *Reliability Engineering & System Safety*, *96*(6), 671–678. https://doi.org/10.1016/j.ress.2010.12.006

Vasquez, A., Rivera, F., de la Llera, J., & Mitrani-Reiser, J. (2017). *Healthcare Network's Response and Resilience in Iquique after the 2014, Pisagua Earthquake*.

World Health Organization. (2006). *Health facility seismic vulnerability evaluation: A handbook*. World Health Organization (WHO).

Yavari, S., Chang, S. E., & Elwood, K. J. (2010). Modeling Post-Earthquake Functionality of Regional Health Care Facilities. *Earthquake Spectra*, *26*(3), 869–892. https://doi.org/10.1193/1.3460359