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Transportation Electrification and Hospital Emergency Planning

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BA with Distinction, University of Washington, 2005

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Because transportation in the San Francisco Bay Area is increasingly dependent on electricity, factors such as limited electricity storage capacity and nontransferability of batteries between vehicles need to be considered by emergency response planners (ERPs). The purpose of this study was to investigate planning for providing the power to provide emergency transportation for hospital staff/administration and those injured after earthquakes. The research questions of transportation need of emergency staff and patients after an earthquake and differences between Bay Area cities and counties in considering transportation needs were addressed in this qualitative study utilizing a collective case study to assess electric vehicle use as articulated in 48 public emergency management and health agency documents that discussed post-disaster transportation planning. Norris, Stevens, Pfefferbaum, Wyche, and Pfefferbaum's community resilience theory served as the theoretical lens for analyzing the impacts of electric transportation on hospitals. Some ERPs included transportation fuel in their documents, whereas ERPs specifically focused on transportation did not. The review, coding, and analysis yielded 2 primary themes: fuel for emergency planning is focused primarily on fuel for generators, with few documents discussing fuel for transportation; many documents lack currency with 28 updated before 2015 or not having an identifiable date. Community resilience from disruption is likely to lead to a state of vulnerability as well as a disconnection between community resilience theory and ERP planning. The implication for positive social change is to help Bay Area ERPs understand how to increase community resilience by including adaptation to changes in transportation fuel sources in their plans.

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Chapter 1: Introduction to the Study

Between 2011 and January 2017, 269,000 plug-in electric vehicles had been sold in California (California Plug-In Electric Vehicle Collaborative, 2017). In California, ground-based transportation is increasingly reliant on electricity as an alternative to hydrocarbon-based fuels, with an estimate of up to 3.5 million electric vehicles on the road by 2020 (California Energy Commission, 2012). Between 2012 and 2015, 49% of electric vehicle purchasers had graduate degrees, 34% had bachelor's degrees, and 10% had some level of college education (California Clean Vehicle Rebate Project, 2015). Hospital staff tend to have higher educational attainment than the general public, but they use ground-based transportation to get to work, which means that they are subject to barriers in ground-based transportation after a disaster (Adams & Berry, 2012; Frenk et al., 2010).

In this qualitative case study, I examined how city and county health care and transportation agencies consider the increased prevalence and reliance on electric transportation, including mass transit, in their plans. Without sufficient planning for this volume of electric vehicles, emergency hospital services after an earthquake are likely to be degraded, leading to a lower quality of care for impacted individuals, particularly those with higher social vulnerability (Schmidtlein, Shafer, Berry, & Cutter, 2011). There is a lack of relevant and recent studies on earthquakes and emergency services; studies have been focused on other major natural disasters where implications for significant infrastructure damage exist. However, areas outside of the San Francisco Bay Area (termed *the Bay Area* throughout this dissertation) have been studied for natural disaster impacts on transportation and included in the literature review to provide further breadth and support for the existing gap in the research that I addressed in my research. In Chapter 1, I provide a background and overview of the gap in the literature. In the rest of Chapter 1, I discuss the problem statement, study purpose, research questions, study framework, the qualitative nature of the study, definitions, assumptions, delimitations, and limitations, and the significance of the study.

Background

The Bay Area is home to more than 7.5 million people across Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma counties (U.S. Census Bureau, 2014b). As represented in Figure 1, the Bay Area is defined by the San Francisco Bay, which divides the area into San Francisco and the peninsula to the west, and the North, East, and South Bays respectively (Google Maps, 2015). According to the 2010 U.S. Census Bureau (2014a), San Francisco-Oakland-Fremont is the 11th largest metropolitan area in the United States, and San Jose, Sunnyvale, and Santa Clara is the 31st largest metropolitan area. Combined they would be the fifth largest area, after the Dallas, Fort Worth, and Arlington areas. The Port of Oakland is the fifth largest shipping port by containers in the United States (U.S. Department of Transportation, 2014). From north to south, the following bridges cross San Francisco Bay: Richmond, Bay, San Mateo, and Dumbarton. The Golden Gate Bridge runs north to south, connecting the North Bay with San Francisco.

Figure 1. Bay Area geography and major highways. From *San Francisco Bay Area bridges map en*, by A. Karnstedt, n.d. Creative Commons Attribution-ShareAlike 3.0.

As shown in Figure 1, Bay Area transportation is dependent on bridges to shorten travel distances. Without considering transportation limitations, more people may be placed at risk of not receiving adequate health care after a disaster, particularly the elderly and those living and working in older buildings more susceptible to damage (Peek-Asa et al., 1998). This is a concern because of the number of earthquakes that California experiences.

Natural disasters such as earthquakes pose a significant threat to lives and property. The three major earthquakes in the Bay Area since 1900 include the 1906 San

Francisco earthquake (with a 7.9 Richter scale magnitude that killed 3,000 people and caused over $500 million in damage), the 1989 Loma Prieta earthquake near Santa Cruz (with a 6.9 magnitude, injuring 3,800 and killing 63, $6 billion in damage; Durkin, Thiel, & Schneider, 1993; U.S. Geological Survey, 2014a), and the 2014 South Napa earthquake (with a 6.0 magnitude, which caused approximately $1 billion in damage; California Department of Conservation, 2013; U.S. Geological Survey, n.d.). One fatality and approximately 200 injuries were associated with the South Napa earthquake (Todorov, 2014). The Loma Prieta earthquake caused one section of the upper level of the eastern span of the Bay Bridge and the Cypress Street Viaduct in Oakland (a major section of a double deck roadway) to collapse, and it caused the closure of 11 bridges and numerous roads (Yashinsky, 1998). Other parts of California and the world have experienced similar disasters.

Outside of the Bay Area in California, other major earthquakes with large fatalities include the 1971 San Fernando earthquake, with 65 deaths and $50 million in damages, the 1933 earthquake near Long Beach, which killed 115, and the 1994 Northridge earthquake which killed 61 (California Department of Conservation, 2013). The Northridge earthquake also injured more than 9,000 people, damaged or collapsed 170 freeway bridges, and caused over $20 billion in economic harm (Updike et al., 1996). Table 1 identifies these selected earthquakes by Richter scale, years, fatalities, and cost. Values for fatalities and costs have some variation between the articles and the California Department of Conservation.

Table 1

Select Major California Earthquakes by Richter Scale, Year, Fatalities, and Cost

Name	Richter Scale	Year	Fatalities	Cost ($ million)
Loma Prieta	6.9	1989	63	6,000
Long Beach	6.4	1933	115	N/A
Northridge	6.7	1994	61	>15,000
San Fernando	6.5	1971	65	50
San Francisco	7.9	1906	>3,000	500
South Napa[a]	6.0[a]	2014[a]	1[b]	1,000[a]

Note. Data for earthquakes except the South Napa earthquake from California Department of Conservation (2017).

[a] California Department of Conservation, 2013; U.S. Geological Survey, n.d.

[b] Todorov, 2014

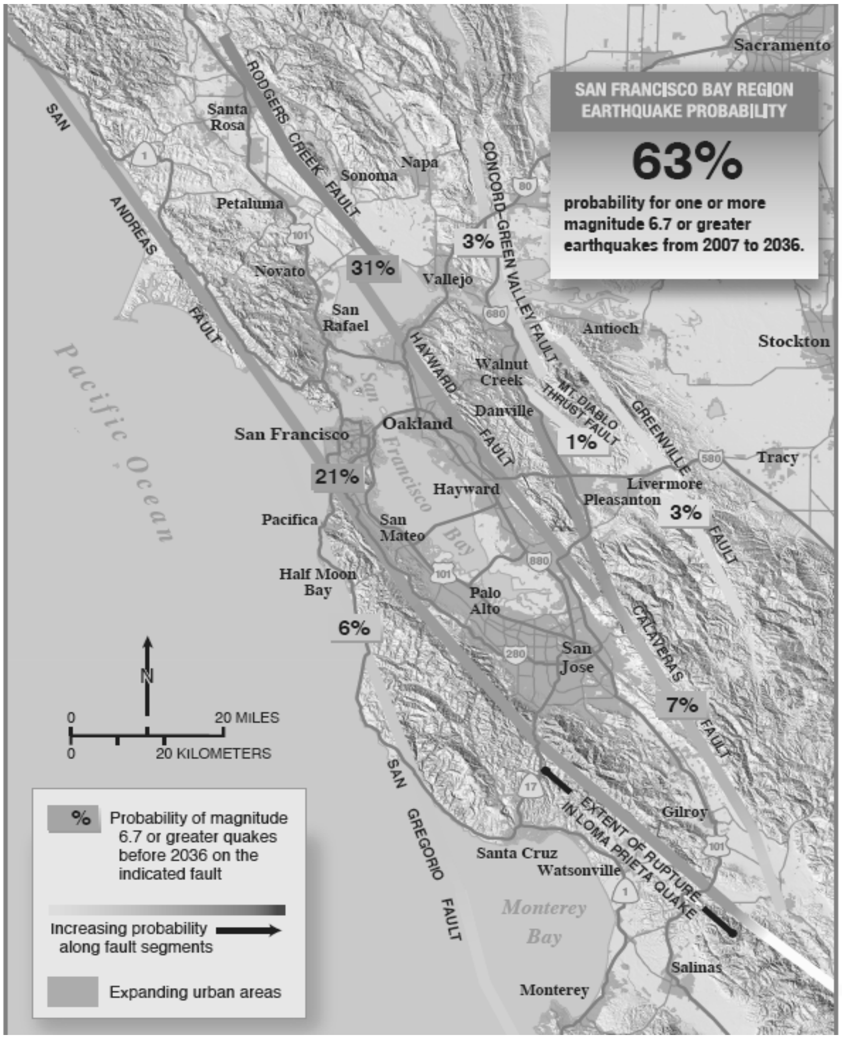

Figure 2. U.S. Geological Survey map of fault line rupture at 6.7 magnitude or greater chances between 2007 and 2036. (U.S. Geological Survey, 2012).

The sum of the probabilities of a 6.7 magnitude earthquake or greater in the Bay Area by 2036 is 63%. The major fault lines parallel the major north-south highways, and as demonstrated in the Loma Prieta earthquake can destroy east-west infrastructure a significant distance away from the rupture site. Figure 3 is a combined image of major highways, fault lines, and counties in the Bay Area. As shown, the major highways cross or run parallel to the major fault lines likely to rupture over the next decades.

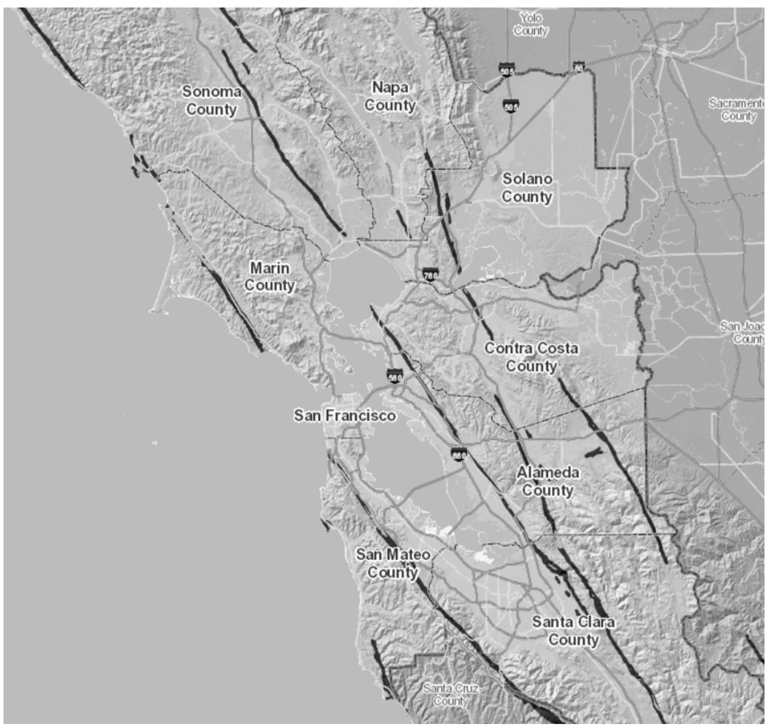

Figure 3. Bay Area map with major roadways in mid grey, earthquake fault lines in black, and counties identified (California Department of Conservation, 2012).

Damaged infrastructure, particularly transportation infrastructure, can play an important role in the ability of individuals to provide and receive medical care. The California Hospital Association (2011) provided guidelines for emergency management programs and an emergency operations plan that included several categories related to transportation. Transporting professional and technical staff as well as key administrators to hospitals in emergencies is essential to operations. Most studies on natural disaster preparedness have been focused on patients and supplies getting to hospitals or evacuations, as I will discuss further in Chapter 2 (Ardagh et al., 2012; Litman, 2006; Mieler & Brechwald, 2013; Paturas, Smith, Stewart, & Albanese, 2010; Sisiopiku, 2007).

However, determining the willingness and ability of staff/administrators to return to hospitals during natural disasters and identifying any barriers is also important. For example, Adams and Berry (2012) found in their survey of 1,342 staff that, depending on the scenario, between 10% and 30% of participants indicated they may not be able to report to work. Additionally, tornadoes or flooding ($p = .047$) had the lowest percentage of participants (75% with children able to report to work for tornadoes, and 68% with children able to report to work with flooding) who may report to work. One of the significant factors identified was transportation limitations by 200 or approximately 15% of participants (Adams & Berry, 2012).

Compounding a general transportation issue during disasters is the increasing use of electrified transportation, such as San Francisco Municipal Transportation Agency and Bay Area Rapid Transit (BART) or Caltrain, which include light and heavy rail and electric buses and cars. For safety reasons, even mass transit systems such as BART, which have backup systems to maintain core system functionality, can be shut down when power failures result in fans not operating and insufficient lighting in stations

(BART, 2005). Transportation systems are dependent on power (Procyk & Dhariwal (2010),and properly preparing for a disaster requires a hazard vulnerability analysis to prepare, respond, and recover from a disaster (Barbera & Macintyre, 2007). As electric transportation use increases, emergency response planners (ERPs) need to take the increased electric dependency and vehicle ranges into account. For the Bay Area, this means mass transit and electric cars in addition to more traditional vehicles that use petroleum-based fuels and other modes of transportation.

Problem Statement

Modes of transportation are subject to disruption during an earthquake or even during the normal course of events that can hamper transportation (BART, 2005). Approximately 280,000 cars, trucks, and motorcycles use the San Francisco–Oakland Bay Bridge daily (California Department of Transportation, 2015). Additionally, four hundred thousand people a day transit the San Francisco Bay using BART (BART, 2013). The San Francisco Municipal Transportation Agency (2014) reported 702,000 weekday boardings on average in 2014. Caltrain (2015) reported 58,000 average weekday boardings in 2014. The boardings for Caltrain more likely reflect two one-way trips per person, whereas the San Francisco Municipal Transit Authority boarding numbers likely reflect several transfers per person to get from the origination to destination and back. Finally, the California Center for Sustainable Energy (2013) reported that 39% of electric vehicle owners in California live in the Bay Area. Figure 4 shows many of the electric vehicle charging stations in California (U.S. Department of

Energy, 2016). BART relies on electricity to keep stations safe and power its trains (BART, 2015). The BART, Caltrain, and Municipal Transportation Agency ridership levels, combined with the growth of electric vehicle owners, demonstrate the vital role of electric transportation to the Bay Area.

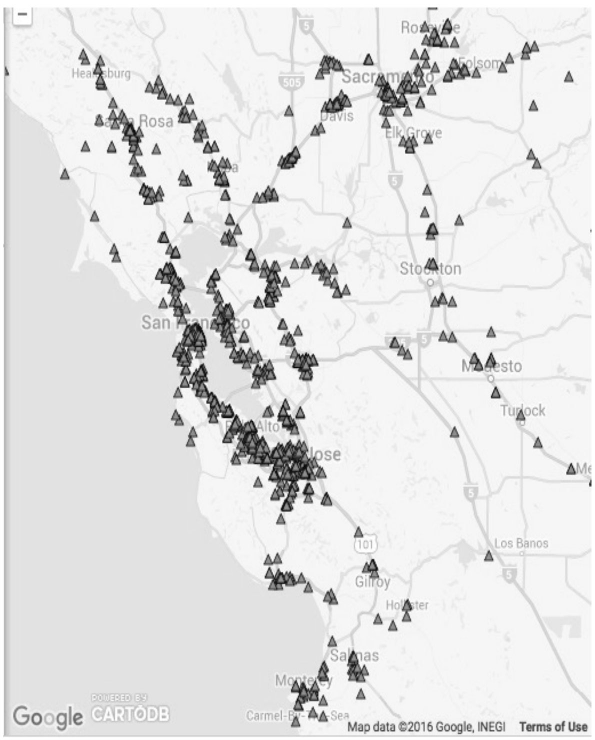

Figure 4. Bay Area map of electric vehicle charging stations (U.S. Department of Energy, 2016).

Emergency response planning for hospitals incorporates transportation issues but not always the implications of transportation choices. The California Hospital Association (2011) has provided an emergency checklist to help hospitals prepare for emergencies and disaster planning that has three elements regarding transportation. First is management of resources and assets, which includes transporting patients, records, staff/administrators, and supplies during an evacuation. Second is management of safety and security, which includes controlling access and movement (people and vehicles). Third is management of utilities, provision, sustainability, and alternate means of providing electricity and fuel.

Based on the literature review, few scholars have focused on how staff/administration may be able to arrive at hospitals after an earthquake or other types of disasters. Most notably, Hess, Bednarz, Bae, and Pierce (2011) examined petroleum shortage impacts on hospital staffing, but they did not consider how transportation reliant on electricity would further hinder or resolve problems caused by petroleum shortages. Additionally, Villez, Gupta, Venkatasubramanian, and Rieger (2011) explored the resiliency of vehicle recharging networks but focused more on smaller disruptions to the charging stations and distances to the next charging station rather than how a disaster like an earthquake can damage or destroy a broad area of infrastructure. In general, scholars on electric transportation have focused on meeting environmental objectives (Deakin, 2011; Deakin & Kim, 2001; Recker & Kang, 2010; Sikes, Hadley, McGill, & Cleary, 2010). Accordingly, there is a gap in transportation and emergency planning literature regarding the implications of increased electric transportation use. In particular, ERPs need to understand how existing and increased usage of electricity powered transportation will affect their emergency management programs, given that 52% of electric car owners have postgraduate degrees, and therefore, hospital staff are more likely to have an electric vehicle (California Center for Sustainable Energy, 2013). These concerns are grounded in public policy through emergency management and homeland security concerns as discussed by Longstaff (2005), who addressed security and resilience in the context of disasters or complex technologies.

Study Purpose

To assess the impacts of transportation electrification on emergency response planning as resulting from hospital staff/administration and potential patients using electric transportation, in this case study I examined data from 41 city and county-level organizations in the Bay Area. I compared the documentation from county and city departments of public health, departments of transportation, and emergency management departments to examine how and if electrified transportation is considered in the role of bringing hospital staff/administration and injured persons to hospitals.

A case study was appropriate because my central focus was on how public documents by county and city departments of public health, transportation, and emergency management document the impacts of transportation electrification on hospital emergency responses during and after an earthquake in the Bay Area. My case study was focused on what descriptions are in planning documents and the implications rather than on past events (see Yin, 2014). The study was bounded by the geography of the Bay Area and focused on city and county existing response plans during and after earthquakes.

Bay Area trauma centers are generally divided by geography yet are located closely enough that a major disaster could impact them all as demonstrated by the Loma

Prieta earthquake (Durkin et al., 1993). Within the Bay Area, the 13 trauma centers are bounded by Santa Rosa Memorial in the northwest, Kaiser in Vacaville in the northeast, Stanford University Hospital in the southwest, and Regional Medical Center of San Jose in the southeast (California Office of Statewide Health Planning and Development, 2010). Figure 5 shows the locations of the major trauma centers. Table 2 lists the Bay Area trauma centers including bed and type of trauma license according to the California Office of Statewide Health Planning and Development, from the greatest number of beds to the least. Level I centers can provide the highest degree of care including extensive in-house specialists and often have associated research centers, whereas Level III centers can provide most care though emergency doctors and general surgeons rather than the dedicated specialists in Level I and II centers (American Trauma Society, 2016).

Figure 5. Locations of major trauma centers in the Bay Area. Dark dots represent locations of the 13 major trauma centers in the Bay Area and the grey lines indicate major roadways (California Office of Statewide Health Planning and Development, 2010).

Table 2

Bay Area Trauma Centers by City, Number of Beds, and Trauma License

Name	City	Beds	License	Ped.
Stanford University Hospital	Palo Alto	613	I	II
Santa Clara Valley Medical Center	San Jose	574	I	II
John Muir Medical Center	Walnut Creek	572	II	
San Francisco General	San Francisco	539	I	
Alameda County Highland Medical Center	Oakland	286	II	
Santa Rosa Memorial	Santa Rosa	278	II	
Regional Medical Center of San Jose	San Jose	249	II	
Marin General	Greenbrae	235	III	
Queen of the Valley	Napa	211	III	
Children's Hospital of Oakland	Oakland	190		I
Kaiser	Vacaville	140	III	
North Bay Medical Center	Fairfield	132	III	
Eden Medical Center	Castro Valley	130	II	
	Total Beds:	4,149		

Trauma centers were an appropriate location for inclusion in the study because they among the primary locations where injured people will go or be taken, and the staff who can treat them, after a disaster (California Office of Statewide Health Planning and Development, 2010; Lee et al., 2016). Reviewing planning documents from city and county departments of health, transportation, and emergency management demonstrated how and the extent to which transportation electrification concerns are being considered in public forums.

Research Questions

The following research questions were driven by the gaps in the literature. There was a need to identify the aspects of transportation that limit health care access as well as measuring the impact of transportation policy and interventions (Syed, Gerber, and Sharp, 2013). Additionally, crisis care plans must include transportation and adequate staffing, and systems and processes are critical to meeting surge capacity (Hick, Barbera, and Kelen, 2013).

Research Question 1: From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, are key factors, if any, do they take into account when considering transportation needs of staff/administration reporting to work after an earthquake?

Research Question 2: From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, what are the key factors that they take into account when considering transportation needs of individuals needing assistance after an earthquake?

Research Question 3: What are the differences in the emergency response plans for electric transportation between cities and counties in the Bay Area?

Theoretical Framework

Preparedness is a core tenet of providing emergency response (California Hospital Association, 2011; Federal Emergency Management Agency, n.d.; McEntire, 2009). ERPs need to consider and understand what transportation modes hospital staff/administration use. How electrification of transportation is considered in ERP emergency planning drove the need for this collective case study comparing written and oral information. Norris, Stevens, Pfefferbaum, Wyche, and Pfefferbaum's (2007) community resilience served as the theoretical lens. Although Holling (1973) first developed the concept of resilience within ecological systems, Norris et al. applied resilience to communities and identified resilience as "processes linking a network of adaptive capacities (resources with dynamic attributes) to adaptation after a disturbance or adversity" (p. 127). A key component of the community resilience definition is the linkages in the network and that transportation can provide many of those linkages. For example, if individuals' transportation shifts from individual cars (or types of fuels) to ferries or trains, then a system would be fairly adaptive. However, with increasing electrification, the transportation system becomes more tightly linked to the electric grid, which is vulnerable to disruption because current storage capacities are limited. Accordingly, community resilience formed the foundation of the study.

Although resilience has many differing usages between the engineering and ecological contexts, the usage applied to this study began with Holling's (1973) work in the 1970s with a focus on human development. Since Holling's original work in the

1970s, resilience has evolved as the emergency management and homeland security fields sought new tools to examine how communities and infrastructure respond to crises. One emergent concern is what impact increasing efforts to electrify transportation will have on community resilience. The Bay Area is susceptible to disruption associated with earthquakes and is on the forefront of environmental and ecological issues. In Chapter 2, I discuss earthquakes and other disasters, transportation, and the role of community resilience in the present study. A collective case study approach allowed me to use the theoretical framework to examine several bounded examples to assess how ERPs and health care planning are taking into consideration a disruptive new form of technology, and how that technological change may impact the resilience of the communities that rely upon hospital services and may be affected by electric transportation.

Nature of the Study

The Bay Area departments of emergency management, health, and transportation were appropriate locations for a study on earthquake disaster resilience because they are the designated points for treating disaster-related injuries. I evaluated the perceptions of the ERPs, as measured through public documents located on 41 city and county websites. I conducted one type of data collection: review of policies and planning documents related to transportation and earthquake response. Document selection is covered in Chapter 3 on methodology.

Definition of Terms

Adaptive management: Decision-making based on an iterative learning process that is focused not only on changing a system but understanding the system itself. It was adapted from the ecological and engineering disciplines (Berkes & Ross, 2013; Engle, 2011; Gunderson, 2010; Holling, 1973; Whicker, Janecky, & Doerr, 2008; Wise, 2006).

Bay Area: The area surrounding San Francisco Bay. This includes (from north to south) Sonoma, Napa, Solano, Marin, Contra Costa, San Francisco, Alameda, San Mateo, and Santa Clara counties. There are 101 cities and towns in the Bay Area, including San Francisco and Oakland (Association of Bay Area Governments, 2013). Seven and a half million people live in the Bay Area (U.S. Census Bureau, 2014b).

Community: The structure of a group of people, including subpopulations, delineated by the group's linkages of either geography or between individuals (Adger, 2000; Cutter et al., 2008; Norris et al., 2007). All communities are not equal, and different parts of a community are more or less advantaged with resilience and resistance capabilities (Adger, 2000).

Community resilience: The capability of a community to quickly adapt and return to similar or improved function after a disruption, such as a natural disaster (Norris et al., 2007, p. 130).

Disaster: An acute event, over a short period of time, caused by natural, technological, or human causes that often leads to trauma (McFarlane & Norris, 2006, p. 4). In this study, a disaster generally referred to earthquakes unless otherwise noted.

Electric transportation: A type of alternative fuel used for vehicles, such as batteries or fuel cells, powered from the electrical grid (Deakin & Kim, 2001). This can include heavy and light rail systems such as BART and municipal rail, buses, and personal vehicles.

Emergency services providers: "Federal, State, and local governmental and nongovernmental . . . emergency medical (including hospital emergency facilities, and related personnel, agencies, and authorities." (6 U.S.C. § 101(6), 2016).

First responders: Includes police, fire, and emergency medical personnel (Public Safety and Homeland Security Bureau, n.d.).

Resilience: A changed end-state after a surprise event (Adger, 2000; Longstaff & Yang, 2008; Norris et al., 2007).

Resilience (ecological): The ability to return to a similar or improved level of overall system function, but not necessarily a stable state (Adger, 2000).

Resilience (engineering): Either a return to the previous state or to a new stable state after a disruption (Leveson et al., 2006).

Resistance: A postdisaster state where no change has occurred from the predisaster function (Longstaff, 2005; Longstaff & Yang, 2008).

Surge capacity: The capability to manage a sudden increase in hospital demands, typically after a major accident or disaster (Hick et al., 2013).

Vulnerability: An undesired outcome caused by a system becoming worse-off after a surprise and on a downward trajectory (Cutter, Boruff, & Shirley, 2003).

Vulnerability (social): "The exposure of groups of people or individuals to stress as a result of the impacts of environmental change" (Adger, 2000, p. 348).

Assumptions

This research was based on the following assumptions. The first assumption was that a significantly powerful earthquake will occur in or near the Bay Area that will damage infrastructure. On the Modified Mercalli scale, this would be a level VIII or greater earthquake. The Modified Mercalli scale is an arbitrary, nonmathematical intensity scale designed to help measure the impact of earthquakes (U.S. Geological Survey, 2014b). Level VIII is explained as "damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chmineys [sic], factory stacks, columns, monuments, walls. Heavy furniture overturned" (U.S. Geological Survey, 2013, para. 12). The Mercalli scale is a relative scale as ranked by human observation, as compared to the Richter scale, which is an absolute recorded measurement.

The second assumption was that documents with adequate responses would be available. Because confidential information was not collected for the study and the public nature of the documentation, there is no expectation that the documents would contain inaccurate statements or falsehoods. However, just because the documents are public does not mean they are valid (Cho & Trent, 2006). The third assumption was that available electronic or written materials would be current, accurate, and address the questions raised. The fourth assumption was that the electrified transportation I considered was purely electric, such as BART, and vehicles like the Nissan Leaf. Hybrid electric transportation, such as the Toyota Prius or electric-gas buses, can operate solely on gasoline, and thus have fewer range limitations when the electric grid or transportation networks fail, although gas pumps do require electricity to function.

Scope and Delimitations

The study was focused on electric transportation and the implications in a geographically constrained area. Geographically constrained areas in the United States, such as the Bay Area, also contain major population centers. This boundary narrowed the analysis to capture changes in transportation and impacts from an earthquake but may also provide value in addressing other geographically constrained areas.

The limited range and capabilities of electric transportation are not as significant to areas where there are many side roads and no major geographic obstacles hinder the movement of people. However, in an area like the Bay Area, the closure of one or two bridges or BART or ferry service can drastically increase the mileage needed to travel between locations (see Figure 1). The high cost of living in the Bay Area leads to increased reliance on transportation networks because people may live far away from their workplace. This phenomenon is demonstrated through the rise in workplace provided shuttles between Silicon Valley and other areas of the Bay Area (Dai & Weinzimmer, 2014). Additionally, regions constrained by large geographical barriers such as the San Francisco bay are likely to suffer from limitations of electrified transportation. Transportation limitations are important because doubling the transportation distance can affect whether an electric car can reach a destination without stoping to recharge. Examining the bridges connecting San Francisco reveals a driving commute from Berkeley to San Francisco changes from 15 miles to nearly 90 miles (assuming BART and ferries are out of service). However, with sufficiently high penetrations of electric vehicles, any widespread electrical disruption could impact an area.

Because the purpose of the study was to examine how ERPs consider the impacts of electrification as demonstrated through publicly available documentation, the plans of individuals who use electric transportation were not considered. Additionally, the relatively small population, even though drawn from a multientity approach, had a moderately low level of representation (see Creswell, 2009a). This delimitation was appropriate because the focus was on publicly available documentation related to transportation planning.

Limitations

Most research into transportation and disaster response has been focused on gas-powered transportation. ERPs have not started to incorporate the impacts of increasing reliance on electrification to meet environmental concerns and policy objectives. My study may not be generalized to areas with readily available alternative transportation networks—for example, areas like Las Vegas or Phoenix, where geography is not a substantial limitation for transportation. The focus on only pure-electric transportation, and the impacts may not be realized in all areas because of the expense of electric vehicles and their adoption in certain geographic regions. This creates a narrower study than if hybrid vehicles were also considered, which may limit the applicability of this research. Additionally, homeland security laws and regulations can restrict access to facility specific information or personnel.

Significance

The significance of the study was in understanding what changes to earthquake disaster management plans for emergency services providers are needed to account for future changes in transportation. Electrification is potentially a disruptive technology, just as the advent of the car was disruptive to emerging cities at the turn of the last century. Unless transportation planning changes to account for the shift to electrification, community resilience will be threatened.

The implication for positive social change is helping ERPs understand what planning changes may be necessary as transportation evolves to respond to individuals affected by a disaster such as an earthquake, thus bolstering community resilience. After earthquakes in California, a rush of patients to health care providers could occur, even in an earthquake with impacts that are relatively short-term (Shoaf, Nguyen, Sareen, & Bourque, 1998). Homeland security and emergency management efforts within public policy are focused on improving responses to disasters (Jellets, 2008; Litman, 2006; Longstaff, 2005; Paturas et al., 2010), which can include examining limitations to transportation. For California, it is only a matter of time before the next big earthquake strikes and damages the bridges linking various areas to one another.

Summary

In Chapter 1, I outlined the background, Bay Area policy context, and the terms for my case study. The Bay Area is vulnerable to large seismic events that can strain both electrical and transportation infrastructure, impacts that will likely increase because of California policies to promote electric transportation. Approximately 41 county- and city-level entities are tasked with planning how to serve the hospitals and trauma centers of the Bay Area. The response capabilities may be reduced if transportation capabilities are disrupted. Using a case study approach, I reviewed publicly available documents to identify any similarities and differences between the planning materials.

In Chapter 2, I describe the literature and key concepts germane to community resilience, disaster management, and transportation electrification. I also identify the gap in the literature to justify the study regarding the role of transportation in hospital staffing after an earthquake. In Chapter 3, I describe the methodological approach of a case study, including the sample and selection methodology, as well as storage, organization, coding, and analysis of the data. In Chapter 4, I describe the results of the case study and document review, including demographics, data collection and analysis, and evidence of trustworthiness. In Chapter 5, I discuss and interpret the findings, review the limitations that arose from the study, provide recommendation for further research, and discuss implication for social change.

Chapter 2: Literature Review

Introduction

Transportation electrification is increasing across the United States, but consideration of the electrification trend among the disaster planning, health care, and transportation sectors is still lacking. The purpose of this study was to understand the impacts of transportation electrification on emergency response planning resulting from hospital staff/administration and potential patients using electric transportation. My study was focused on the impacts to health care personnel and injured people arriving in Bay Area hospitals. I used document reviews to assess qualitatively how the present and expected future use of electric vehicles will pose a problem after an earthquake and what planning needs to occur. In Chapter 2, I describe my literature search strategy, the theoretical foundation, and key concepts before closing with a summary.

The literature since the end of the first decade of the century, as compared to the earlier or seminal literature, has been more focused on establishing frameworks within specific areas of community resilience. Earlier literature has established the broad frameworks, such as adaptive management or community resilience. However, transportation has played a critical role in the provision of health care, and health care is an important part of community resilience. The theoretical foundation for this study was based on work conducted first by Holling (1973) and more recently by Norris et al. (2007). Community resilience theory was selected because of the interactive nature and focus on finding the gaps in how communities respond after disasters. Community resilience provided a lens for simplifying the complexity inherent in systems to allow further study. Community resilience also provides the foundation under which transportation electrification can be examined, both before and after a disturbance.

Literature Search Strategy

I used digital databases for the literature search as well as the websites for the Association of Bay Area Governments, SPUR, and the University of California Transportation Center. For the digital databases, I conducted searches in Google Scholar, Political Science Complete, SAGE's Political Science Collection, ABI/INFORM Complete, the IEEE Xplore Digital Library, Science Direct, the Homeland Security Digital Library, and PubMed. The search, to the extent possible, was limited to peer-reviewed articles and to dissertations. Key search terms were *community resilience*, *resilience, community resilience and transportation, resilience and transportation, resilience and transportation and electricity, earthquake and electric vehicle*, and *lifeline transportation.* Major articles cited by 20 or more sources were the focus of my first search on community resilience. My second search was time-restricted to articles published since 2010. I examined the University of California Transportation Center's faculty research paper and policy brief websites going back to 2008, and dissertations going back to 2005. I searched SPUR's website for *resilience, electric,* and *vehicle*. Lastly, I searched the Association of Bay Area Government's website for *resilience, electric, vehicle* and also reviewed the electric vehicle readiness page. For reference to the methodological approach, as I discuss in Chapter 3, I read prominent texts on qualitative research from Anderson (2005), Patton (2002), Stebbins (2001), and Yin (2014).

Despite the expansiveness of the literature review search, I discovered little to no research about resilience and electric transportation. Therefore, I conducted additional searches on *security and electric vehicle*. These searches revealed articles on enhancing electrical grid reliability by using electric vehicles as a form of distributed generation, and on securing communications about the car's energy use. A search for *resilience* and *electric vehicle* or *electric transport* delivered similar results.

Theoretical Foundation

Community Resilience

Community resilience formed the core theory for the present study. Community resilience draws on engineering and ecology, combining both resilience and community to understand how different forces interact with the human system. Norris et al. (2007) applied community resilience to disaster management and outlined community resilience as a theory, a metaphor, capacities, and a strategy. Though the term *community* has many broad definitions, in the context of resilience, community is the structure of a group of people who are bound together by critical linkages of individuals or geographic areas (Adger, 2000; Norris et al., 2007). All communities are not equal, and different parts of a community will be more or less advantaged with resilience and resistance capabilities (Adger, 2000). It is also important to consider differences in resistance capabilities within subpopulations when assessing resilience (Cutter et al., 2008). Therefore, community is defined in the study as the structure of a group of people, including subpopulations, delineated by the group's linkages of either geography or between individuals.

Resilience, in contrast to community, draws on both physical and environmental sciences. As early as 1973, Holling applied resilience in the ecological context, though in 1676 the engineering concept of resilience was initially described by Robert Hooke (Leveson et al., 2006). In either context, resilience can be defined as how quickly a system can return to its previous state after disruption. Norris et al. (2007) described resilience as the capability to adapt to changes and that resilience is a capability, not an outcome, as well as "a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance" (p. 130). The restoration point differs between the engineering and ecological constructs.

In engineering, resilience can be either a return to the previous state or to a new stable state after a disruption (Leveson et al., 2006). In the ecological sense, resilience is not linked to stability but instead to overall system function for which there may be negative outcomes (Adger, 2000). Linking both the engineering and ecological realms, Bruneau et al. (2003) defined resilience as social units mitigating hazards, containing them, and then recovering while also working to lessen future impacts (p. 735). This link between engineering and social aspects are important because resilience, from the community resilience perspective, relates both to the physical resilience of the infrastructures relied on as well as the resilience of the people impacted by a crisis. Given localization and mobility, discussed later, both elements are critical for recovery from a crisis.

Major premise. The major premise of community resilience is that a crisis will lead to one of three results: (a) resistance, (b) resilience, or (c) vulnerability (Norris et al., 2007). Resistance is the best result to a crisis because no disruption occurs (Longstaff, 2005; Longstaff & Yang, 2008). In other words, the community has sufficiently strong resources and infrastructure that the disaster did not significantly impact. Resilience, on the other hand, is a changed end-state after a "surprise" event (Adger, 2000; Longstaff & Yang, 2008; Norris et al., 2007). With many alternatives available, such as alternative means of transportation, resilience may come quickly and may lead to a permanent change in the structure of a community or its infrastructure.

Alternatively, resilience could lead to a change in pattern or structure, such as relocating services or a more permanent shift in transportation patterns. Vulnerability is an undesired outcome because the system is worse-off after the surprise and is on a downward trajectory (Cutter et al., 2003). Social vulnerability, according to Adger (2000), "is the exposure of groups of people or individuals to stress as a result of the impacts of environmental change" (p. 348). For example, a disaster may leave parts of a community uninhabitable such as occurred after the Christchurch, New Zealand earthquakes in 2010 and 2011, which revealed unknown vulnerabilities in geology and construction (Cubrinovski et al., 2011). Accordingly, it is also important to examine the ecological roots of resilience and how the natural environment plays into community resilience.

Resilience. Resilience is tied into environmental and ecological factors. Under cases of extreme environmental factors, such as a disaster, migration of people can occur as a symptom of broken resilience (Adger, 2000). For example, examination of migration back to areas affected by Hurricane Katrina revealed statistically significant results based on "location-specific capital," an individual measure of ties to a community such as time lived in the community and family in that area (Groen & Polivka, 2010, p. 823). The linkages on the infrastructure end were less clear because restoration of services may have been a factor in migrants returning or a result of demand from migrants returning.

At the junction of community resilience and ecology is sustainability (Tobin, 1999). Social, economic, demographic, and climate change factors all pose challenges to the overall sustainability of a community (Cutter et al., 2008; Tobin, 1999). For example, Tobin (1999) studied Florida's response to disasters through the sustainability lens and found a conflict between hazard planning, environmental issues, and maintaining communities after disasters. Furthermore, policy to support social, economic, and demographic considerations may be misaligned with disaster knowledge, which may be partially caused by a lack of full autonomy (Magis, 2010) because many modern communities are linked to each other; therefore, what occurs in one community will impact another community. As an example, a community that does not improve bridge infrastructure may have a detrimental impact on all communities linked by that bridge if the bridge fails. The most resilient communities are those that feel the most empowered to guide their own fate as long as they are aware of the challenges they may face in the future (Magis, 2010). Additionally, at the core of community resilience is the ability to change and adapt, as suggested by Adger (2000), Magis, and Norris et al. (2007). Lastly, adaptation and resilience are further driven by specialization, which decreases resilience, and localization, which strengthens resilience (Adger, 2000).

Homeland security and emergency management. Resilience is an important concept to homeland security and emergency management, especially in understanding how disruptions are resolved (Department of Homeland Security, 2010). The best approaches to assessing the impact to communities have been under examination, particularly since Hurricane Katrina, but there is no consensus yet. For example, adaptive management has been used to address system restoration after a human disaster or a terrorist attack (Whicker et al., 2008), which is still applicable to other disasters such as an earthquake because the same issues of resistance, resilience, or vulnerability exist. Adaptive management has been determined as the best model for success using Hurricane Katrina as a case study (Wise, 2006), which includes both the ecological and human resilience as appropriate views in examining disaster responses (Gunderson, 2010). However, Engle (2011) directly assessed adaptive management outside of the ecological context, and separately from resilience, summarizing the problem as "adaptive capacity is a relatively under-researched topic within the sustainability science and global change communities, particularly since it is uniquely positioned to improve linkages between vulnerability and resilience research" (p. 647). Engle's sentiment was echoed by Berkes and Ross (2013), who also found the strong history of adaptive management in ecology but only within the last 15 years for localities and communities.

With sufficient forecast increases in electrical vehicle use, community resilience theory indicates that agencies should begin planning in order to be prepared for this shift in technology. In this sense, this study was designed to confirm either the occurrence of resilience or resistance or confirm the need to consider what other steps, such as robustness, redundancy, or rapidity of restoration need to be considered in establishing the capacity to deal with an earthquake. For example, the "Ready, Set, Charge, California" guidance document put together by Bay Area government, planning, and environmental advocacy groups does not include a single section on earthquake or disaster response, instead focusing on how to grow electric vehicle penetrations through electric rate design, Americans with Disabilities Act compliance, signage, and other such matters (Association of Bay Area Governments, Bay Area Climate Collaborative, Clean Fuel Connection, EV Communities Alliance, & LightMoves Consulting, 2011).

Literature Review of Key Concepts / Variables

As established in the National Health Security Strategy for the United States, transportation provides a key component for the provision of health services (Department of Health and Human Services, 2009). Health services in turn affect the health and resilience of a community. Broadly speaking, Bruneau et al. (2003) were amongst the first to describe and document the resilience equation and graph from a community resilience perspective. Qualitatively, a system begins in a stable state, is then disrupted leading to lower services, and then returns to some point of stability.

Most studies conducted to date have focused on broad generalizations of community resilience at a conceptual level rather than attempts to quantify the impacts or level of resilience. More current research, such as that conducted by Hick et al. (2013), Syed et al. (2013), and Hess, McDowell, and Luber (2011), has changed to incorporate quantification of resilience, rather than addressing resilience from a conceptual level. These authors focused on the present infrastructure state, not the future infrastructure state. However, compared to earlier studies, those three studies advanced community resilience assessments by narrowing down the examination to a specific area. These studies are consistent with the underlying Bruneau et al. (2003) approach and methodology, and the current study continued that trend. As part of the infrastructure impacting community resilience, emergency response and the ability to provide it plays an important role (Norris et al., 2007).

Infrastructure

Extending from Von Lubitz, Beakley, and Patricelli's (2008) all-hazards approach is the critical recognition of the importance in maintaining medical and water services as part of a community's resources. Hospital, electrical systems, and local emergency management were three of their five key areas for assessing community resilience. Morton and Lurie (2013) indicated that physical infrastructure needs to be combined with social capital for truly resilient communities to emerge, whereas Zhong et al. (2014)

observed the sparsity of good methods for assessing resilience in hospitals. Coming a few years ahead of Morton and Lurie (2013), Hess, McDowell et al. (2011) examined the health care sector finding that only environmental health was significantly covered, but not the impacts of petroleum shortages on transportation. Hess, McDowell et al. then assessed the impacts of petroleum shortages and found moderate short-term vulnerabilities, particularly for transportation, but expected larger vulnerabilities under long-term shortages. Similarly, Syed et al. (2013) found that transportation barriers were a significant barrier to health care access, even without the stress of a disaster on the system, and found that further research was needed on how much transportation limits health care access. Paturas et al. (2010) cautioned that during a major disaster, hospital staff absenteeism can exceed half of staff. Reliance upon electrified transportation could further increase absenteeism.

The approach of Syed et al. (2013), wherein transportation barriers to long-term health care were assessed, is most similar to this study. Syed et al. conducted searched peer-reviewed studies based on needs for ongoing health care given transportation barriers in the United States. The result was a 48-study matrix listing the author, population, methods, measure of transportation barriers, and results of the study. Importantly, the review discovered mixed evidence for distance from care and receiving the care; six studies found distance as a barrier, two found no difference, and one found a benefit from increased distance (p. 987). The approach undertaken, focusing on long-term and primary conditions, was one limitation, as it did not focus on acute conditions that may arise out of a disaster, as was another limitation assuming normal transportation conditions rather than disrupted conditions that may occur after a disaster. Many of the studies reviewed were also cross-sectional, limiting the ability of the authors to make strong conclusions. According to Mann (2003), cross-sectional designs are useful for discovering prevalence of a problem and identifying associations, but are weak in determining cause and effect. However, Syed et al. highlighted a key distinction: subjective questions indicated that distance was a burden, but objective measurement found distance to not be a barrier. In short, the type of transportation has a greater impact than distance travelled. Using a bus to travel ten miles is a much different proposition than using a car to travel the same distance. Cimellaro et al. (2011) identified several different calculations for assessing the impact of bridge closures, assuming there is an alternate path. In the Bay Area, there are alternate paths, but they can radically increase travel distance and time.

Hick et al. (2013), for example, focused on different definitions of hospital surge capacity needs, but still emphasized that they were establishing a framework for consideration of needs. Hick et al. approached the problem as a lack of good frameworks for establishing hospital response capabilities after a disaster. In their approach, Hick et al. started by critiquing the current approach and then proposed their own method based on certain definitions and broad approaches for categorizing surge capacity. The weakness to the Hick et al. approach is that although their components in responding are well documented, the three subsets of response are what they are developing. Without some case study, or a further step in analyzing the underlying capabilities, the authors were forced to rely upon sample calculations and the appropriateness or consensus within the field for their underlying model cannot be ascertained. In their conclusion, taxonomy and standardized data are both raised as areas for next steps, but not confirmation of their proposed approach.

Transportation. The Bay Area has evolved into a linked network with San Francisco as the central hub from the outlying counties (Mieler & Brechwald, 2013; SPUR, 2010). The Bay Area linked network is subject to several potential transportation bottlenecks: the Transbay Tube (used by BART), the Bay Bridge, the Richmond Bridge, the Golden Gate Bridge, the San Mateo Bridge, and the Dumbarton Bridge. There is also limited ferry capacity, which can currently carry only 2,000 people an hour (Metcalf & Amin, 2013). The Transbay Tube (connecting the East Bay with San Francisco) had 212,000 commuters on average in 2013, with average daily ridership across the system at over 350,000 (BART, 2013). Although natural disasters such as the 1989 Loma Prieta earthquake and man-made problems like the BART strikes in 2013 have created solid data around transportation infrastructure disruptions, SPUR (2013) identified the need for land use and planning data to be able to better plan and react to disasters including “identifying failed infrastructure and its consequences” such as roads, bridges, and electrical infrastructure (p. 61). These studies demonstrate the Bay Area is a linked network that is vulnerable to transportation disruptions from a variety of causes including earthquakes.

Dorbritz (2011) used simulation tools to assess the resilience of the Swiss railways and tram networks running through Zurich. The focal point of the study was to assess the resilience of the transportation network to disruption after a disaster. One key set of infrastructure impacting the rail network was the status of energy subsystems. Scale-free networks are comprised of linked nodes that are highly susceptible to disruption if a few key nodes are disrupted (Barabási & Bonabeau, 2003; Zhao, Park, Lai, & Ye, 2005). In the transportation context, the Bay Bridge (or the Transbay Tube) would be a key node connecting San Francisco with the East Bay. Many roads lead into the Bay Bridge on both sides of the San Francisco Bay, but the entire network begins to collapse if the Bay Bridge is not in service.

Hobson and Quiroz-Martínez (2002) and Syed et al. (2013), advocated for asking both subjective and objective questions when asking questions about transportation. In their study, Hess, Bednarz, et al. (2011b) the independent variable was imported crude oil prices (reflecting potential shortages in the market), and the dependent variable was the consumer product index inflation for medical care. The authors found a modest link between these two variables. Procyk and Dhariwal (2010) examined both earthquakes and floods and their potential impacts on transportation. However, whereas Procyk and Dhariwal's study was conceptual, they did illustrate the dependency of transportation and the provision of health care on electricity. Procyk and Dhariwal focused on road and rail damage, whereas Eidinger and Kempner (2012) identified electrical transmission as another weakness in earthquake situations. However, the broader linkage between electricity and cars has focused primarily upon broad benefits in early studies like Deakin and Kim (2001), and more recently on narrow benefits such as greenhouse gas reductions like Deakin (2011). Therefore, although the literature has linked electrified transportation with ecological goals, it has not addressed the implications of the ecological goals, such as the shift from petroleum, and how that affects resilience. In turn the lack of linkages presents challenges for earthquake planning and homeland security because the negative consequences are not currently being assessed for transportation electrification.

Distance from health care. Distance and time play an important role for receiving medical services, particularly in disadvantaged neighborhoods. Hobson and Quiroz-Martinez (2002) undertook a convenience-based sample and conducted Geographical Information System analysis based on that sample. Hobson and Quiroz-Martinez's found that 67% of residents needed to travel 30 minutes, or a half-mile walk or more, to reach a hospital. Although doctors and nurses are unlikely to fall within the disadvantaged category, Hobson and Quiroz-Martinez's study provides several important for this study, for example, how the respondents travel to work, number of cars owned, if they use public transit, and what problems are experienced on public transit. Different data sets including transit route data, population data, and health facility data were overlaid in Hobson and Quiroz-Martinez's study to examine problems, such as closing a regional hospital and its effect on health care access. For purposes of the present study, the weakness of Hobson and Quiroz-Martinez's study was the focus on disadvantaged communities, and as noted in the study, the problem with consistent responses and interpretations of survey questions.

Hess, Bednarz, et al. (2011) approached petroleum shortages from several angles, including Graphical Information System (GIS) assessment of distances traveled by health care workers to their workplace. The strength of the Hess, Bednarz, et al. approach was their broad examination of how the entire petroleum industry impacts health care provision. The major weakness, despite several types of case studies was that none of the analysis and documentation dove deeply into the what and how elements of their research. Yet Hess, Bednarz, et al. addressed current literature examining similar variables and problems considered in the present study.

Transportation range and uptake. Vehicle uptake and range varies greatly by technology type. Recker and King (2010) used recorded data and found that most vehicle users traveled fewer than 20 miles a day. Manufacturers are building electric vehicles with ranges as low as 20 and over 500 miles per charge. Regarding vehicle uptake, Hidrue, Parsons, Kempton, and Gardner (2011) found that more affluent individuals were more likely to be consumers of electric vehicles, and the University of California San Francisco (2010) is increasing infrastructure to support electric vehicles. Similarly, the California Energy Commission (2012) forecasted more than 3.5 million electric vehicles in California by 2020.

Transportation Modeling

Although not their focus, Hess, Bednarz, et al. (2011) examine how far hospital staff lived from their place of work using ArcGIS and the collection of work and home zip code data. In Atlanta, that the average staff member traveled approximately 14 miles each way. Hess, Bednarz, et al. presented the most comprehensive quantitative assessment of transportation and potential impacts on health care out of those located and reviewed during the literature search. In contrast, Sisiopiku (2007) used the Corridor Simulation (CORSIM) model, but used a case study approach to examine an emergency report. The primary result was a finding of the need to test an approach to see what impacts or improvements were needed and an acknowledgement of regional planning tools beyond CORSIM's capabilities. As a third type of transportation model, Naghawi and Wolshon (2010) used the Transportation Analysis Simulation System (TRANSIMS) to study evacuation routes in New Orleans. Naghawi and Wolshon used a similar process to Sisiopiku, involving the collection of transit plan data, alternatives, and then comparing scenarios. Murray-Tuite (2006)'s fourth model, Dynamic Network Assignment-Simulation Model for Advanced Roadway Telematics, Planning Version (DYNASMART-P), used a suite of variables, including evacuation time, response vehicle travel time between zones, line length, average line length, average speeds versus modeled speeds on a given transportation system, and the volume over capacity for a given transportation system. Notably, Murray-Tuite indicated that results from any transportation simulation will be limited to the area studied and are not typically generalizable.

Summary and Conclusions

The literature is scant in regard to transportation resilience in the event of an earthquake or other disaster. Through the literature review I identified a need for further study to develop variables, particularly for time and resilience after an earthquake. More studies have been conducted around transportation modeling, using a variety of planning tools. Most notably, Wells et al. (2013) stated "there are no operational models of how to build [community resilience]" (p. 1172). The lack of operational models is confirmed by other works coming after the National Heath Security Strategy, such as Chandra et al. (2010), who mentioned evacuation as a core component for health security, but not the capability to bring health care workers to the scene.

Two main themes surfaced in the literature. First, community resilience is a relatively new field, having arisen out of adaptive management in the mid-1990s; second, community resilience has been recently moving from generalizations into more specialized areas. However, a robust quantitative method is still lacking to determine resilience. What is known is that community resilience provides a broad framework for assessing what happens pre- and post- disaster. Community resilience is an area increasingly under examination across multiple fields. Researchers from across disciplines, ranging from medical practitioners to land-use and disaster specialists, are examining how to implement community resilience. These studies have explored what community resilience is, and how transportation impacts community resilience. What these studies have not done is focus on the role electric transportation has in the transportation-community resilience-disaster nexus.

This study filled a gap in the existing literature by incorporating electric transportation into a new framework that examines what electrification may mean for future community resilience assessments. The present study built upon work by Hick et al. (2013) and Syed et al. (2013), but with a targeted focus on transporting the health care workers who are needed to meet the surge response. Through a case study approach, by analyzing documents on planning, I identified themes about the state of current preparedness and consideration for electric transportation. Accordingly, the present study extended knowledge in the discipline by beginning to incorporate the ongoing trend of transportation electrification into the area of community resilience. In Chapter 3, I will present the methodological approach, a qualitative case study consisting of document review of emergency plans.

Chapter 3: Research Method

Introduction

In this qualitative study my purpose was to assess the impacts of transportation electrification on emergency response planning through a case study examination of Bay Area emergency planning, public health, and transportation entity documentation. By exploring and comparing the planning documents, my intent was to understand what differences in planning for electrified transportation exist in how ERPs conduct their planning, how the plans are formed, and if electrified transportation was considered in the plans (Creswell, 2009b). In Chapter 3, I present the detailed research design and rationale based on the three research questions. In Chapter 3, I also discuss the methodology, including participant selection logic, instrumentation, data collection, data analysis, trustworthiness, and ethical procedures.

Research Design and Rationale

The following questions guided this research:

Research Question 1: From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, what key factors, if any, do they take into account when considering transportation needs of staff/administration reporting to work after an earthquake?

Research Question 2: From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, what are the key factors that they take into account when considering transportation needs of individuals needing assistance after an earthquake?

Research Question 3: What are the differences in the emergency response plans for electric transportation between cities and counties in the Bay Area?

The central concept of my collective case study was to examine if and how ERPs and emergency plans currently consider electrified transportation in their planning and how they may include it in the future. In particular, I reviewed public documentation to see if there is a level of electrification that needs to occur before ERPs start including it in their planning assessments, if the ERPs are not already doing so. Additionally, I examined what roles transportation takes in emergency plans and planning in the staffing/administration in Bay Area hospitals, and for victims, after an earthquake. I limited the research to the Bay Area county and city emergency planning, public health, and transportation entities. The Bay Area covers a diverse geographical area and types of governance area, helping to provide greater breadth to the study.

I selected a collective case study approach because studying what is currently done in a given setting is appropriate for a case study (see Yin, 2014), and I examined emergency planning in the bounds of the Bay Area. Because the literature review shows that transportation electrification's impact on emergency planning has had little exploration to date, an inductive approach such as a case study was appropriate (Stebbins, 2001). As part of my methodological consideration I also considered ethnography, field research, phenomenology, and grounded theory approaches, and rejected each. Because the research questions do not guide the research toward generation of a theory, grounded theory was not appropriate (Cohen, 1969; Corbin & Strauss, 1990). Although the end goal of the study was to understand how ERPS perceive electric transportation, the research questions were not designed to gain understanding of how the world is viewed by others, so phenomenology was not chosen. Additionally, an ethnography was not appropriate because the study was not limited to understanding a single culture or organization, although ERPs in the hospital setting potentially share many similar elements (see Creswell, 2009a).

Role of the Researcher

As the researcher, I selected and reviewed the documents, interpreted the materials in the documents, reviewed plans, and analyzed the collective results to understand what role transportation electrification has or may have for emergency planning. To serve in this role, I reviewed electronic or hard copies of the planning documents. To my knowledge, I had no professional relationships with any of the ERPs or any of the counties or cities in a transportation or emergency planning function. Because the documents I reviewed were public, I had no concerns about confidentiality or informed consent. To my knowledge, I had no other ethical concerns in this research. My current employment focuses on the natural gas sector, on wildfires, and other issues impacting electric infrastructure but not earthquakes. The primary bias I was aware of was my expectation that ERPs and emergency plans are not considering transportation electrification and reliance on electrical systems. Through reviewing written plans and documents, I was able to use bracketing to address any biases that I potentially became aware of during the research.

Methodology

Participant Selection Logic

I selected the Bay Area because of its geography and the high prevalence and use of electric transportation in the region. My study represented separate emergency, public health, and transportation departments in all nine counties in the Bay Area, and 16 out of 85 cities in the Bay Area. Many of the cities in the Bay Area do not have their own departments of public health and transportation, which are instead handled at the county level. The number of departments examined allowed some latitude in case some entities do not have information publicly available. Yin (2014) indicated that validity grows for a qualitative study as the number of experiences examined increases. Orne and Bell (2015) described this type of sampling as theoretical sampling, or based off of gathering a full range of diversity. Given the geographical spread of the counties and cities selected, I attained a range of diversity by including these facilities in the study.

To collect the data, I reviewed the publicly available documents for each department on their websites and then collected public but not online documents as I come across them for the entity that has the information. Because this information was public, I needed no freedom of information requests and had no significant problems collecting the data. I reviewed the emergency plans and coded them for terms and themes as discussed later in this chapter.

Instrumentation

I used one set of instrumentation, written plans and documents, and in particular the portions of those plans involving emergencies and transportation. I had no reason to suspect that documents would not be reputable, as they are primary documents in the public domain and the best source of data based on my research questions.

Procedures for Recruitment, Participation, and Data Collection

Data were collected from the websites of the entities I examined. In-office visits were not necessary. Document review of the plans took between 2 to 3 hours each. As I was able to attain data saturation, I did not need to expand the scope beyond the Bay Area to other neighboring regions, such as the Central Coast or San Joaquin Valley.

Data Analysis Plan

The data connected to all three questions, although Question 3 was based on the interpolation of the data collected. In order to code responses to questions, I used topic, conceptual, and analytic coding. For topical coding, my primary interest was in types of transportation or fuel types, for staff and for individuals needing assistance, that are brought up in the documents. Question 1 addressed the staff/administrative aspect of transportation, and Question 2 addressed individuals needing assistance. Rubin and Rubin (2012) explained that topical markers are usually self-evident, and I this was true as I analyzed the data collected from the documents. Conceptual terms included terminology like *transportation* or *electricity*, which are more generic but capture themes I expected to arise during the review. Lastly, Richards (2015) described analytic coding as coding based on interpretation and reflection. This type of coding requires detailed understanding of the collected data in order to reveal meanings and was of particular use in answering Question 3.

Coding the data was done using NVivo analytical software. NVivo is an iterative tool that helps identify themes across data types by importing data, coding the data, querying the data, interpreting it, finding common themes, and then writing the results of the query. In this coding process, outliers were revealed. Outliers play an important role in qualitative research, and I included notable examples in the results of the study. Barbour (2001) recommended qualitative research include outliers in order to help provide juxtaposition. I used to compare cods across data entries, such as documents collected from different departments of transportation, to see if there were differences, discrepancies, or a need to consolidate similar coding into a common platform.

I used the NVivo software platform to conduct analysis of the data for the written documents. Richards (2015) cautioned that software packages can be problematic for qualitative researchers because rich data can be coded in unwieldy detail and depth, possibly preventing completion of the study. In order to counter this, Richards recommended focusing on the researcher's interest in the data rather than blindly coding the data (2015). A full and rich set of data helps establish trustworthiness of the data.

Issues of Trustworthiness

Trustworthiness for qualitative research reflects credibility, transferability, dependability, confirmability, and coding reliability (Patton, 2015). Each of these factors is analogous to internal validity, external validity, reliability, and objectivity in a quantitative study. In order to establish credibility, Patton listed four related elements: systematic fieldwork, conscientious data analysis, researcher reliability, and belief in the value of qualitative inquiry. The first step to maintaining credibility was to seek out data supporting alternative positions than those I may have believed in. Patton described that the data support this when a researcher can find the "best fit, the preponderance of evidence" (2015, p. 654). The process of coding the data allowed me to review to see if any outliers were in fact errors (Shenton, 2004).

By reviewing planning documents at different entities, such as between transportation and public health, and for cities versus counties, I was able to attain data saturation. Transferability, or external validity, was attained through my reaching out to multiple entities, across the Bay Area region, in order to account for local differences, demographics, and geography, all of which should provide the data set with variation in types and levels of governance, geography, and demographics. Although the research questions were driven by an area with geographical constraints that more strongly impact transportation with limited ranges, other areas in the United States and elsewhere would have similar limitations, such as New York City.

Dependability was demonstrated through keeping notes as I reviewed and coded data, and through provision of details in the results section regarding the detail of how documents were gathered and obtained. I also noted the dates and revision numbers of emergency plans in case they changed over time or if conflicting documents emerged.

During the course of the study I remembered to reflect frequently on the entities and locations I was reviewing, changed them as necessary, and documented the changes and why I undertook them. There was also an overlap between the different types of documents within a governmental entity, such as city, and with entities of similar types such as departments of transportation in neighboring counties, a process which Shenton (2004) referred to as “overlapping methods” (p. 71).

Similar to dependability, confirmability was demonstrated through triangulation of information. To this end, earlier in this chapter I discussed my own biases and background. I logged my decisions and choices so another observer could follow the path and course undertaken during my document review.

Ethical Procedures

Because the documents I reviewed were public, there were no ethical concerns with human participants. None of the documents I collected required me to contact staff. All data were stored on an USB drive and on a hard drive on my personal computer. No other ethical issues applied.

Summary

In my case study I examined and explored the perceptions and concerns of ERPs from nine Bay Area counties and 15 cities about electrification of transportation, and the implications during and after an earthquake. This occurred through the review of existing public documents from emergency planning, health care, and transportation departments at these governmental entities. In Chapter 3, I presented the methodological approach I undertook for my study. In Chapter 4 I will present the results of the study undertaken to examine the three research questions including the setting, demographics, data collection, data analysis, evidence of trustworthiness, and results.

Chapter 4: Results

Introduction

The purpose of this qualitative study was to assess the impacts resulting from hospital staff, hospital administrators, and injured people using electric transportation through a case study of emergency planning, public health, and transportation entities in the nine-county San Francisco Bay Area Region. I explored three research questions:

Research Question 1: From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, what key factors, if any, do they take into account when considering transportation needs of staff/administration reporting to work after an earthquake?

Research Question 2: From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, what are the key factors that they take into account when considering transportation needs of individuals needing assistance after an earthquake?

Research Question 3: What are the differences in the emergency response plans for electric transportation between cities and counties in the Bay Area?

The chapter is organized into the following sections: Setting, Demographics, Data Collection, Data Analysis, Evidence of Trustworthiness, Results, and a Summary.

Setting

The research setting was my home office. I reviewed the ERP documents over several months. Where plans were written before January 1, 2017, I searched the appropriate websites or other sources after I had reviewed and analyzed all documents to see if there had been an update. In October 2017, wildfires caused extensive damage in Sonoma and Napa counties (Krishnakumar, Fox, & Keller, 2017). Both counties have dedicated websites to postdisaster recovery as of May 12, 2018. The recovery efforts may have resulted either in delays to planned document updates or encouraged resource planners to update their documents, even though wildfires are outside of this study's scope on earthquake-related factors.

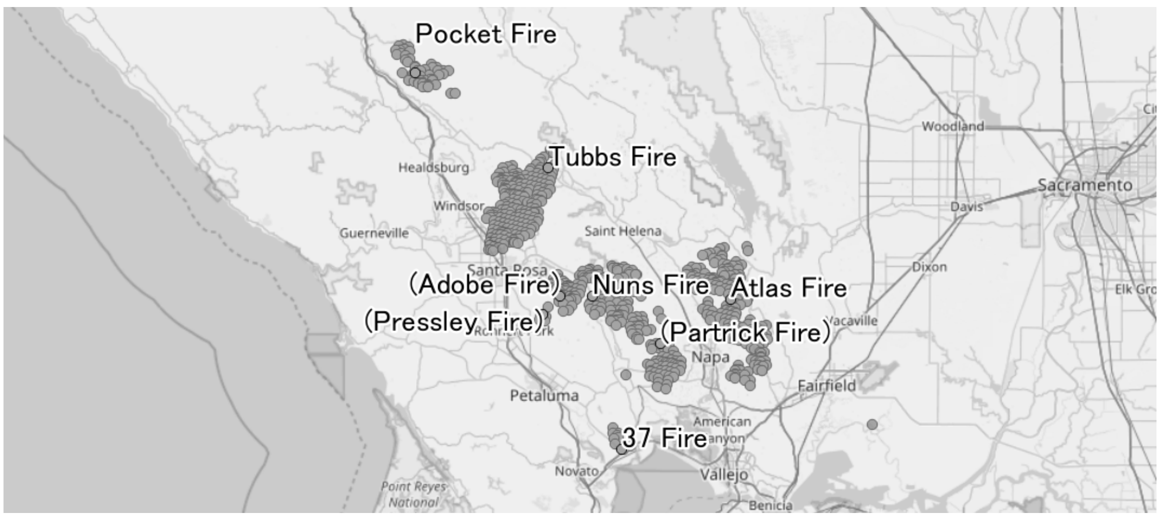

Figure 6. Dark dots represent locations of the fires whereas lines indicate major roadways, by Phoenix7777, 2017. Creative Commons Attribution-ShareAlike 3.0.

Demographics

The scope of the research was the nine Bay Area counties and a selection of 16 cities out of the 85 in the nine counties. The research included statewide and federal planning documents when either a county-level or city-level document referenced the statewide or federal planning processes. The statewide entities included via reference were the California Department of Public Health, California Office of Emergency Services, California Hospital Association, and the Great California Shakeout. The U.S. Department of Health & Human Services, Office of the Assistant Secretary for Preparedness and Response, was the federal-level entity referenced by local and county documents. Including state and federal documents expanded the original data collection scope. This additional scope resulted in the addition of additional publicly available documents.

Data Collection

My data collection resulted in a review of 63 websites and documents and analysis and coding of 48 website documents. The information was imported into NVivo software for analysis. Some websites were not imported when they clearly did not involve electrified transportation—for example, hospital surgery and triage procedures for disasters. Each webpage was searched for direct documents, such as emergency operations plans, for links to direct documents, or for directly usable information regarding city or county plans. In this latter case, the webpages were converted into Adobe pdf files and imported into NVivo for analysis.

Each document was reviewed for the terms *fuel, transportation, electri, alternative, emergency, disaster*, and *critical infrastructure*. The term *electri* was used to capture different terms reflecting considerations regarding electric infrastructure, particularly electrification, electric, and electricity. These search terms also helped ensure that the documents had transferred correctly into NVivo for analysis.

Once I had retrieved the documents, they were reviewed and imported into NVivo. With the exception of converting webpage analysis via pdf, and the use of Microsoft Excel to analyze the date of the documents, the data collection plan from Chapter 3 was followed for the documents. In two cases, documents could not be reliably uploaded into NVivo, so I reviewed the documents externally, and I imported summary notes and quotations into NVivo for coding and analysis. In total, 48 documents were analyzed in NVivo. Nine documents had both *fuel* and *transportation* coded, indicating an overlap between the document containing information that I coded as relevant to transportation and postdisaster impacts as well as including the term *fuel.* Thirteen documents contained the term *fuel* but were not coded for transportation, and 12 documents were coded for transportation but did not include the term *fuel.* More information on my coding methodology is discussed in the data analysis.

Data Analysis

I first reviewed each of the 48 documents to identify the sections pertaining to transportation and emergency planning and response. After identifying these sections, I then performed the key term review to ascertain whether I had missed any other areas involving transportation, such as fuel, alternative fuel vehicles, emergency, and electric-related activities. Each of these key terms was evaluated and identified, and then consolidated into the fuel theme. *Fuel* was included in the analysis after the first several documents were coded, and fuel was identified as an emergent theme for postdisaster logistics.

Fuel was coded when it was in a document. This was regardless of the use as a fuel for a vehicle, or a generator, or other power system. I included fuel in this manner, as a power generator that uses fuel can power an electric vehicle. I also included fuel as a forward-looking term because electricity is comparable to gasoline or diesel as a fuel for transportation. Fuel was identified in 22 of the documents after searching for the term in each document. The Bay Area Urban Areas Security Initiative (2017) identified "within the first 24 to 48 hours of an incident, the County OES [Office of Emergency Services] has processes and procedures in place to prioritize fuel needs and distribution among critical infrastructure (e.g., hospitals and gas stations) and responders (e.g., public safety and utility crews)" (p. 59). The Alameda County Transportation Commission (2016) identified increased fuel economy and electric vehicles as an environmental benefit but not within the context of emergency use. California Public Health and Medical Emergency Operations Manual (2011) included the term *fuel* as part of overall logistics 35 times. As I continued to review documents, nodes that I had originally thought were independent were consolidated into themes, such as combining alternative vehicles into the fuel node. The overall frequency of fuel coding is identified in Figure 7.

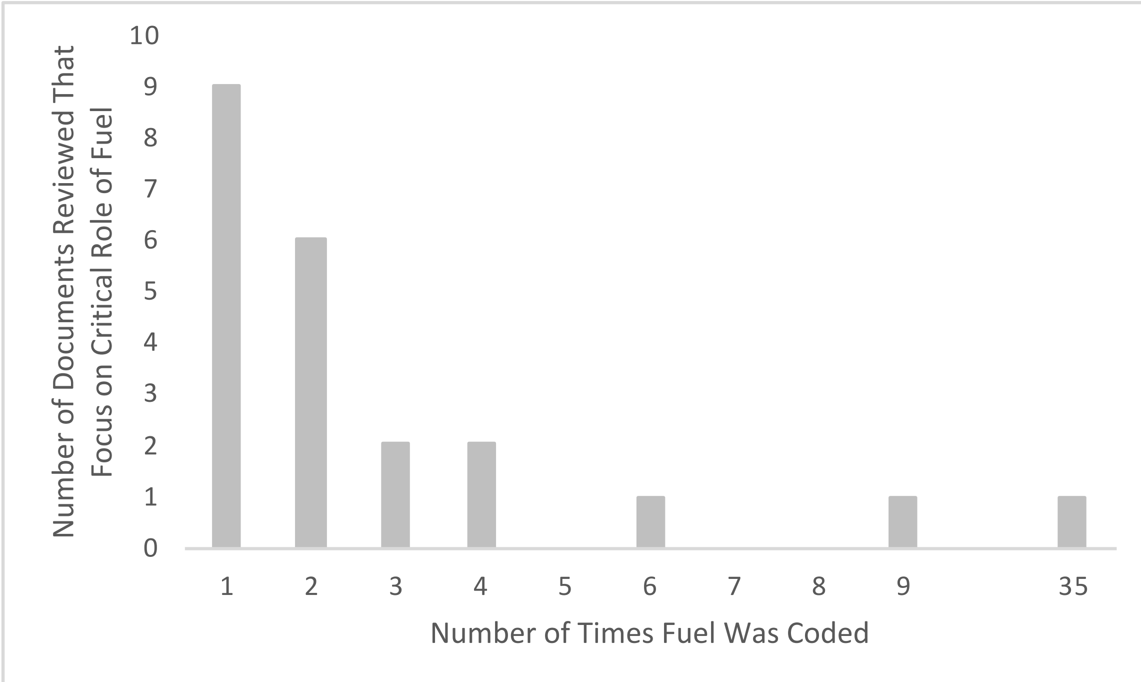

Figure 7. Frequency of fuel coding in reviewed EPR documents.

The second emergent theme was transportation. Transportation was coded in 21 of the documents reviewed. In contrast to my coding of fuel, I only coded transportation when it was paired with disasters, emergency management, and hospitals. This narrowed scope was due to the transportation commission documents and other planning agencies including many factors unrelated to disasters or emergencies. After reviewing the results and examining some of the documents again, I also coded transportation when a document included electrical impacts, such as a loss of electricity as a transportation impact.

The Metropolitan Transportation Commission (2008) identified electrical power loss as impacting transportation. The Department of Health and Human Services (2016) identified transportation as critical infrastructure for healthcare but did not identify fuel under the transportation section. The City of San Jose (2004) Emergency Operations Plan included in 2004 that “the transportation system needed to take the person elsewhere” in areas impacted by the loss of power in the section on interdependencies (p. P-4). The City of San Jose, however, does not go further in addressing how the risk and application of electrical interdependency planning should occur. Other documents, such as the Metropolitan Transportation Commission (2018) referenced the challenges of reducing greenhouse gasses but not the potential reductions in community resilience from shifting transportation fuel sources. The number of coded references to transportation by document is in Figure 8.

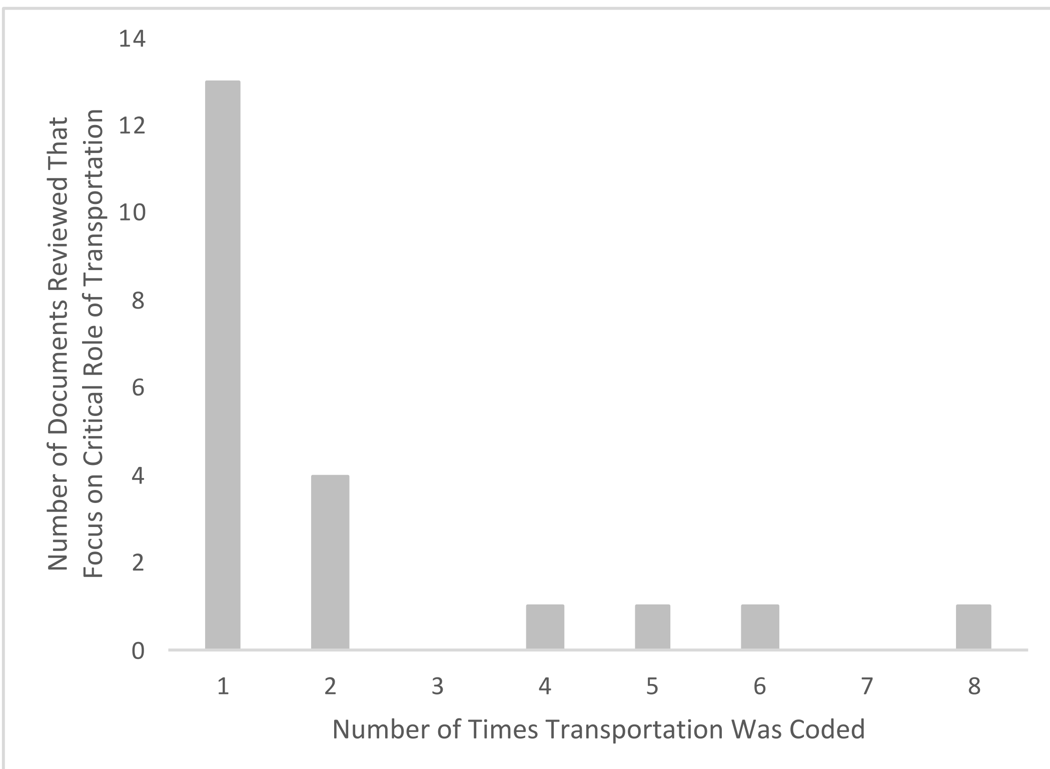

Figure 8. Frequency of transportation coding in reviewed EPR documents.

Microsoft Excel was used to analyze the date of the documents and perform graphic analysis of the data. For documents without a date, I counted them as having a (n.d.) entry for no date. Twenty-seven percent of the documents had no date, and 73% had a date. Eighty percent of the documents with a date had been updated in 2012 or more recently, or 58% when counting documents without a date as occurring prior to 2012. This indicates that many of the documents have been updated in the time frame where electric transportation and policy objectives to increase electric transportation in the Bay Area and California were identified by the California Energy Commission (2012). Figure 9 shows the number of reviewed documents and their year.

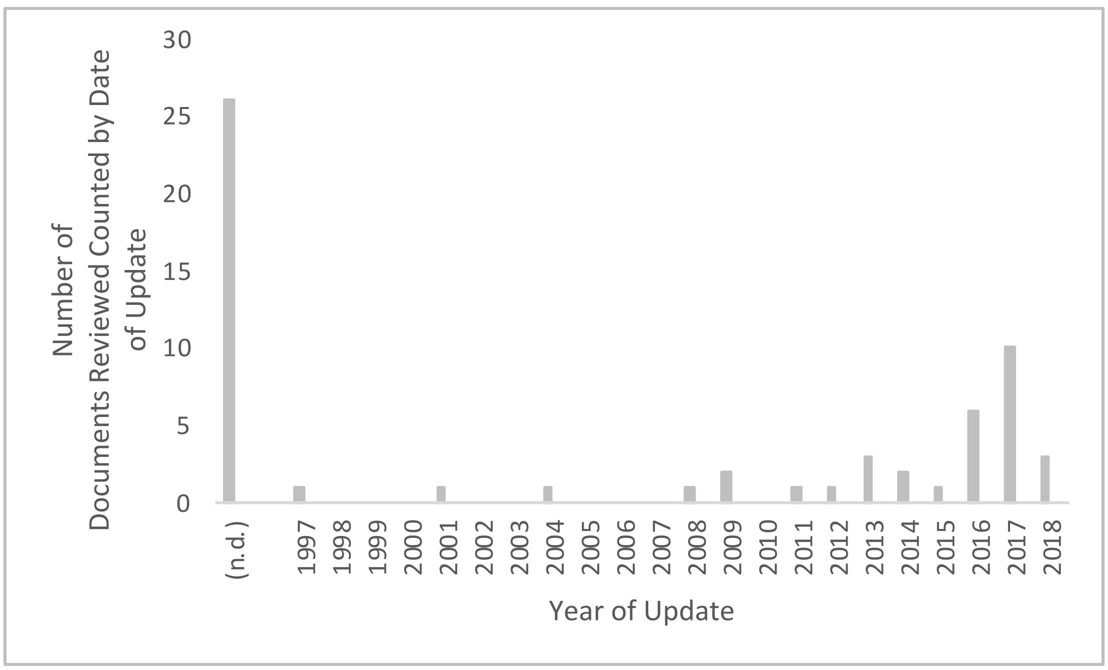

Figure 9. Number of documents reviewed, counted by date of update.

In particular, the comparison of the document date with the California Energy Commission’s (2012) identification of electric vehicle targets in 2012, helps provide evidence of trustworthiness, as it demonstrates that policy objectives for electrification existed as early as 2012.

Evidence of Trustworthiness

Credibility was established by obtaining and analyzing documents from a broad set of local, county, state, and federal documents. Although initial examination indicated electric transportation was not included by EPRs in their planning documents, I was hopeful that EPRs were considering electric transportation. I systematically reviewed the webpages and documents for evidence that transportation fuels were considered in the documents. I reviewed and sought out terms and passages that support the inclusion of electric transportation and to code them in NVivo. As described in the data analysis section, several passages were identified that, if read inclusively, support the idea that some ERPs are considering electric transportation in their planning. Transferability was attained, as all counties except for Solano and San Francisco had publicly available emergency operations plans or transportation plans. The addition of the statewide and federal documents also provided for a broad range of local differences, demographics, and geography and different levels of ERP analysis.

This does not remove the key limitation of the geographic restrictions considered in the study. Dependability was demonstrated through the note keeping process and the description of the document gathering process. The inclusion of the dates of revision, and the last search for any document updates from earlier in the review also enhances dependability in case plans were modified during the research and analysis process. No updates were discovered between the start and conclusion of the research. Confirmability occurred through logging decisions and choices, as well as preserving the ERP documents in NVivo in case of subsequent plan changes. The results provide further evidence of this analysis.

Results

The results are organized by each of the three research questions. The data were analyzed primarily in NVivo, with supplemental analysis in Microsoft Excel, and I provide quotes in support of the themes.

Research Question 1

From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, what key factors, if any, do they take into account when considering transportation needs of staff/administration reporting to work after an earthquake?

The term *staff* was contained in 31 of the documents reviewed. Only six documents used staff in the context of transportation. The California Public Health and Medical Emergency Operations Manual (2011) stated, “During disasters, Operational Area Emergency Operations Centers (EOCs) will activate to coordinate information flow and resource requests (e.g., medical supplies, staff, and personal protective equipment)” (p. 132). Earthquake Country Alliance (n.d.) asked, “Would transportation issues affect staff patient/resident access?” for determining exercise objectives (p. 3). Hughey and Smith (2013) addressed a similar question “Are there earthquake related injuries to patients or staff at any health care impacted that access to the facility is impaired or impossible?" (p. 11). These documents demonstrated that ERPs are aware of transportation limitations after a disaster. The documents provided questions but not specific answers to how transportation and staff access to hospitals are impacted. As the documents were reviewed for the term *staff*, two new themes developed that could answer this question: fuel and critical infrastructure.

Fuel. *Fuel* was one of the most common terms used by both medical and transportation ERPs. The term fuel is included in federal, state, county, and local documents. Fuel is used in emergency planning, hospital planning, and transportation planning. I included the term *electricity* in the examination of fuel, as it is the fuel for electric transportation. My review and analysis identified the term fuel in 22 (46%) of the documents. Fuel was commonly associated with backup electrical generation; for example, the California Association of Health Facilities (2017) identified "Emergency Power Generator Type" and "Emergency Power Generator Fuel" in its emergency operations program and plan manual (p. 8).

The term *electricity* was identified in 11 of the documents reviewed and was not directly associated directly with transportation or as a transportation fuel. The Bay Area Urban Areas Security Initiative (2017) listed as a capability outcome to provide within the "first 12 to 72 hours of an incident . . . emergency power to critical facilities, fuel support for emergency responders" (p. 219). Similarly, the City of San Jose Emergency Operations Plan (2004) identified a need for alternatives for "power-dependent systems such as communications, water supply, fire fighting, and waste treatment." (p. 40). San Jose's documents do not include transportation as one of the power-dependent systems. The San Jose documents were dated to 2004, when electric transportation was in lower use and not a broad state policy objective and when electric transportation was less common. The San Mateo County Hazard Mitigation Plan, which was updated in 2016, also excludes electricity for transportation, although the use of standby generators could potentially generate electricity for transportation

> BB-10—Critical Fuel Supply. Provide local fuel supply (none presently exists in the community) capable of supporting 3-5 days of fuel needs for emergency responders and standby generators (including those at water & sewer pump stations). (Tetra Tech, n.d., p. 81)

The identified fuel needs by San Mateo do not include transportation as a critical infrastructure.

Critical infrastructure. Medical ERPs generally included transportation as part of their critical infrastructure. Medical ERPs often included multiple items as critical infrastructure, including electricity and transportation. Electricity was most commonly associated with water or with providing electrical needs and was not clearly associated with electricity needed to operate transportation such as vehicles.

> [Health care coalition] members should perform an assessment to identify the health care resources and services that are vital for continuity of health care delivery during and after an emergency. . . . This information is critical to

> uncovering resource vulnerabilities relative to the [hazard vulnerability analysis] that could impede the delivery of medical care and health care services during an emergency. . . . The resource assessment should include but is not limited to the following:
>
> • Critical infrastructure supporting health care (e.g., utilities, water, power, fuel, information technology [IT] services, communications, transportation networks). (Department of Health and Human Services, 2016, p. 14)

Tetra Tech (2018) identified energy, health care, and transportation systems as part of *critical facilities,* consistent with Department of Homeland Security definitions of critical infrastructure.

> The Steering Committee has decided upon the following definition of Critical Facilities for this planning process:
>
> Critical facilities and infrastructure are those assets, systems, and networks, whether physical or virtual, considered so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination, per the Department of Homeland Security. For this hazard mitigation plan, the 16 critical infrastructure sectors as defined by the Department of Homeland Security will be used. The 16 sectors are [excerpted]:
>
> - Energy

- Health care and Public Health
- Nuclear Reactors, Materials, and Waste
- Transportation Systems (p. 3).

In contrast, transportation ERPs focus on providing overall access, but have minimal discussion of disasters and their direct relation to health care linked transportation. For example, the Santa Cruz County Regional Transportation Commission (2018) only uses the term *disaster* in one paragraph and does not reference either transportation or critical infrastructure for hospital staff.

> Security/Emergency Services. Transportation systems can be greatly impacted by natural disasters or security incidents. Transportation systems are also a critical part of the response effort by connecting law enforcement and safety responders to the incident site and handling the public's transportation needs in response to the incident. Consistent with the California Strategic Highway Safety Plan and emergency relief and disaster preparedness plans, the 2040 RTP continues to invest in projects that provide security and emergency services. (p. 6-6)

This gap between medical ERPs and transportation ERP was consistent between documents reviewed.

Summary of ERP Planning for Staff and Administration Transit Needs

The documents review suggested ERPs are generally aware that staff and administration arriving at hospitals after a disaster is a factor in emergency planning albeit not a well-explored issue. Transportation planning documents touch upon the issue, but on the whole, focus on other issues than hospitals and staffing after disasters. Fuel is a particularly common topic between health care and transportation. Usage was split between emergency generation and transportation, but the connection between emergency generation for transportation was absent. Linkages between transportation, electricity, and health care have been identified in some of the documents, but similarly have not been thoroughly explored in the ERP documentation.

Research Question 2

From the perspectives of Bay Area emergency response planners, as demonstrated through public documents, what are the key factors that they take into account when considering transportation needs of individuals needing assistance after an earthquake?

Needs of individuals needing assistance was generally subsumed within broader transportation planning and hardening existing infrastructure. Infrastructure hardening includes measures such as earthquake retrofitting. Bay Area ERP documents reviewed included references to individual shelter in place plans. No further planning efforts were revealed in my documentation review, with two exceptions: Napa County and Santa Cruz County. Hughey and Smith (2013) identified damage to transportation channels as a key factor for Napa County to take into account after an earthquake for hospital surge capacity.

> Damage to transportation channels. A significant risk associated with earthquake is a disruption in transportation. Staff may not be able to reach their usual place of employment. Pre-hospital care may not be able to deliver patients to acute care

> facilities. Patients may not be able to reach hospitals. Evacuation plans may be disrupted. And, the usual vendors of materials and supplies may not be able to reach the facilities in order to maintain needed supplies. (p. 11)

The Santa Cruz County Regional Transportation Commission (2018) identified “transit dependents” as people relying on transportation other than private vehicles.

> Transit Dependent: An individual who because of age, income, physical/mental condition, geographic location, or personal choice, does not have a private vehicle available and relies on transit for his/her transportation needs. (GA-18)

My closer examination of the Santa Cruz County Regional Transportation Commission document did not reveal how or where transit dependency was considered in their plan. Because of this limited information, the focus appears greater on maintaining emergency services rather than individual services. Accordingly, my review found medical ERP and one transit ERP considered individual transportation as part of their planning efforts but not extensively or in depth. At this point, the primary mechanism ERPs have for individual assistance is sheltering in place and self-sufficiency, with emergency transportation used for those who cannot shelter in place. Ready Marin (n.d.) put this point most succinctly:

> After a major disaster, professional first responders will be overwhelmed and your neighborhood may be on its own for days. The primary objective of a neighborhood response program is to do the greatest good for the greatest number of people, and ensure assistance is available to those who need it most (para. 2).

Ready Marin also included knowing which neighbors have generators. The timing differences between the two documents that mentioned individual plans changed little over the five years. Additionally, electrification of transportation was not listed for any individual assessment or impacts on their ability to attain health care after a disaster in the documents reviewed. The City of Fremont (2017) has a webpage dedicated to electric vehicles and lists their benefits but no disadvantages. It had no further reference to emergency planning.

Research Question 3

What are the differences in the emergency response plans for electric transportation between cities and counties in the Bay Area?

Regarding differences in emergency response plans between cities and counties, I found limited differences between cities and counties. The documents I reviewed showed greater difference between medical and transportation ERPs than between areas of the Bay Area. Electric vehicle advocacy was included in several transportation planning documents, such as the City of Fremont (2017), the Transportation Authority of Marin (2018), and the Sonoma County Transportation Authority (2016). The Sonoma County Transportation Authority stated

> the utilization of plug-in electric vehicles (PEVs or EVs) has the potential to reduce petroleum consumption and greenhouse gas emissions dramatically, and increase energy independence through the utilization of locally produced energy. [Later in the document, the Sonoma County Transportation Authority] identifies

the increase in EVs that would be needed to meet the GHG reduction goals of the CTP and discusses targets set by the state and CA2020 (p. 3-28).

The City of Fremont (2017) has 5,800 electric vehicles and "Fremont's 94539 zip code is home to more [electric vehicle] drivers than any other zip code in California!" (para. 1). Statewide documents follow a similar pattern. California's Governor Brown issued Exec. Order No. B-48-18 (2018) and directed "all State entities [to] work with the private sector and all appropriate levels of government to put at least 5 million zero-emission vehicles on California roads by 2030" (para. 11).

Most ERPs do not acknowledge this shift toward increased electric transportation. Most ERPs included fuel as a key concern in their emergency planning, and several included energy and transportation as critical infrastructure. Six ERPs included staff level transportation concerns within their documents. More thorough examination and consideration of the interrelated nature of electric and transportation critical infrastructures is needed by ERPs, as the literature has already identified this issue, but in practice the issue is lagging, as identified in the emergent themes.

Emergent Themes

Fuel was the primary emergent theme in reviewing the collected data. Fuel for emergency planning focused primarily on fuel for generators, although several documents included fuel for transportation. "Within the first 24 to 48 hours of an incident, the County OES [Office of Emergency Services] has processes and procedures in place to prioritize fuel needs and distribution among critical infrastructure (e.g., hospitals and gas stations) and responders (e.g., public safety and utility crews)" (Bay Area Urban Areas Security Initiative, p. 59). This theme emerged from the data, as compared to the narrow initial key terms of electrification and alternative as related to transportation. The examination of fuel allowed a more comprehensive examination of what was contained in the ERP documents.

A second emergent theme was the date the document was provided or the date the document was updated. Twenty-eight of the documents were updated before 2015 or lacked an identifiable date. This theme would need broader analysis in a subsequent study, as the impacts of the date and frequency of ERP is outside the scope of my study. If the state and local governments did not have changing priorities regarding transportation critical infrastructure, the lack of recent updates may not be a problem. However, as critical infrastructure is changing, more frequent updates are likely necessary to ensure that community resilience is maintained.

Summary

Transportation and emergency response planning in California is currently not focused on additional needs associated with electrified transportation and the Bay Area's and state's long-term objectives. As demonstrated through public documents, ERPs have examined the need for fuel for vehicles and emergency power generation and, in some cases, directed the planners to consider transportation as critical infrastructure or related to energy. Transportation for staff, however, appears to be a secondary factor to other considerations such as medical supplies. Individuals after an earthquake are largely relegated to sheltering in place, based on the ERP documents. Many ERPs, based on references and links in emergency planning webpages at the city and county level, assume that emergency services will be overwhelmed and direct the public to assume that they may spend up to a week without service or assistance. Based on my interpretation and analysis, there are essentially no differences in emergency response plans for electric transportation between cities and counties in the Bay Area. Medical ERPs tended to have greater focus on fuels than transportation ERPs. None of the documents included electricity needs as a fuel for vehicles and transportation, although the City of San Jose (2004) did include electricity as potentially transportation needs. This results in my determination that there is no significant planning for electric transportation after a disaster, as reflected in planning documents, despite the state's directive for greatly increased zero emission vehicles through 2030.

In Chapter 5, the purpose of the study and the findings implications are organized within the conceptual framework of the study. Further research recommendations and social change implications are provided, along with the conclusory remarks on the study.

Chapter 5: Discussion, Conclusion, and Recommendations

Introduction

The purpose of this qualitative study was to assess the impacts resulting from hospital staff, hospital administrators, and injured people using electric transportation through a case study of emergency planning, public health, and transportation entities in the nine-county San Francisco Bay Area Region. I posed three questions to understand what role electric transportation has in ERP planning after an earthquake. I found that transportation for staff was a secondary factor to other needs such as medical supplies. My analysis also revealed that although transportation was considered a critical infrastructure by some ERPs, there were no specific plans or documentation regarding electric transportation. Lastly, there were no significant differences between city and county plans, but there were differences between medical ERPs and transportation ERPs. The medical ERPs tended to have a greater focus on fuels than do the transportation ERPs.

Interpretation of the Findings

The findings confirmed the literature reviewed in Chapter 2, which included little to no research on electric transportation and resilience. I reviewed literature on enhancing electric grid reliability through discharging electric vehicle batteries because battery discharge can help provide electricity to the electric grid when the cars are plugged in to charging stations at home or at an office. I also reviewed literature about community resilience, and about transportation planning. My literature review led to finding a gap in the consideration of electric transportation and its impact on community resilience.

Research Question 1

Fuel and generators but not electric transportation. The first research question supported past findings in the literature review that transportation limitations after disasters are considered by ERPs. For example, the Earthquake Country Alliance (n.d.) specifically asked if transportation affects staff. Hughley and Smith (2013) focused on staff injuries impacting health care. Fuel, an important resource as stated by both medical and transportation ERPs, was identified in nearly one half of the documents reviewed but most commonly in association with backup power generation for a facility. The City of San Jose Emergency Operations Plan (2004) confirms this finding by identifying "communications, water supply, fire fighting, and waste treatment" as "power-dependent systems," but not transportation.

These findings confirm that for the Bay Area, a transportation vulnerability state will likely exist after a disaster or disruption, as a worsened state occurred after hurricanes Katrina and Rita (Litman, 2006) and overall population health can be worsened after a disaster (Morton, 2013). In this case, California's environmental goals could be lowered if health and safety issues for transportation are negatively impacted after an earthquake. Because the ERPs are not currently considering how electric transportation will affect their hospital services, a vulnerability state is more likely. With increased planning, this potential vulnerability state could be avoided. Depending on needs, standby generators, such as those considered in the San Mateo County Hazard Mitigation Plan, could be used if electric transportation is critical for staff at San Mateo County hospitals (Tetra Tech, n.d.).

The document review identified a gap between medical and transportation ERPs. Medical ERPs often included transportation as part of their critical infrastructure. The Department of Health and Human Services (2016), a federal department, indicated that the "resource assessment should include . . . critical infrastructure supporting healthcare," which included transportation networks (p. 14). This focus compared with the more local Santa Cruz County Regional Transportation Commission (2018), which used the word *disaster* only one time and did not include transportation or critical infrastructure for hospital staff. Instead, the Santa Cruz County Regional Transportation Commission referenced emergency services and first responders but not the needs for staff to arrive at hospitals, or how the fuel network might be disrupted by a disaster. In contrast, Procyk and Dhariwal (2010) identified the linkage between transportation and power. Similarly, my study has confirmed that ERPs do consider transportation and has also confirmed that electric transportation is not an area that ERPs are currently considering.

Research Question 2

Transportation, subcommunities, and individual preparedness are considered. ERPs considered transportation after an earthquake but not how transportation would be replaced if it were disrupted. Electricity for transportation was not one of the key factors I identified. The two key factors I identified were the availability of transportation and the ability to shelter in place.

In terms of available transportation, Hughey and Smith (2013) argued that disruption in transportation after an earthquake would prevent both staff and patients from reaching hospitals in Napa County. Identifying a disruption is consistent with community resilience, because a disruption is necessary to trigger the response to an event (Longstaff & Yang, 2008). Depending on how many staff or patients can reach Bay Area hospitals, the result may be resistance, resilience, or vulnerability. Identifying transportation disruption makes it less likely that the community will result in vulnerability because planning actions can be taken to address the potential vulnerability.

Additionally, the Santa Cruz County Regional Transportation Commission (2018) identified transit dependents as a potential vulnerability but did not further explain how planning for transit dependents was occurring. This recognition by the Santa Cruz commission, as compared to Hughey and Smith (2013), is less likely to result in resilience or resistance. Santa Cruz has not taken the additional steps to address how transit dependents can arrive at a hospital. The type of transportation in Santa Cruz was not identified either, so it was unclear if further transit dependent vulnerabilities would exist if the electrical system were sufficiently disrupted compared to the availability of gas supplies.

In terms of sheltering in place, Ready Marin (n.d.) indicated that people should plan on being on their "own for days" and recommended people know which neighbors have generators (para. 2). Ready Marin acknowledged that transportation will be vulnerable after a disruption and a neighbor with a generator may be able to provide power to smaller electric transportation methods like a car. Because there is no disruption in this circumstance where a generator is available to provide electric fuel for the car, there would be a state of resistance. If instead, after the earthquake the electric car owner purchased a generator, then there would be a state of resilience.

The balance of understanding infrastructure, its alternatives, and the consequences from failed infrastructure was identified by SPUR (2013) during my literature review. Ready Marin (n.d.) provided one potential solution to electric transportation's reliance on electricity but failed to take the final analytical step of including electric transportation as the reason a community would need to know who has generators and where they are in a community. Without identifying where there are generators, a vulnerability may exist in Marin County's planning efforts.

Electric transportation and getting electricity to transportation is not considered. These findings suggest a disconnection between the literature and the ERP planning documents in the Bay Area. The literature indicated infrastructure and its alternatives as a key component for community resilience. For example, Procyk and Dhariwal (2010) linked transportation and health care provision with electricity. Ready Marin (n.d.), the Santa Cruz Regional Transportation Commission (2018), and Hughey and Smith (2013) identified various aspects of disruptions and their impacts. None of these three, however, made the linkage to electricity, transportation, and health care.

Understanding that the Bay Area ERP documents have not made this connection confirms that there is a disassociation between community resilience and the planning efforts in the Bay Area.

Research Question 3

Differences are more distinct between medical and transportation ERPs than between Bay Area cities and counties. Neither medical nor transportation ERPs had emergency response plans for electric transportation. Medical ERPs had greater concern over their resistance and resilience to transportation disruptions than transportation ERPs. However, the most common thread between cities and counties was electric vehicle advocacy. The City of Fremont (2017), the Transportation Authority of Marin (2018), and the Sonoma County Transportation Authority (2016) all included resources identifying the benefits, but not the vulnerabilities, of increasing electric transportation. All three primarily focused on electric cars.

The City of Fremont (2017) enthusiastically stated, “Fremont’s 94539 zip code is home to more [electric vehicle] drivers than any other zip code in California!” (para. 1). The City of Fremont also describes benefits but does not list or provide documentation for fueling an electric car if electricity is lost. This means the subpopulation of Fremont is more vulnerable to disruption than other subpopulations (Adger, 2000).

The Sonoma County Transportation Authority (2016) stated that electric vehicles have “the potential to reduce petroleum consumption and greenhouse gas emissions dramatically and increases energy independence through the utilization of locally produced energy” (p. 3–28). Similar to the City of Fremont (2017), the Sonoma County Transportation Authority does not address the increased vulnerability associated with electricity powering transportation. The adaptation to help address climate change as a positive adaptive capacity is creating a different vulnerability to earthquakes and their disruption (Norris et al., 2007).

Medical and transportation ERPs should work together to better understand their joint vulnerabilities to disruption and the impact to their critical transportation infrastructures. As the Bay Area increases its electrical transportation penetration, the ERPs will need to understand the changing vulnerability of transportation to electrical disruptions. The common element identified between cities and counties was their advocacy for increasing electric transportation for environmental objectives. The Governor of California’s order in Exec. Order No. B–48–18 (2018) solidifies this cooperation by ordering “all State entities to continue to partner with regional and local governments to streamline zero-emission vehicle infrastructure installation processes wherever possible” (para. 13). This conflict between environmental and other priorities has occurred in Florida, as identified by Tobin (1999). The Bay Area should learn from Florida’s mistakes and work to balance emergency planning with environmental planning in order to enhance community resilience.

Community Resilience and ERPs

The Norris et al. (2007) community resilience theory served as the theoretical foundation for this study. I reviewed documents to identify how electric transportation was considered for emergency planning. Planning can increase resilience, as it links "adaptive capacities to a positive trajectory of function and adaptation after a disturbance" (p. 130). With each document reviewed I was able to identify different themes to understand how and if ERPs were planning for electric transportation as part of their emergency planning postdisaster.

Community resilience consists of the community and resilience. There can be different elements of the same community. The Bay Area community was largely homogenous within similar types of planning documents, or similar subpopulations of ERPs. However, a difference in looking at fuel for transportation arose between subpopulations of medical ERPs, who were concerned about fuel, and transportation ERPs, who were not. This consideration of capabilities is consistent with Cutter et al. (2008) and their identification of different resilience capabilities within subpopulations. Several documents did consider the different subpopulations. Transportation was identified as critical infrastructure for medical facilities such as hospitals (Santa Cruz County Regional Transportation Commission, 2018). Fuel was a concern for medical ERPs but not for transportation ERPs. The transportation ERPs were also concerned about their transportation network, of which hospitals are one component, whereas medical ERPs were concerned about making sure their specific facilities were able to demonstrate resiliency. These different concerns are indicative of different subpopulations, which indicates different resilience capabilities.

The resilience capabilities of the hospital versus transportation subpopulations is different. Hospitals need electricity or fuel for generators, staff, medical supplies, and a way to get patients to the hospital. The medical ERPs identified these as issues in their documents. On the other hand, transportation systems need fuel for the vehicles that use them, and then construction materials in case the road or rail line fails. If a particular road is damaged, other alternative routes typically exist, but at greater fuel cost or time. Geographically constrained areas, like the Bay Area, are an exception to this resilience, as seen in Figure 1. This makes their transportation networks less resilient.

Similarly, the increasing penetration of electric vehicles, with their fuel limitations, decreases transportation resilience unless powering them is accounted for in planning efforts. A decreased state of resilience is vulnerability (Norris et al., 2007). This is consistent with Adger (2000), and the inclusion of a worsened state after a disturbance. A different state may emerge after a disturbance. Bruneau et al. (2003) included lessening future impacts as a definition of resilience. If planning does not occur, then the future impact may be lessened if hospitals make requirements for nonelectric vehicles for key staff in case there is a disaster. This would be resilience, a changed end-state (Adger, 2000; Longstaff & Yang, 2008; Norris et al., 2007). If planning does occur, then a positive adaptation would be for hospitals to make available electric fuel sources for transportation, such as solar panels or electric generators. This result is resistance, the best outcome, where there is no disruption in response to the crisis (Longstaff, 2005; Longstaff and Yang, 2008).

With current electric vehicle penetrations, the outcome after a disruption is unclear. Any of the three community resilience outcomes is possible: resistance, resilience, or vulnerability. As electric vehicles increase in penetration, without proper planning, Bay Area hospitals are likely to emerge from a disaster in a state of resilience or a state of vulnerability.

Limitations of the Study

The primary limitation of the study was its focus on the Bay Area. The document review and analysis led to the inclusion of state and federal planning documents, and analysis of the state and federal planning documents. Local ERP use of state or federal documents does not mitigate the specific geographic and other defining features of the Bay Area.

An additional limitation I discovered during the research was the idea that geography and distance constraints can place geographic restrictions on nonelectric transportation. For example, a car that is nearly empty can travel the same distance as a partially charged electric vehicle. If the gas stations do not have electricity, then gas cannot be pumped for the car's tank. This limitation on fuel and distance is discussed in several studies, even though those studies do not discuss electric vehicle limitations (O'Rourke, 2007; Procyk et al., 2010). These studies, however, differ from the documents used by ERPs. The ERP documents, as described earlier, generally did not include fuel in the limitations.

A third limitation is that my study did not focus on the impacts of the timing and frequency of ERP document updates. As technology or geographic constraints change, ERP documents may need more frequent updates. For this study, over half of the documents had been updated or created in 2016 or later, which may mean that timing and frequency of updates is not a significant factor. These considerations are outside the scope of my study.

Recommendations

Several recommendations emerged from my study. The first is that ERPs should analyze their communities to understand how many of their staff use electric transportation and thus are subject to vulnerabilities. Further research into this subject as California and the Bay Area move toward having five million electric vehicles on the road by 2030 is necessary to ensure that a new vulnerability in community resilience is not being created (Exec. Order No. B–48–18, 2018, para. 11). Such research is consistent with Barbera and Macintyre (2007), who stated that a hazard vulnerability analysis is needed to prepare, respond to, and recover from a disaster. ERPs should also examine their communities to understand if they have similar geographic limitations to the Bay Area that can impact how far transportation can go after a disaster or disruption.

Second, ERPs should examine how fuel for transportation has affected their communities during power outages when gas stations were not operational. Although this study was focused on electric transportation, electricity is needed to operate gas stations. Fuel was identified primarily for generators and first responders such as fire fighters, not for staff and their capability to arrive at a Bay Area hospital after an earthquake. Electricity should be incorporated into ERP documents as a fuel type for transportation.

Third, ERPs should work on analyzing subpopulations, particularly electric transportation users, to ensure that the subpopulations have appropriate community resilience. The commonality between Bay Area ERPs on the benefits of electric transportation needs to be matched by addressing the vulnerabilities of electric transportation for hospitals. Performing a vulnerability analysis may let Bay Area ERPs turn a vulnerability into a state of resistance or resilience (Cutter et al., 2003).

Fourth, further study is necessary to create quantitative metrics that allow a more thorough and accurate assessment of vulnerabilities to transportation disruption for hospitals based on a network analysis such as CORSIM or TRANSIMS (Naghawi and Wolshon, 2010; Sisiopiku, 2007). Murray-Tuite (2006) identified the limitations to DYNASMART-P, particularly the lack of generalization, suggesting the DYNASMART-P model is not particularly appropriate to the Bay Area; an analysis of a particular county or city may be appropriate. Further research can develop the metrics needed to populate these transportation models and help researchers and planners better understand if their specific hospitals are subject to transportation disruptions. Such community resilience planning may help turn potential vulnerabilities into a state of resilience or resistance and allow the community to become more resilient and resistant.

Fifth, the academic community should work more directly with ERPs to better develop and understand the linkages from community resilience theory with practice. The gap revealed by this study shows a general disconnect between changes in critical infrastructure and planning. This gap persists in the Bay Area even though fuel and transit have been identified for many years in the literature as being critically important (Dorbritz, 2011; Procyk et al., 2010).

Implications

Positive Social Change

This study revealed a gap at the policy and societal level between community resilience and emergency disaster planning occurring in the Bay Area. This is the first time that a case study approach has applied community resilience to ERPs in the Bay Area. With California's electric vehicle goals, the increased prevalence and reliance upon electric transportation will only exacerbate staffing challenges when an earthquake occurs.

These challenges can still be addressed in the Bay Area by encouraging planners to review the impacts of electric transportation on their hospital staffing, and to begin developing plans sooner rather than later. This will ensure that ERPs are prepared for electrification of the transportation sector and that this change for environmental objectives will not increase the vulnerability of hospitals to disruptions. Several Bay Area cities and counties are at the forefront of attaining and working towards the electric transportation targets contained in Exec. Order No. B–48–18 (2018). To mitigate potential vulnerability and hospital service degradation or disruption after an earthquake, I will share my findings with the appropriate ERPs and other entities, such as the California Office of Emergency Services.

Implications for Community Resilience

The findings are consistent with community resilience theory. Previous researchers have emphasized a need for quantitative analysis of community resilience; several used quantitative modeling tools. My findings show that ERPs may not be aware of the potential impacts of transportation electrification. Without this awareness, it may be difficult to develop the quantitative data necessary to assess community resilience and the impacts of transportation electrification. Further research is needed to see how community resilience can be adapted to situations with poor quantitative data and the specific impacts that planning has on changing resistance, resilience, and vulnerability.

Conclusion

Norris et al. (2007) applied resilience to communities and identified resilience as "processes linking a network of adaptive capacities (resources with dynamic attributes) to adaptation after a disturbance or adversity" (p. 127). Transportation generally has dynamic attributes, as road closures can impact how far drivers need to travel. With proper planning and consideration of other dynamic attributes such as fuel source, adaptation can occur after a disaster like an earthquake. Currently, adaptation may occur after a disaster and a state of vulnerability. The results of this study show that electric transportation and how to power it following an earthquake has not considered by ERPs in the Bay Area. Before electric transportation levels increase to the targets set by the state of California, planning efforts need to adapt so that ERPs are prepared before a disaster—not after one.

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