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ABSTRACT

This paper examines the opportunities for addressing evacuations by leveraging the sharing economy. To support this research, we use a mixed-method approach employing archival research of sharing economy actions, 24 high-ranking expert interviews, and a survey of individuals impacted by Hurricane Irma in 2017 (n=645). Using these data, we contribute to the literature in four key ways. First, we summarize sharing economy company actions in 30 U.S. disasters. Second, we discuss results from 24 expert interviews on 11 sharing economy benefits (ranging from resource redundancy to positive company press coverage) and 13 limitations (ranging from driver reliability to the digital divide). Experts included six directors/executives of emergency/transportation agencies, two executives of sharing economy companies, and eight senior-level agency leaders. Third, we use these interviews, specifically negative opinions of the sharing economy, to inform our Hurricane Irma survey, which contributes empirical evidence of the feasibility of shared resources. Despite just 1.1% and 5.4% of respondents using transportation network companies (TNCs, also known as ridesourcing and ridehailing) and homesharing respectively during the Irma evacuation, some respondents were extremely willing to offer their own resources including transportation before evacuating (29.1%), transportation while evacuating (23.6%), and shelter for free (19.2%) in a future disaster. We also find spare capacity of private assets exists for future evacuations with just 11.1% and 16% of respondents without spare seatbelts and beds/mattresses, respectively. Finally, we conclude with practice-ready policy recommendations for public agencies to leverage shared resources including: communication partnerships, surge flagging (i.e., identifying and reducing unfair price increases), and community-based sharing systems.

Keywords: evacuations, sharing economy, shared mobility, transportation network company (TNC), Hurricane Irma, emergency management

INTRODUCTION

In the past 20 years, transportation has grown to become an integral part of emergency management. For a variety of hazardous events, evacuations are the primary method to ensure the safety of large populations in the United States (U.S.). While large-scale hurricane evacuations have gained the majority of attention, wildfires in California have also led to the evacuation of hundreds of thousands of residents. At the same time, officials continue to struggle with managing transportation in preparing for, responding to, and recovering from disasters. With the spread of new technological advances, agencies have an opportunity to leverage new ideas to increase evacuation compliance rates, reduce congestion, support vulnerable populations, and ensure resident safety (Wong et al. 2018a; Li et al. 2018). One key advance has been the development of the sharing economy, an Internet-based collection of company-to-peer and peer-to-peer transactions where goods and services are shared and obtained. Companies, including Airbnb, Lyft, Uber, Turo, and Getaround, have disrupted traditional economic and service structures, gaining immense popularity. This online "collaborative consumption" has grown with the help of information and communications technology (ICT), consumer awareness, and sharing economy "companies," rather than just online communities (Hamari et al. 2016). With the proliferation of smartphone technology, consumers are able to access resources through the sharing economy rapidly and efficiently. The explosive growth of these companies has also exposed them to external forces in the marketplace, including disasters. The size and reach of some sharing economy companies suggest that their presence (or lack thereof) in disasters could impact transportation and sheltering operations in communities (Wong et al. 2018a). Research on the application of the sharing economy to disaster response and relief is needed to better assess its feasibility.

To bridge the gap between evacuations and the sharing economy, we employ a mixed-method approach composed of archival research, expert interviews (n=24), and a survey of impacted individuals from Hurricane Irma (n=645). We begin by presenting relevant literature on evacuation behavior and logistics followed by methodology. Next, we summarize the actions of sharing economy companies in 30 disasters. These disasters include large-scale events (involving the evacuation of thousands and millions, such as large hurricanes and wildfires) and small-scale events (leading to only localized impacts with lower evacuation needs such as: small floods, snow storms, and shootings). Given the widespread actions of companies across disasters, we formulated an interview guide to elicit opinions from experts on the benefits and limitations of a shared resource strategy. We present these expert interview findings on use cases, benefits, and limitations. Expert concerns over the potential lack of capacity and willingness to provide resources informed our survey questions, focusing our attention on exploring providers' willingness to share. We next present the survey results on shared resources. Finally, we conclude with policy recommendations to build a framework for shared resources in disasters.

LITERATURE ON EVACUATION BEHAVIOR AND LOGISTICS

In this section, we provide background on evacuation behavior, logistics of mode and shelter demand, and literature gaps. We blend the literature of evacuation behavior and logistics to highlight demand for key evacuation resources and provide context for the sharing economy strategy, which aims to better match evacuation resource demand and supply.

Evacuation Behavior

For evacuations, individuals must make a number of critical decisions (to evacuate or stay, departure time, transportation mode, route, destination, shelter type, reentry time). These choices have important impacts on evacuation response and outcomes. For example, the number of individuals who decide to evacuate affects the transportation system and may require supply-side strategies, such as contraflow (reversing lanes to all flow away from a hazard) to manage demand. Research on evacuation behavior has been predominately spurred by the devastating impacts of disasters. Some of the earliest research focused on how individuals received evacuation orders for the Big Thompson Flood and their subsequent actions (Gruntfest 1977). The Three Mile Island Accident in 1979 also drove research into evacuation behavior and risk perception. Cutter and Barnes (1982) found that individuals experienced significant confusion about the hazard and evacuation process. The lack of information (along with social influence) led more people to evacuate than was expected, overloading roads. Following Three Mile Island, research in the field also focused on the development of evacuation time estimates (ETEs) (Lindell and Perry 1992; Urbanik 1994). These time estimates remain the primary metric for evacuation modeling, as they indicate when a population has been safely evacuated. ETEs are also heavily influenced by evacuee behavior. For example, if households take multiple vehicles, ETEs will rise and can impact transportation response. Lindell and Prater (2007) provide a comprehensive review of behavioral assumptions that must be made for ETEs, especially as they relate to evacuation modeling. Early work also has been instrumental in summarizing evacuee behavior. Perry et al. (1981) compared the evacuation decision-making process between nuclear and nonnuclear threats, finding that those who chose not to evacuate did not believe they were in danger. Along with Perry et al. (1981), multiple studies have also focused on how evacuees receive information and what they decide to do with it (see Drabek 1986, Sorensen et al. 1987, Sorensen 1991, Drabek 1999, Sorensen 2000 for overviews).

Notable advances in hurricane evacuation literature have included choice making and logistics analysis (Urbanik 1979, Baker 1979, Baker 1990, Baker 1991, Gladwin 1997, Dow and Cutter 1998; Baker 2000). Baker (1990) and Gladwin (1997) found a lack of compliance in evacuation zones (geographic areas given evacuation orders) and an increase in shadow evacuations (large evacuations by households without evacuation orders) to be problematic in hurricane evacuations. While low compliance indicates an obvious safety issue, shadow evacuations (along with background traffic) are also safety issues because they significantly increase demand and ETEs. This is because congestion from shadow evacuations and background traffic can propagate into evacuation zones, increasing the risk that evacuees will be impacted by the hazard. Baker (1991) summarized the state of evacuation behavior research by assessing twelve hurricanes. This study found that a number of variables impacted evacuation behavior including: 1) risk level, 2) action by public authorities, 3) housing (current residence), 4) risk perception, and 5) hurricane-specific factors (e.g., category, storm surge predictions). Baker (1991) also found demographics to be poor predictors of evacuation behavior, but social cues (e.g., neighbors) were influential. Dow and Cutter (1998) focused on decisions in multiple evacuation events, particularly the influence of false alarms. Repeated false alarms were hypothesized to decrease future evacuation rates, but Dow and Cutter (1998) found the “crying wolf” impact was negligible.

In 1999, Hurricane Floyd led to the evacuation of 2.5 million people, exposing the inability of emergency plans and transportation systems to adequately move large populations. Some of the

first large-scale attempts at contraflow were instituted for Floyd, but the capacity improvements were tempered by issues of safety, in-bound accessibility, and cost (Wolshon 2001). The public outcry over the Floyd traffic jams led to increased involvement of state transportation departments and transportation professionals. State and local plans were reworked to include new evacuation strategies (Urbina and Wolshon 2003; Wolshon et al. 2005). While many of these strategies were focused on increasing capacity along roadways and assessing evacuee behavior, several included increasing involvement of the transportation engineering community in emergency planning and developing interstate cooperation to support transportation management.

Evacuation behavior analysis has continued to evolve dramatically by employing rigorous methods to determine the influencers of choice. Many of these studies have employed statistical methods, such as discrete choice modeling to analyze decision-making in disasters (see Wong et al. 2018b for a review). While most studies have focused on the decision to evacuate or not (Hasan et al; 2011; Huang et al. 2012; Murray-Tuite et al. 2012), other papers address additional aspects of evacuee decisions. Key examples include departure timing (Fu and Wilmot 2004; Fu et al. 2006); shelter type (Mesa-Arango et al. 2013); route (Sadri et al. 2014a; Sadri et al. 2015); and transportation mode (Sadri et al. 2014b).

For logistics, shelter type and transportation mode are two primary choices that have broad impacts on evacuation outcomes. In Sadri et al. (2014b), respondents without vehicle access were given a hypothetical hurricane scenario to make a modal decision. In addition to assessing the factors that impact mode choice (in particular income, household size, age, and shelter), the study found that 41% would ride with someone from another household, about 34% would take an evacuation bus or regular bus, and 8% would take a taxi. Deka and Carnegie (2010) also assessed transportation mode decisions, finding that mode split in the community and vehicle ownership were key factors along with some demographic characteristics including: education, age, race, marital status, and having an individual with a disability in the household. Wong et al. (2018b) also found vehicle ownership to be significant, along with stronger impacts of destination and weaker influence of income, age, and length of residence. For shelter type, Mesa-Arango et al. (2013) found work requirements, mandatory evacuation orders, income, and variables associated with the final destination impacted shelter decision-making. Other shelter choice studies, including Whitehead (2000), Smith and McCarty (2009), and Deka and Carnegie (2010), found the presence of demographics influencing shelter choice such as: age, homeownership, marital status, race, income, length of residence, and household size. These behavioral studies have played a key role in developing more accurate evacuation models that predict traffic patterns and bolster data-driven preparedness strategies. Similar to Mesa-Arango et al. (2013), Wong et al. (2018b) found that destination was highly correlated with shelter choice. The study also found weak impacts from risk perceptions and age, but some correlation with length of residence, pets in the household, and income.

Evacuation Logistics - Mode and Shelter Demand

While understanding the factors that impact choice are critical, assessing the modal and shelter type split is also useful for determining evacuee demand. For mode, the number of evacuating vehicles – or demand – is a critical metric that impacts evacuation response and outcomes. Naturally, road network capacity and the number of possible evacuation routes (supply) constrain the number of evacuating vehicles. Lindell et al. (2019) provides an in-depth review of the

interplay between supply and demand. For most hurricane evacuations, research has found that evacuees almost always use their own private vehicles to evacuate (Table 1). Consistent results across hurricanes, including Hurricanes Bret, Lili, Katrina, Rita, Ike, and Irma, indicate that private vehicles account for 87% to 96% of evacuee modal choice (Prater et al. 2000; Lindell et al. 2011; Wu et al. 2012; Wu et al. 2013; Wilmot and Gudishala 2013; Wong et al. 2018b). As seen in Table 1, carpooling or receiving a ride from someone else accounts for 2% to 10% of the modal split. Public transit use is low, hovering around 1% across studies, while other modes represent 0% to 7% of mode choice. A number of these studies have also calculated the number of vehicles per household that evacuate, which tends to vary substantially. Households choose to evacuate with multiple vehciles for a variety of reasons, beyond ensuring that every household member has a seat. Evacuees may want to take additional luggage, protect their vehicles, or have great flexibility in travel near their destination. Some studies, including Wu et al. (2013), calculated the percent of registered vehicles used in an evacuation. In this case, 62% of registered vehicles were used for Hurricane Ike. Using correlation tables, several studies found factors that correlated with modal choice and taking additional vehicles (Dow and Cutter 2002; Lindell et al. 2011; Wu et al. 2013; Yin et al. 2014). This research is summarized in Lindell et al. (2019), along with some additional work on the relevance of trailers on roadways for impacting vehicle demand.

Table 1: Transportation Mode by Disaster (adapted from Lindell et al. 2019)

Author(s) (Year)	Hurricane (Year)	Sample Size (Survey Distribution)	Own Vehicle	Received Ride	Public Transit	Other	# of Evacuating Vehicles
Prater et al. (2000)	Hurricane Bret (1999)	79 (mail)	88%	7%	1%	4%	1.34
Lindell et al. (2011)	Hurricane Lili (2002)	263 (mail)	90%	9%	1%	0%	1.10 to 2.15
Wu et al. (2012)	Hurricanes Katrina/Rita (2005)	1056 (mail)	89%	8%	<1%	3%	1.42
Wilmot and Gudishala (2013)	Hurricane Gustav (2008)	300 (mail)	96%	3%	1%	<1%	NA
Wu et al. (2013)	Hurricane Ike (2008)	346 (mail)	87%	10%	1%	2%	1.25
Wong et al. (2018b)	Hurricane Irma (2017)	368 (online)	90%	2%	1%	7%	NA

Similar to mode choice, shelter choice split assesses evacuee demand for public resources, especially public shelters. As seen in Table 2 below, most evacuees have sheltered with friends and family, ranging from 44% to 70%. Public shelter usage was far lower, between 2% and 11%. While these percentages may indicate minimal need, applying a 5% public shelter usage rate across an evacuating population of 1 million would require 50,000 beds. Hotels and motels tend to be used highly, with a range of 16% to 46%. A number of shelters were also classified as “other,” which includes second residences, recreational vehicles, places of work, and private vehicles. One important note is that Wong et al. (2018b) found that 5% of evacuees sheltered using a peer-to-peer sharing economy service (such as Airbnb). This result points to a potential for the sharing economy as a sheltering strategy, which is addressed in the next section.

Table 2: Shelter Type for Recent Hurricanes (adapted from Lindell et al. 2019)

Author(s) (Year)	Disaster (Year)	Sample Size (Survey Distribution)	Friends and Family	Public Shelters	Hotels/ Motels	Other
Prater et al. (2000)	Hurricane Bret (1999)	82 (mail)	62%	3%	27%	9%
Whitehead (2003)	Hurricane Bonnie (1998)	235 (telephone)	70%	6%	16%	9%
Smith and McCarty (2009)	Hurricane Charley Hurricane Frances Hurricane Ivan Hurricane Jeanne (2004)	11,559 (telephone)	57% to 65%	3% to 11%	7% to 25%	13% to 18%
Cheng et al. (2011)	Hurricane Floyd (1999)	1136 (telephone)	60%	4%	32%	5%
Lindell et al. (2011)	Hurricane Lili (2002)	263 (mail)	54%	3%	29%	14%
Wu et al. (2012)	Hurricane Katrina/Rita (2005)	1028 (mail)	61%	3%	18%	18%
Wilmot and Gudishala (2013)	Hurricane Gustav (2008)	300 (mail)	44%	2%	46%	8%
Wu et al. (2013)	Hurricane Ike (2008)	338 (mail)	63%	2%	30%	5%
Yin et al. (2014)	Hurricane Ivan (2004)	853 (telephone)	62%	2%	22%	14%
Wong et al. (2018b)	Hurricane Irma (2017)	368 (online)	59%	4%	27%	10%*

* Approximately 5% of evacuees used a peer-to-peer service such as Airbnb for sheltering

Finally, while many previous disasters have led to significant congestion on roadways due to limited road network capacity, Hurricane Katrina in 2005 most acutely displayed the impacts of a lack of transportation and sheltering availability. Prior to Hurricane Katrina, the New Orleans evacuation plan did not include a process for providing transportation for carless residents (Wolshon 2002; Renne 2006). Wolshon (2002) predicted that upward of 200,000 to 300,000 did not have access to personal transportation. Katrina led to a renewed effort to identify lessons learned and create extensive recommendations for various levels of governance (Litman 2006; Renne et al. 2008). Very soon after Katrina, officials issued a massive mandatory evacuation for Hurricane Rita, causing severe congestion, fuel and emergency supply shortages, and leading some to turn back home. Afterward, professionals and planners refined demand prediction models along certain routes, developed new models for shadow evacuations, and began to look into addressing the need for services along highways (Murray-Tuite and Wolshon 2013). Other studies have also offered recommendations for vulnerable populations including ideas for transporting older populations (Gibson and Hayunga 2006); aiding carless and special needs populations (Renne et al. 2011); and helping independent living individuals who are older and/or disabled (Cahalan and Renne 2007). Recent work has focused on building more robust and equitable evacuations by leveraging public transit strategies (Bish 2011) and optimizing transit pickup locations for

vulnerable groups (Bian and Wilmot 2017). Despite this equity push, research has found that one-third of the 50 largest cities in the US do not have evacuation plans (Renne and Mayorga 2018). This research also found that less than half of cities with evacuation plans mention carless or vulnerable populations. Even for the relatively successful Hurricane Irma evacuations, issues with evacuating nursing homes, hospitals, and carless populations were widespread (Bliss, 2017). Hurricane Maria, which devastated Puerto Rico in 2017, caused significant damage across the island to its transportation system (Lazo 2017) and electricity grid (Federal Emergency Management Agency 2018), forcing many to seek housing in inadequate public shelters (Allen and Penaloza 2017). In an after-action report, the Federal Emergency Management Agency (FEMA) acknowledged that the agency did not anticipate the widespread damage that Maria would cause to Puerto Rico (Federal Emergency Management Agency 2018). The report recommended increasing transportation planning and management capacities and building a stronger relationship with private-sector partners to recover more quickly. Finally, the report noted the crucial role of volunteers, non-profit organizations, and the private sector across the 2017 hurricane season for providing transportation and sheltering (Federal Emergency Management Agency 2018).

Key Literature Gaps

As evidenced throughout this review, several key gaps in the literature emerge. First, much of the research has focused on the vehicle demand but not on strategies for increasing transportation supply. While most individuals continue to use private vehicles, a significant proportion of people continue to rely on carpooling, public transit, and other modes. Moreover, modal split statistics fail to capture the number of people who did not evacuate because they did not have access to transportation. Indeed, carless households in the US continue to comprise a large proportion of at-risk cities for hurricanes such as: Houston (8.6%), Charleston (7.6%), Tampa (10.9%), Miami (19.8%), and New Orleans (19.2%) (U.S. Census Bureau 2018). In Houston alone, 8.6% of carless household would equate to over 70,000 *households* that would have no access to a private vehicle in the event of an evacuation. Moreover, even some individuals with private vehicles may be unable to transport themselves. This might include individuals with disabilities, older adults, or people without immediate vehicle access (e.g., vehicle in repair).

Second, the majority of logistic studies continue to focus on shelter type split without addressing the high need for free sheltering options through public shelters. Moreover, it remains unclear how many people decide to forgo evacuating because they do not have adequate shelter. Wong et al. (2018b) found that 31% of non-evacuees stated that one reason they did not evacuate was because they did not want to go to a public shelter. At the same time, 14% said that they did not have enough money to evacuate. Evacuees often view public shelters as a last resort, and some cannot afford to travel far distances to friends and family or pay for a hotel. Increasing sheltering supply, especially supply that is considered adequate and comfortable, may help increase compliance rates and alter evacuee behavior.

Finally, ad hoc resources for evacuations remain an understudied research area. While some work has been conducted on public shelter, public transit, and carpooling logistics, little research has considered the role of the sharing economy. This is especially relevant given the ease of emerging technologies and communication that could facilitate matching supply and demand in evacuations. Moreover, some planning guidelines encourage consideration of all available and accessible transportation resources into evacuation plans (Federal Emergency Management Agency 2010).

State emergency plans, for example in Texas, note that large-scale events may require additional transportation resources beyond public ones, and volunteer assistance (either planned or spontaneous) may be required in these events (State of Texas 2016). The California Emergency Plan also recognizes the role of private entities through the creation of the Business Operations Center, which is housed in the logistics section of the state operation center (Cal OES 2016). With these needs and policy mechanisms already in place, the sharing economy could play a strategic role in filling unused capacity in vehicles and shelters and improve evacuation outcomes.

RESEARCH QUESTIONS AND CONTRIBUTIONS

The goal of this paper is to bridge the gap between two distinct research tracks: evacuations and the sharing economy. To our knowledge, no research paper has compiled sharing economy actions during disasters or assessed the willingness of individuals to provide their own resources in a disaster via the sharing economy. While the idea of shared resources has been described before (Wong et al. 2018a) and assessed in a Chinese context (Li et al. 2018), this paper is the only U.S. study to investigate the application and potential of the broader sharing economy in evacuations. More specifically, we offer archival evidence of past sharing economy actions, expert opinions on shared resource benefits and limitations, and empirical evidence from individuals recently impacted by a disaster on their willingness to provide resources. While Li et al. (2018) also interviewed experts on benefits and limitations, the paper surveyed carless individuals, not individuals impacted by a disaster, which helped assess sharing demand. In our paper, we focus on the capacity of shared resources, which is a prerequisite for implementing a shared resource strategy for evacuations. To guide this study, we formulated several research questions:

(1) What is the role of the sharing economy in disasters?
(2) What are the benefits and limitations of public-private partnerships that involve the sharing economy?
(3) What is the magnitude of spare capacity in vehicles or houses to evacuate and shelter?
(4) Are individuals willing to provide rides or shelter for evacuees?

These four research questions each contribute to the overall assessment of the sharing economy in evacuations. With the first question providing background on the sharing economy, the second question begins to address the feasibility and theoretical framework of the sharing economy in disasters through qualitative data gathering. While qualitative data develops the framework, empirical evidence helps answer questions three and four, which finds a quantitative capacity for the sharing economy. Together, the four questions theoretically and empirically explore the sharing economy strategy for evacuations and provide a starting point for future work in the field.

METHODOLOGY

To answer the research questions, we employed a mixed-method approach to bring together evacuation and sharing economy research. Addressing the first research question, we first conducted a comprehensive archival review of current sharing economy company actions in 30 U.S. disasters. This review provides context for the current role of the sharing economy in evacuations and informed our expert interviews. Next, we conducted a series of high-ranking expert interviews between February and April 2017 to answer the second research question. We developed a list of potential experts based on several factors including:

1) Experience and knowledge in developing or implementing transportation management policies, procedures, or protocols for disaster situations;
2) High-ranking leaders and/or senior officials with authority in disaster situations;
3) Geographic diversity in areas that traditionally experience natural disasters including the West Coast (earthquakes and wildfires), Gulf Coast and South (hurricanes), East Coast (hurricanes and winter storms), and Midwest (tornadoes); and
4) Employment diversity in different fields related to emergency management.

Using these criteria, we compiled a list of U.S. experts. We asked each to participate in an interview via email and to also identify other evacuation experts. We employed this snowball sampling technique to increase the interview pool and leverage the persuasive influence of a referral system. Expert interviews averaged about one hour and were completed with 24 experts. This method was intended to increase the diversity of answers and opinions (Weiss 1995). Near the end of the interviewing process, a number of answers provided were duplicates of past interviews; this suggested a saturation of usable information and led the team to end with 24 interviews. More importantly, the 24 interviews successfully answered the research questions.

While experts offered high-level opinions of the sharing economy, full implementation of a sharing economy strategy requires that evacuees and non-evacuees have the willingness and capacity to share resources. Experts were highly concerned about the feasibility of the sharing economy, explaining that people may not want to share in a disaster. Specifically, they were concerned that drivers may be unwilling to provide transportation and that a number of reservations (e.g., concerns about safety and security, worry about interacting with a stranger) would severely limit the sharing economy strategy. Moreover, several experts asserted that only a small number of individuals would provide services and it would be inadequate for community needs. Given these negative expert opinions, we crafted a survey addressing sharing capacity, willingness to share, and potential reasons against sharing. In contrast to Li et al. (2018), which surveyed a general population without disaster experience, we distributed the online survey to individuals impacted by Hurricane Irma in 2017 between October and December 2017 across the state of Florida. The survey offers empirical evidence to answer the third and fourth research questions.

Hurricane Irma, one of the most powerful hurricanes ever recorded, led to one of the largest evacuations in U.S. history with over six million people, mostly in Florida, ordered to evacuate. Even though Irma weakened significantly after making landfall, the storm resulted in an estimated $50 billion in damages and 92 deaths in the U.S. (National Oceanic and Atmospheric Administration, 2018). Considering the large size of Hurricane Irma and the wide-spread evacuations, we posted the survey online to various locations including: Facebook, Twitter, online websites, and alert subscription services with the help of local emergency management, transportation, public transit, and planning agencies. These agencies were selected based on the population size of their jurisdiction and their proximity to Hurricane Irma. Respondents were incentivized with the opportunity to win one of five $200 gift cards. The survey yielded 1,266 responses, 938 completed surveys (74% completion rate) and 645 final responses after intensive data cleaning for analysis.

ARCHIVAL RESULTS AND DISCUSSION

Recently, the ubiquitousness of the Internet and social media has ushered in new strategies for emergencies, opening new doors for dissemination, resource access, and data collection for transportation emergency management. The catalyzing event for this switch towards Internet-based strategies was Hurricane Sandy in 2012, one the most severe disasters in the U.S. since the beginning of mass consumption of social media and smartphone technology. New York City Transit used Twitter to provide updates about the storm, subway service, closures, false reports, and recovery efforts (Chan and Schofer 2014). For other services – such as fire and police – agency websites, Twitter, Facebook, and Nixle were used for communicating messages regarding the storm for some departments (Hughes et al. 2014). For federal agencies, social media was used across different platforms for a variety of purposes (Department of Homeland Security 2013). Recent research has used Twitter data to determine user activities across time and space during Hurricane Sandy (Sadri 2016), identify storm-phase patterns of communication (Sadri et al. 2018), gauge evacuation compliance (Martin et al. 2017), and follow the progression of perceiving and responding to evolving risks (Demuth et al. 2018).

Despite this increase in media consumption via the Internet, evacuees continue to receive information via traditional media forms such as: television, radio, and telephone. For example, Wong et al. (2018b) found that of those who received a mandatory evacuation order for Hurricane Irma, 56% obtained it via a television announcement, 30% through telephone, and 19% through radio. About 48% received the order through social media and 33% via an Internet website. The results indicate that individuals received the order through a number of sources, which confirms previous research on social milling where people seek warning confirmation from other sources (Lindell, 2018). However, social media and Internet use was likely inflated due to the high technology usage of the survey sample. For a boil water order in Boston, Lindell et al. (2017) found that 66% of respondents learned about this order in Boston via television. In the same study, 34% received information via the Internet, 25% through telephone, 21% radio, and just 3% via social media. Lindell et al. (2017) also found that people depend on multiple sources (approximately 1.76 additional channels). Other research has found that individual rely on a number of information sources with just 25% depending on social media during Hurricane Sandy for information (Sadri et al. 2017). At the same time, not all individuals have access to smartphone technology. Recent research has found that 23% of Americans do not own a smartphone (Pew Research Center 2018a), and 11% do not have broadband Internet access (Pew Research Center 2018b) Despite these limitations on social media notifications and the clear need to continue using multiple methods of communication in disasters, the spread of smartphone technology has allowed information to move more rapidly through Internet-based media. Moreover, emerging technological capabilities have instigated the rise of the sharing economy in emergency situations as an evacuation strategy. Generally, the sharing economy is coordinated online and allows for obtaining, sharing, and accessing goods and services from peers or businesses.

Transportation network companies (TNCs, also known as ridesourcing and ridehailing), such as Lyft and Uber, allow users to request car rides through a smartphone application and charge riders based on distance and travel time (Rayle et al. 2016). To encourage market equilibrium when demand is high and driver availability is low, TNCs raise prices through a mechanism called primetime or surge pricing. Immediately following Hurricane Sandy, Uber instituted a surge of twice the base price to meet the increase in demand. It received intense criticism on social media

by users who saw the move as an unethical method to price gouge customers during an emergency (Walk 2012; Weiner 2014), leading Uber to give 100% of proceeds from rides directly to the driver. Another sharing economy platform, Airbnb (a marketplace of homes and rooms where people have the opportunity to rent their space or another's space in hundreds of countries known as homesharing) and its renters displayed the positive benefits of sharing economy networks. In a peer-created movement, nearly 400 Airbnb renters offered their apartments and houses free of charge to anyone in need of housing after Hurricane Sandy (Airbnb 2017a). The positivity and success of ad hoc homesharing during Sandy led Airbnb to create the Disaster Response Program (now called Open Homes). This program provides alerts to Airbnb renters near disaster areas and encourages them to provide their house free of charge to victims by waiving all fees (Airbnb 2018a). The sharing economy has acted in 30 disasters in the U.S. since 2012, including Hurricane Sandy (Table 3).

The policy decisions of sharing economy companies during emergency situations have continued to evolve in the U.S., as noted in Table 3. The table reflects a clear progression that sharing economy companies are increasing their presence in emergency events. Airbnb has maintained a consistent protocol for large disasters, opting to use its Disaster Response Tool (Open Homes) and waiving all fees for transactions to help evacuees. Actions by Lyft and Uber have been more sporadic and dependent on geographical offices. More recently, a number of devastating disasters in 2017 and 2018 have revealed additional actions by sharing economy companies that are more extensive, structured, and visible in the public eye. In particular, Hurricanes Harvey and Irma and the wildfires in the North San Francisco Bay Area and Southern California required large evacuations and displaced thousands of people. As seen in Table 3, Lyft and Uber focused their support on offering free and discounted rides to and from evacuation centers and hospitals. Along with guaranteeing monetary contributions, Uber also delivered free meals to first responders during the Southern California fires and began to focus their services toward carless individuals (with an emphasis on older adults) during Hurricane Irma and the North San Francisco Bay fires. Lyft also pledged monetary donations through its Round Up and Donate program. In addition, Lyft pushed its concierge service to reach individuals without smartphones during Hurricane Irma and suspended its Primetime pricing during the Las Vegas shootings. For most of the disasters, Airbnb ran its Open Homes program and received a high number of willing hosts for Hurricanes Harvey (~700), the North Bay wildfires (~900), Hurricane Florence (~600), Hurricane Michael (~1000), the Camp Fire (~2000), and the Woolsey Fire (~1600). While it remains unclear how many people used Airbnb, Uber, and Lyft in these disasters, the improved communication and clear switch toward free relief are indications that these sharing economy companies intend to play key roles in disasters. Additional details and descriptions of sharing economy company actions can be found in Figure A1 in the appendix.

It should also be noted that many sharing economy companies – including Airbnb, Lyft, and Uber – operate internationally. While this paper focuses on U.S. disasters, multiple disasters in recent years around the world have also prompted the support of these companies. Airbnb continues to implement its Open Homes program for not just international disasters but also for housing refugees. While Lyft's operations have only recently expanded to Canada, Uber operates in numerous countries. The two most notable international actions of Uber in emergencies were during the Sydney Hostage Crisis in 2014 – when Uber prices surged but received considerable

public backlash (BBC 2014) – and the Manchester Bombings in 2017 during which Uber provided free rides to safety for concert goers into the morning (Marinova 2017).

Table 3: Summary of Sharing Economy Actions Across 30 Disasters

	Airbnb	Lyft	Uber
Years Active in Disasters	2012 to present	2015 to present	2012 to present
Disaster Cases with Sharing Economy Actions			
Hurricanes 	Sandy (2012) Matthew (2016) Harvey (2017) Irma (2017) Florence (2018) Michael (2018)	Matthew (2016) Harvey (2017) Irma (2017) Florence (2018) Michael (2018)	Sandy (2012) Matthew (2016) Harvey (2017) Irma (2017) Florence (2018) Michael (2018)
Wildfires 	Northern California (2017) Southern California (2017) Mendocino Complex (2018) Carr (2018) Camp (2018) Woolsey (2018)	Northern California (2017) Southern California (2017) Carr (2018) Camp (2018) Woolsey (2018)	Northern California (2017) Southern California (2017) Woolsey (2018)
Floods 	Houston (2015) Louisiana (2015) Central Texas (2018) Tennessee (2019) March Midwestern U.S. (2019) May Midwestern U.S. (2019)	Austin (2015) March Midwestern U.S. (2019)	Houston (2015) Austin (2015) Missouri and Illinois (2015) March Midwestern U.S. (2019)
Snow Storms 	None	Juno (2015)	Nemo (2013) Electra (2013) Juno (2015) Linus (2015)
Tornadoes 	Lee County Tornadoes (2019)	None	Texas Tornadoes (2015)
Other 	Oroville Dam Crisis (2017) Las Vegas Shootings (2017) Kilauea Volcano (2018)	Las Vegas Shootings (2017)	Las Vegas Shootings (2017) Montecito Mudslides (2018) Kilauea Volcano (2018)
Summary of Sharing Economy Actions			
	2012 to 2013	**2015 to 2016**	**2012 to 2015**

Early Actions (Ad hoc approaches)	• Offered homes free of charge to Hurricane Sandy evacuees in a peer-led movement	• Capped Prime Time surge pricing across early disasters • Suspended service during the disaster	• Increased trip prices (surged) across hurricanes and winter storms and worked to cap surges • Employed UberRELIEF Program on a case-by-case basis, which allowed riders to donate to a disaster relief organization (e.g., American Red Cross)
Intermediate Actions (Semi-structured approaches)	**2014 to 2016**	**2017**	**2016 to 2017**
	• Developed Disaster Response Program, which allowed hosts to provide their homes for free on the Airbnb website • Created Memoranda of Understanding with cities to offer housing to disaster relief and share information	• Developed Round Up and Donate Program that allowed users to round up the cost of their trip to the nearest dollar and donate toward a charity, including the United Way for disaster relief • Developed Relief Rides Program, which organizes rides for disaster relief • Offered ride credits to and from evacuation centers	• Offered ride credits to and from evacuation centers following some disasters • Altered the value of credits on a case-by-case basis • Pledged specific dollar amounts for rides, food, and relief for each disaster
Current Actions (Highly structured approaches)	**2017 to present**	**2018 to present**	**2018 to present**
	• Rebranded Disaster Response Program as the Open Homes Program to include refugee housing • Continues to expand and currently deploys the Open Homes Program following most major disasters, including international disasters • Deploys Open Homes Program for rural disasters	• Rebranded Relief Rides Program as Wheels for All Program, which expanded ride credits to disadvantaged individuals • Partners with a number of organizations including the American Red Cross, Team Rubicon, and United Way • Acts in most disasters where the company operates • Continues to offer ride credits to and from evacuation centers and sometimes hospitals	• Developed the Global Security Center, which now handles most disaster actions of the company • Continues to pledge specific dollar amounts for rides, food, and relief for each disaster • Continues to offer ride credits to and from evacuation centers and sometimes hospitals

As sharing economy companies have grown in the U.S., public-private partnerships have also increased for disasters. In partnerships with cities, including San Francisco and Seattle, Airbnb has pledged to initiate their resources to increase the amount of housing for displaced residents and service workers and pass on critical information to hosts (Airbnb 2019e). The notable surge prices during Winter Storm Electra in 2013 led to an agreement between Uber and New York State, capping Uber surge pricing during emergencies. The agreement prompted Uber to adopt these standards as a national policy (New York State Office of the Attorney General 2014). More recently, Uber has taken the initiative to begin tracking incidents and managing operations through its Global Security Center, signaling its push to reconstruct its disaster policy (Hawkins 2018). Lyft has also more concretely defined its disaster response program – Lyft Relief Rides – for recent disasters, while Airbnb rebranded its disaster policy program as Open Homes.

EXPERT INTERVIEW RESULTS AND DISCUSSION

To develop a richer understanding of the future of sharing economy companies in disasters, we conducted 24 expert interviews between February and April 2017. Experts in disaster response were asked a range of questions regarding their opinions on the sharing economy and associated disaster use cases, benefits, and drawbacks. An overview of expert characteristics and their opinions on several topics are found in Figure 1 below.

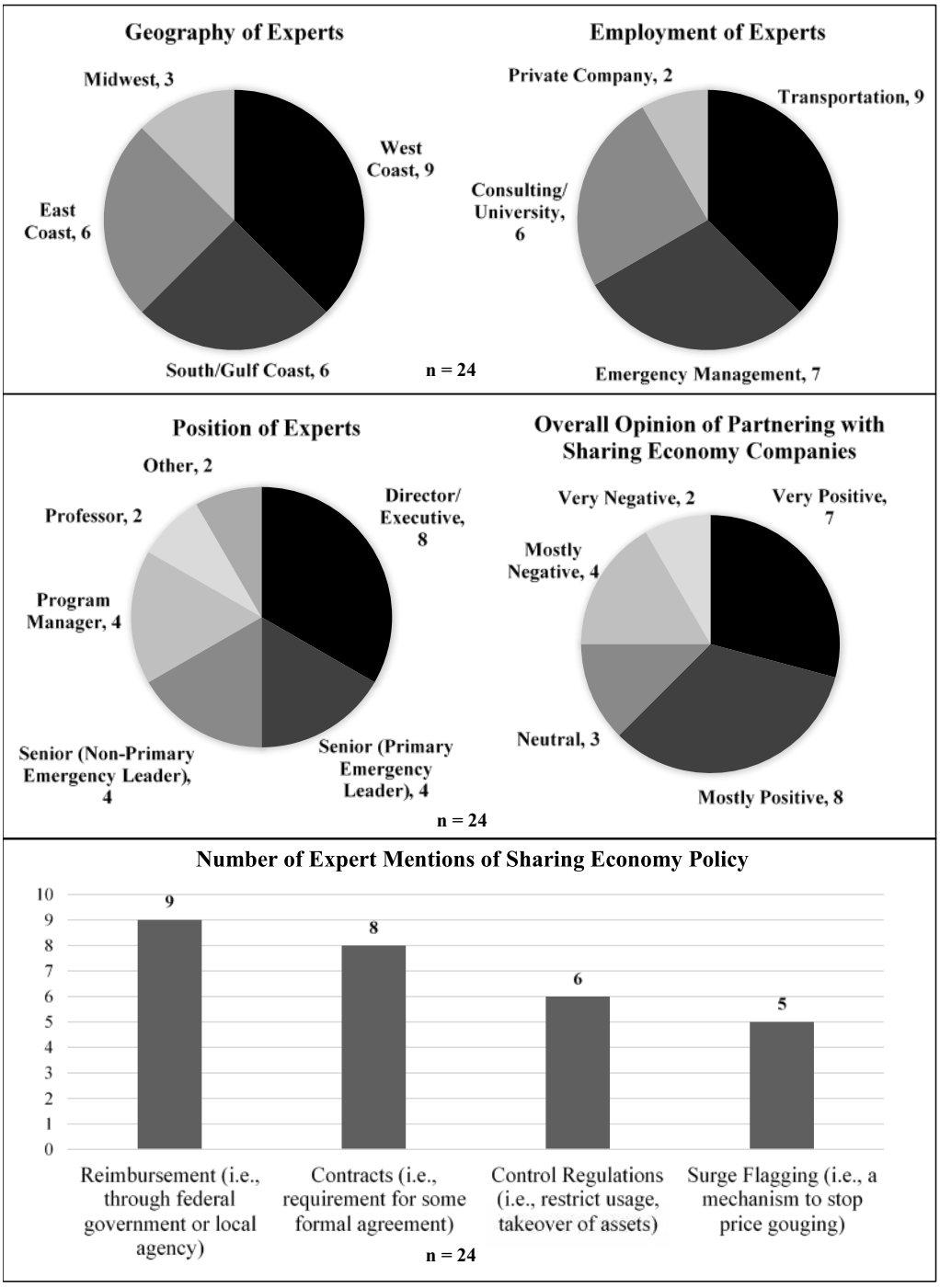

Fig. 1 Overview of Expert Characteristics and Opinions

Possible Sharing Economy Use Cases

We first asked experts about the potential use cases for the sharing economy in disasters. Answers were subsequently grouped into three separate categories: events, transportation benefits, and non-transportation benefits, and they are presented in Table 4 below. For events, experts noted that the sharing economy could be used for no-notice events (e.g., terrorist attacks, wildfires) or small-scale events (e.g., limited impact or small evacuation disasters) where adaptable resources would be beneficial. Events in dense, downtown locations could use sharing economy resources due to their established presence in major cities. However, experts were not as optimistic about large-scale disasters (e.g., hurricanes, earthquakes), as all people would be affected (including drivers and hosts) and more vehicles on the roadway could lead to congestion. For a direct response, experts suggested that pickups at individual homes would increase accessibility. Direct pickups could specifically assist vulnerable populations, while connections to public transit would increase the use of high-capacity transportation modes. For an indirect response, experts suggested focusing on communication. Sharing economy platforms, particularly on smartphones, could serve as a communication tool for connecting with drivers and passengers through push notifications or within-app notifications.

Table 4 Key Sharing Economy Use Cases Noted by Experts (n=24)

Events *Hazard types and situations*	**Transportation Benefits** *Direct transport response*	**Non-Transportation Benefits** *Indirect transport/housing response*
No-notice events (e.g., wildfires, terrorist attacks)	Pickups at individuals' homes and drop-offs at evacuation centers	Situational awareness of on the ground events
Small-scale disasters (e.g., disasters with localized impacts)	Re-entry to impacted areas	Communication with drivers or passengers of current dangers
Disasters in dense, downtown locations	First-mile, last-mile connections to public transit	Data gathering of behavior during disasters
Some large-scale disasters (e.g., hurricanes) due to size and disaster scope	Rides for vulnerable populations (e.g., carless, older adults) including supplementing paratransit resources	Accommodations for those who need it and methods to train residents

Sharing Economy Benefits

Next, we asked experts about their opinion of sharing economy benefits and how it might help private sharing economy companies and local governmental agencies. Emergency management and transportation agencies stand to gain considerably from partnerships, especially related to resource availability. Private sharing economy companies could benefit in areas of market and customer growth. Table 5 below presents various benefits mentioned by experts.

Table 5 Key Sharing Economy Benefits by Experts (n=24)

Local Governmental Agencies	Sharing Economy Companies
Added resources to move or shelter individuals (supplementing public resources)	Positive press coverage (strengthening media presence to gain more customers)
Redundant resources (ensuring extra resources)	Improved business continuity (helping the community return to normal operations)
More flexible and adaptive resource pool (activating resources quickly)	Asset removal and protection (safeguarding resources, if a company has them)
Supporting vulnerable populations adequately (offering rides and shelter)	More amenable regulatory environment (building positive partnerships for good working relationship for future negotiations)
Information gathering and data access (gaining disaster-related data)	Stronger connections with local communities (providing support in disaster situations)
Direct communication to a subset of population (alerting drivers and customers)	

Sharing Economy Limitations

While these benefits might indicate that leveraging the sharing economy could be a major strategy in evacuating residents, experts were clear that there are numerous drawbacks to using shared resources. These limitations are important to highlight, particularly as this strategy is new and largely untested. Experts offered challenges that can be grouped into three areas: 1) personnel, 2) congestion and communication, and 3) equity (Table 6). Beyond these categories, other limitations could pose problems. These include:

- Conflicts between expansion-oriented model of most sharing economy companies and the humanitarian model of governments in disasters;
- Low supply of drivers/hosts in many U.S. cities in contrast to the evacuation needs of a community;
- Lack of trust in strangers or companies; and
- Language barriers in providing service.

Several experts were strongly opposed to the sharing economy as a general evacuation strategy (as shown in Figure 1 above) and noted a number of the limitations in Table 6. These strongly opposed experts were mostly concerned about pre-disaster planning and communication infrastructure required to properly distribute shared resources in a disaster. This was discussed in the context of a lack of sufficient resources (i.e., time, money) to develop partnerships. They also expressed distrust for private companies to act benevolently during the disaster. At the same time, several experts were concerned with congestion issues that could arise from the influx of shared resources, particularly vehicles into a disaster area. The inability of agencies to control these vehicles could significantly hamper the evacuation process for others. This concern over control was discussed in the context of a rapid terrorist attack in a downtown area. Experts were also worried about relying heavily on private resources to provide assistance, as agencies would not have control of drivers.

Most critically, questions remain in the structure and mechanics of any future partnerships in evacuations. Memoranda of Understanding are a first step to establishing the groundwork for cooperation. Future partnerships could include legally-binding agreements, as well as guidelines and procedures for surge flagging. The total number of expert mentions of these various policy mechanisms are provided in Figure 1 above.

Table 6 Key Sharing Economy Limitations by Experts (n=24)

Personnel	Congestion and Communication	Equity
Ensuring drivers/hosts show up and arrive on time in risky conditions	Increasing number of vehicles attempting to evacuate	Determining who shoulders service costs
Paying and increasing the number of drivers without surge pricing	Changing destinations due to the sparser distribution of Airbnb houses	Overcoming the digital divide (i.e., inequality in accessing computers/Internet)
Ensuring safety of providers and users of shared services	Changing traffic patterns due to reliance on GPS systems	Ensuring low costs for those most vulnerable
Reaching sufficient driver/host knowledge of how to handle unique situations, such as correctly assisting an older individual or an individual with limited mobility to a vehicle	Failing to match drivers and riders due to communication issues (i.e., power outage)	
Determining liability (i.e., who is responsible for safety and guaranteeing rides or housing)	Overloading the wireless network	

HURRICANE IRMA SURVEY RESULTS AND DISCUSSION

To supplement the expert interview findings and begin to assess sharing economy feasibility in evacuations, we offer empirical results from the Hurricane Irma survey. Survey respondents resided primarily in three Florida counties: Brevard, Lee, and Collier. Hurricane Irma heavily impacted Lee and Collier counties and a large portion of Brevard evacuated. Other counties that we targeted included: Miami-Dade (3.7%), Broward (2.9%), Monroe (2.6%), and Pinellas (2.5%). Respondents were predominately white (94.0%), well educated (only 6.5% with a high school degree or less), mostly female (81.9%), drivers (94.3% drive to work alone), and higher income (30.1% above $100,000 for household). This skew is a function of the areas surveyed along the predominately wealthier coastlines of Florida and the use of an online survey that requires Internet access. Overall, age, employment status, household size, housing type, length of residence, and hazard experience were more evenly distributed. Moreover, 97.4% of respondents were the sole, primary, or equal household decision-maker. Regarding mandatory evacuation orders, 69.5% reported that they were ordered to evacuate and did so, 30.5% reported that they were ordered to but did not evacuate, 46.4% reported that they were not ordered but still evacuated, and 53.6% reported that they were not ordered and did not evacuate. This is comparable to results from a

telephone poll of registered voters that found the split for those given mandatory orders to be 57% evacuated and 43% not evacuated (Mason-Dixon Polling and Research 2017). Our survey indicates a higher amount of mandatory evacuation compliance that may be a result of the targeted focus on Lee, Collier, and Monroe counties where Irma made landfall (i.e., non-representativeness of the sample). Another possible explanation for the difference is that evacuees often have misconceptions over evacuation terminology, in particularly what notices are mandatory versus voluntary (Lindell et al. 2019). With different jurisdictions using variable language for evacuation orders, some individuals may have thought they received a mandatory order when they only received a voluntary order. This is often an artifact of peer communication rather than official sources (Lindell et al. 2019). Additional demographic information on the survey respondents can be found in Table A1 of the appendix.

One key area of interest was how willing individuals would be to offer accommodations or transportation to other evacuees in a future disaster. Respondents were given four scenarios to consider which are described in Table 7 below. We also asked respondents a series of questions regarding their current use of the sharing economy and use during Hurricane Irma (Table 8). Table 8 below also includes the results of the sharing scenarios.

Table 7 Description of Sharing Scenarios for Future Disaster

Scenario	**1**	**2**	**3**	**4**
Resource Type	Sheltering	Sheltering	Transportation	Transportation
Label	S1-Shelter-Cost	S2-Shelter-Free	S3-Transport-Before	S4-Transport-During
Number of Respondents	645 (all)	645 (all)	368 (evacuees only)	368 (evacuees only)
Explanation of Scenario	Individual's willingness to offer to shelter other evacuees at a **cost per night**	Individual's willingness to offer to shelter other evacuees **for free**	Individual's willingness to offer a ride to other evacuees **before the evacuation process begins**	Individual's willingness to offer a ride to other evacuees **during the evacuation**, enroute to the destination
Additional Information to Survey Taker	Shared home is safe and has not been ordered to evacuate		No additional information	
Recipient Description	The individual(s) receiving assistance is not specified beyond "individual(s)"			
Question Design	Likert scale from 5 (extremely likely) to 1 (extremely unlikely)			

Table 8 Sharing Economy Use and Likelihood to Share in a Future Disaster

Current Usage of Sharing Economy (n = 645)

Frequency	**TNC**	**Carsharing**	**Homesharing**
Regularly (several times a week or more)	0.9%	0.0%	0.2%
Often (about once a week)	1.4%	0.0%	0.2%

Sometimes (several times a month)	11.9%	0.5%	2.0%
Rarely	33.0%	2.8%	33.3%
Never	51.0%	86.4%	62.2%
I don't know what this	1.7%	10.4%	2.2%

Use of Sharing Economy in Hurricane Irma Evacuation (n = 368)

Decision	TNC	Carsharing	Homesharing
Yes (for both evacuation and reentry)	0.8%	0.0%	
Yes (for evacuation only)	0.0%	0.0%	5.4%
Yes (for reentry only)	0.3%	0.0%	
No	98.9%	100.0%	94.6%

Likelihood to Use or Share Shelter Resources in a Future Disaster (n = 645)

Likelihood	Use Airbnb as Shelter in Evacuation	S1-Shelter-Cost	S2-Shelter-Free
Extremely likely	18.3%	6.7%	19.2%
Somewhat likely	27.8%	17.5%	20.3%
Neither likely nor unlikely	13.6%	12.4%	13.3%
Somewhat unlikely	16.1%	26.2%	13.3%
Extremely unlikely	24.2%	37.2%	33.8%

Likelihood to Share Transportation in a Future Disaster (n = 368)

Likelihood	S3-Transport-Before	S4-Transport-During
No personal vehicle	2.7%	2.7%
Extremely likely	29.1%	23.6%
Somewhat likely	25.3%	24.2%
Neither likely nor unlikely	10.1%	10.1%
Somewhat unlikely	16.8%	18.5%
Extremely unlikely	16.0%	20.9%

Most respondents are not frequent TNC, carsharing, or homesharing users. About 11.9% of respondents sometimes use TNCs, and approximately 33% rarely use TNCs and homesharing. Carsharing usage was extremely low, and over 10% of respondents did not know what it was. These low values parallel use during Hurricane Irma. Only 1.1% used TNCs for some aspect of the evacuation, and no one used carsharing. This was expected given the prevalence of auto ownership in many areas of Florida, particularly those most impacted by Hurricane Irma. However, 5.4% used homesharing, and almost 18% of respondents said they would be extremely

likely to use Airbnb as a shelter for a future hurricane. These results suggest a rise in homesharing interest for evacuation accommodations. Over 17% said that they knew about the Airbnb Disaster Response Program (Open Homes).

Table 8 indicates that very few respondents (6.7%) were extremely likely to offer shelter to an evacuee at a cost (S1-Shelter-Cost). However, we found that a larger proportion (19.2%) were willing to provide shelter to an evacuee for free (S2-Shelter-Free), indicating some respondent compassion. Respondents were somewhat willing to share at 17.5% and 20.3% for S1-Shelter-Cost and S2-Shelter-Free respectively, which represents individuals who might be persuaded to help. However, a large proportion was extremely unlikely to share, which indicates a "ceiling" in willingness to share. For S3-Transport-Before and S4-Transport-During, individuals were more willing to help provide transportation than sheltering. This may reflect the higher inconvenience of sheltering an evacuee for extended periods of time as compared to transporting an evacuee in a day or over several hours. Over 29% of respondents were extremely willing to share for S3-Transport-Before, and 23.6% were extremely willing to share for S4-Transport-During. We also find that a sizable number were extremely unlikely to share transportation, but it is less pronounced than sheltering.

Additional descriptive statistics were used to help determine the current capacity of transportation and sheltering resources available and individuals' reservations in sharing resources (Table 9).

Table 9 Current Capacity and Reservations for Sharing Sheltering and Transportation

Number of Spare Beds/Mattresses (n=645)	
0	16.0%
1	25.1%
2	28.4%
3	16.9%
4	7.8%
5	2.6%
More than 5	3.3%
Charge Per Night to Rent to Evacuee (n=645)	
$0	56.0%
$1-$40	17.1%
$41-$80	9.3%
$81-$120	4.4%
$121-$160	0.5%
$161-$200	0.2%
More than $200	2.9%
No answer	9.8%
Reservations About Renting to Evacuee (n=645)	
Uncertainty about one's own safety or security	74.1%
Feeling responsible for the additional house guest(s)	60.9%
Having to interact with a stranger	51.6%

Not having enough water and/or food	45.7%
Disruption of everyday tasks	36.6%
General dislike of hosting	33.2%
Not having enough space for the additional guest(s)' belongings	31.6%
Having to drive the individuals around	17.2%
No government oversight	7.8%
Other	16.1%
I do not have reservations	1.2%

Number of Spare Seatbelts Across All Evacuating Vehicles (n=368)

0	11.1%
1	8.4%
2	13.9%
3	17.4%
4	12.8%
5	13.0%
More than 5	19.8%
Didn't Use Personal Vehicle	3.5%

Maximum Time Deviation to Provide Transportation (n=368)

No time deviation	10.1%
Less than 10 minutes	4.1%
10-19 minutes	18.8%
20-29 minutes	17.9%
30-39 minutes	19.8%
40-49 minutes	3.5%
50-60 minutes	8.2%
Over 60 minutes	4.1%
No answer	13.6%

Maximum Miles Carrying to Provide Transportation (n=368)

No distance	7.1%
Under 10 miles	3.8%
10-19 miles	11.1%
20-29 miles	13.6%
30-39 miles	6.0%
40-49 miles	4.3%
50-99 miles	11.9%
100-199 miles	9.8%
Over 200 miles	15.5%
No answer	16.8%

Reservations of Providing Transportation (n=368)

Uncertainty about one's own safety or security	57.9%
Not having enough space for the additional passenger(s)' belongings	54.3%
Feeling responsible for the additional passenger(s)	47.3%

Not having enough fuel	40.8%
Having to interact with a stranger	40.8%
Adding extra time to the evacuation	39.7%
Having to deviate from evacuation route	30.2%
Having to drive the individual(s) for a long period of time	25.0%
Not having enough water and/or food	22.0%
No government oversight	4.3%
Other	12.5%
I do not have any reservations	2.4%

As shown in Table 9, we find that most individuals have spare beds and mattresses to house evacuees, and only 16.0% have no spare bed/mattress. In addition, respondents were moderately unwilling to charge people for sheltering, perhaps indicating some disaster-context compassion. This phenomenon, more typically known as altruistic behavior or the therapeutic community, has been extensively studied in disasters (see Tierney et al. 2001 and Lindell et al. 2006 for summaries). From a sample of just evacuees, we found that 77% of evacuating vehicles had at least two spare seatbelts, while just 11.1% had no seatbelts. We note that two spare seatbelts would be sufficient for one evacuee and their luggage. This indicates that evacuating vehicles were not fully used during the Hurricane Irma evacuation. Interestingly, 37.2% of respondents were open to carrying an evacuee over 50 miles, which is not insignificant. However, 50.9% were only willing to deviate a maximum of 30 minutes from their evacuation route, and 10.1% were unwilling to deviate at all. These results suggest that a potential passenger's proximity to the evacuation route is a key factor.

We also asked respondents about their reservations with sharing transportation or sheltering (Table 9 above). Similar to willingness to share findings, respondents tended to have more reservations related to sheltering than transportation. Safety/security was the top reservation for both resources, with 74.1% stating concerns for sheltering and 57.9% for transportation. The value for sheltering is likely due to the personal nature of hosting an evacuee at one's home. Feeling responsible for the individual(s) was also a major concern (60.9% and 47.3%), along with having to interact with a stranger (51.6% and 40.8%). Approximately 54% were also concerned about having enough space for the passenger(s) belongings in the case of transportation.

In summary, we found that spare capacity exists for transportation and sheltering in disasters. Moreover, some individuals were extremely willing to share, albeit with significant reservations. These results indicate that resident-oriented networks of shared resources could be feasible in an evacuation. Indeed, research has found that TNCs could be a viable evacuation strategy in China, despite some limitations (Li et al. 2018). On the demand side, Li et al. (2018) found that 83% of carless individuals would opt to take shared mobility in a hypothetical disaster, indicating a clear community need for shared resources.

LIMITATIONS DISCUSSION

Study Limitations

While this research makes notable contributions to understanding shared resource evacuation strategies, it has several limitations. First, the interviews may not capture the breadth of expert opinions, despite the steps taken to gather a diversity of experts. Second, experts opted into the

study, indicating some self-selection bias. This is especially notable for sharing economy companies of which only two were willing to participate. Attempting to overcome this limitation, we targeted our search to high-ranking agency officials in large cities with a strong presence of sharing economy companies. The online survey also reflects some self-selection bias, as individuals opt into the study. We attempted to address this by providing a lottery incentive and by seeking assistance from over 20 agencies with different jurisdictions to help distribute the survey. We acknowledge online surveys have some sampling bias. Online surveys only reach individuals with Internet access, oversampling younger individuals (Kaplowitz et al. 2004) and oversampling wealthier populations (Sheehan and Hoy 1999). We also found that for our survey, the sample geographies were wealthier, more highly educated, and racially whiter than Florida. However, our survey did reach a wide range of ages, household types, lengths of residence, and evacuation experience. Our online survey method allowed us to access a unique population of evacuees, reduce the time needed to conduct the survey, lower the monetary costs associated with survey research, and increase the complexity of the survey (Wright 2005). The online sampling also reduced sample bias related to displaced individuals who may have a new physical address.

With these sampling limitations in mind, we note several impacts on our results. Two key demographic characteristics exhibited bias in the sample: income (skews to higher income) and vehicle ownership (skews to more vehicles). We hypothesize that these two variables would bias our results upward for spare capacity. We found that spare capacity in seatbelts and beds is relatively even across income group, indicating little to no impact on results. However, when we calculate the number of spare seatbelts by vehicle ownership, we find that there is an increase in spare seatbelts as vehicle ownership increases. Most critically, since we severely undersampled carless individuals, we note that any result on spare seatbelts is significantly over-estimated. Additional details on these calculations and analyses can be found in Table A2 and Table A3 in the appendix.

Moreover, some respondents may have been confused about the term “spare seatbelts.” We do not know if respondents accounted for space that would be taken by luggage. This deficiency in the survey design likely biases the results on capacity upwards. In future surveys, this question should be composed of two parts: 1) the number of total seats with seatbelts available across evacuating vehicles and 2) the number of seats with seatbelts occupied by people, luggage, and pets across evacuating vehicles. The difference of these two numbers would be the spare capacity. We also mention that a spare seatbelt only refers to *potential* capacity. Indeed, most evacuees carry luggage, which occupy some seats. The *actual* capacity is likely to be lower in an evacuation. Consequently, a ratio of two seatbelts per user of shared resources is a more realistic assumption for policy development.

We also note that peers (e.g., family and friends) are often used for sheltering accommodations. In our survey, we found that 15.8% of evacuees sheltered with friends, and 43.5% of evacuee sheltered with family. This reflects similar results presented in the literature review (e.g., Lindell et al. 2019). The preference for accommodations via peers biases our spare capacity calculations for beds upwards. While this limitation diminishes the number of spare beds available for other evacuees, this does not diminish the goal of shared resources—leveraging unused capacity. Indeed, friends and family may be vulnerable during disasters and may require transportation and sheltering. Networks of friends could be a pathway for increasing shared resources.

Another limitation is that our sample biases significantly toward females (81.9%), which may impact willingness to share. However, we find that this oversampling has little impact on the likelihood to share, as women and men stated they would be extremely likely to share at similar rates. We also hypothesize that income could impact willingness to share, with those with a higher income more likely to share their assets since they have more resources. However, we find that likelihood to share across the four scenarios is relatively consistent across income groups. While there are small differences, they are not enough to make any concrete conclusion regarding the potential bias. Additional details focused on willingness to share and these two demographic variables can be found in Table A4 and Table A5 in the appendix.

We also note that a number of other demographic characteristics that were slightly under- or over-sampled could impact our results (e.g., age, education, household size, homeownership). To overcome these sampling limitations, we recommend that further research should incorporate multi-variate modeling tools, such as discrete choice analysis, to determine the factors that impact willingness to share. This is a clear next step for research on shared resources in evacuations.

Additional Considerations for the Sharing Economy

We also provide additional considerations for the sharing economy in disasters. We note the availability of sharing economy resources will be highly dependent on geography and hazard type. Some geographies may not require a significant amount of private resources – from companies or other residents – even in a disaster. Moreover, the level of coordination within jurisdictions between government and private companies or residents will differ drastically. For example, some jurisdictions may prohibit vehicles to enter evacuation zones or travel near hazards, diminishing their usefulness in providing transportation. This restriction may also be different depending on the hazard. For example, for hazards with substantial lead time (e.g., hurricanes), all TNC rides would need to be conducted prior to any evacuation zone restrictions. Shared resources will not be a *primary strategy* for evacuating or sheltering residents, but a tool in the response toolkit. Most evacuations continue to be dominated by personal automobiles and sheltering in peer residences. Nevertheless, providing transportation and sheltering to some evacuees – including peers – could be crucial to saving lives and improving evacuation outcomes. The sharing economy has the potential to better allocate resources, even among peers.

We also note that the sharing economy is highly dependent on communication and technology. However, disaster situations may lead to power and communication outages that hamper technological strategies. The sharing economy could contribute to a network overload, as individuals attempt to match over the Internet. We recognize that this is a key limitation, especially for catastrophic disasters. However, for smaller, localized disasters where utilities continue functioning, sharing could be a feasible tool for evacuation logistics. Moreover, the ability to share resources would not be impacted in areas outside the anticipated impact region. To combat catastrophic event limitations, significant planning may be necessary. For a community-based approach, individuals will have to identify carless neighbors ahead of time, and community organizations would have to match members and evacuees in advance. At public shelters, transportation sharing may require physical carpooling boards for trips to stores and health appointments. Sheltering would also require planning in advance through neighbors or community organizations. A similar approach would be needed for private companies to plan in advance where

to send drivers and contact potential hosts. We note that advanced planning for evacuation logistics is not only applicable for the sharing economy but also other forms of transportation and sheltering that may be impacted by power and communication outages.

Finally, we recognize that the sharing economy could be an equitable strategy for transporting and sheltering individuals. However, as asserted by the experts, different vulnerable groups could also face considerable challenges accessing and using the sharing economy. For example, some may be unable to request rides or shelters if they do not have technology access (digital divide). Overcoming this divide may require low-tech solutions, including options to call for rides and shelters, rather than solely offering a smartphone app. For example, call-in strategies have been used before in disasters to coordinate shared transportation through faith-based organizations, non-governmental organizations such as social services, and emergency management agencies (Lindell and Perry 1992). Another strategy may be to leverage 2-1-1, a public service hotline that provides information about resources via landlines. Research has found that 2-1-1 was a critical tool in disasters (Bame et al. 2012) and has assisted vulnerable populations (Hall et al. 2012). Moreover, 2-1-1 call patterns could be used to more adequately deploy disaster resources for unmet needs (Bame et al. 2012). Strategies may also require person-to-person contact or physical bulletin boards.

Individuals with disabilities may also face difficulties requesting services due to a lack of accessible vehicles or communication mechanisms. Other groups, such as immigrants, may have difficulty navigating English-only applications or services. Moreover, individuals may be hesitant to accept services from strangers, especially if providers do not have proper emergency or situational training. These challenges limit the potential of the sharing economy. Consequently, we recommend that additional equity research to identify vulnerable groups, along with identifying the benefits and challenges for each group to better assess feasibility. We recommend that this be achieved through an equity framework (such as STEPS, which stands for Spatial-Temporal-Economic-Physiological-Social as seen in Shaheen et al. 2017), along with in-depth interviews or focus groups with vulnerable populations.

RECOMMENDATIONS

To consolidate the results and discussion, we developed a set of actionable policy recommendations for public officials at emergency management and transportation agencies at all levels of government. We formed these recommendations (Table 10) based on the expert interviews and the survey results. Given the current low usage of the sharing economy in evacuations based on the survey results, these policy recommendations are a first step in constructing a practice-ready framework for agencies to increase the amount of assets at their disposal. Policies are ordered by general feasibility and recommendation level. We also divided the policy recommendations into two categories: company- and resident-oriented. While there remain numerous challenges to shared resources, the recommendations act as a launching point to encourage agencies to consider adding shared resources – whether from companies or residents – into strategies for evacuation and sheltering response.

Table 10 Policy Recommendations for Shared Resources in Disasters

Company-Oriented			Resident-Oriented		
Policy Concept	**Description**	**Recommendation**	**Policy Concept**	**Description**	**Recommendation**
Creating partnerships with sharing economy companies	Companies have an extensive network of assets that can be leveraged quickly. However, asset availability depends on the willingness of drivers/hosts to participate. Partnerships also require substantial planning, and some people may not trust companies to help in disasters.	Recommended for larger cities with a strong presence with sharing economy companies	Bolstering neighborhood /community networks	Private residents may be a more trustworthy source of resources and assets (i.e., neighbors) and have capacity and willingness to share. However, the decentralized nature of sharing resources may lead some to forgo helping, especially if the disaster is dangerous for the provider. Activating resources will also take more time.	Recommended for all communities, but especially smaller localities without the presence of sharing economy companies
Policy Lever, Mechanism, or Strategy for Shared Resources in Disasters					
Stakeholder Communication	Requires agencies to set up a working relationship with companies and include them in stakeholder meetings	Highly recommended for all jurisdictions	Community-Based Outreach	Increases the amount of information available about how to help other people in disasters and specifically target reservations individuals may have	Highly recommended for all jurisdictions
Alliance Development	Encourages companies to connect with a non-governmental organization (NGO) that builds an alliance of private companies for emergency purposes	Highly recommended for all jurisdictions with a NGO focused on private companies	Integration into CERT	Includes shared resource strategies and discussion in Community Emergency Response Team (CERT) training and encourages leaders to implement strategies during a disaster	Highly recommended for jurisdictions with strong CERT teams
Training Exercises	Allows companies to observe or participate in training exercises	Highly recommended for jurisdictions with consistent exercises	Community Organization Outreach	Increases the amount of information available about how to help other people in disasters, but it is specifically geared to how local CBOs (e.g., social work non-profits, religious organizations, neighborhood associations) can leverage their networks	Highly recommended for all jurisdictions
Surge Flagging	Increases agency oversight of price gouging violations and requires a public information campaign	Highly recommended for all jurisdictions	Community Organization Control	Transfers some transportation/sheltering management and/or responsibilities to CBOs away from local governments or NGOs (e.g., American Red Cross, Salvation Army), if those entities become overwhelmed with transportation and sheltering demand	Moderately recommended and only if community organizations are well integrated, have wide networks, and are disaster ready
Pilot Programs	Tests the feasibility of partnerships through first- and last-mile connections, paratransit supplements, and/or driver retention mechanisms	Highly recommended for jurisdictions with a strong transportation company presence	Shared Resource Reserve Team	Creates a disaster-specific team (similar to CERT) that would spearhead resource sharing in disasters and would be required to assist	Moderately recommended since it would require extensive training and strong community cohesion

Memoranda of Understanding (MOU)	Creates informal partnerships between agencies and companies, beginning first with information sharing and situational awareness	Moderately recommended for all jurisdictions, as companies may not have capacity for multiple MOUs	Matching Program	Develops a program to specifically match providers and shared resource recipients	Not recommended as this system would be time-consuming to construct and may require a smartphone app
Formal Contracts	Creates formal partnerships between agencies and companies, which sets parameters for information sharing and asset sharing under set conditions	Moderately recommended and only after successful MOUs			
Reimbursement Schemes	Allows companies and drivers to receive funds in return for providing a service	Not recommended as companies already offer services for free (or steeply discounted) to users in disasters			

CONCLUSIONS

This paper contends that the sharing economy could be a source of moderate to substantial benefits to help solve current problems faced in emergency management. Nevertheless, it is just one tool in the evacuation strategy toolkit. We first found through archival research that sharing economy companies have acted in 30 U.S. disasters and their involvement in disasters has been steadily growing. Next, expert interviews (n=24) revealed that the sharing economy has a number of benefits and limitations in evacuations. Benefits include increasing the number of resources available, assisting vulnerable groups, moving assets more quickly especially in no-notice events, sharing information, and situational awareness. Limitations include ensuring that drivers/hosts are available, determining who pays for the resources, overcoming the digital divide, and reducing the impact of vehicles on congestion.

Based on the Hurricane Irma survey, we found minimal sharing economy use in this evacuation. However, we found that spare capacity in the form of spare seatbelts and beds/mattresses exists (just 11.1% had no spare seatbelts and 16.0% had no beds/mattress). Respondents were fairly willing to deviate from their evacuation routes at least 20 minutes (53.4%) and carry evacuees at least 20 miles (61.5%). Moreover, we discovered a relatively high *stated* willingness of disaster-impacted individuals to provide these resources, especially for transportation before the evacuation (29.1%), transportation during the evacuation (23.6%), and sheltering for free after the evacuation (19.2%). We note that there is a clear "ceiling" in this willingness: at least 20% of the sample would be extremely unlikely to share transportation, and 30% would be extremely unlikely to share housing. This indicates that regardless of the situation, these individuals would not share resources. Moreover, respondents had a number of concerns about the sharing economy, especially safety. Social equity is another major consideration.

While there are a number of limitations that must be overcome, this paper argues that the sharing economy could constitute an additional and innovative tool for evacuations that could solve some issues including: resource deficiency, slow responsiveness, poor communication, and low support for vulnerable groups. Moving forward, emergency management and transportation agencies could consider developing policies that leverage sharing economy company assets; address potential concerns (e.g., digital divide, equity, and safety); and maximize benefits to emergency preparedness, response, and recovery.

ACKNOWLEDGEMENTS

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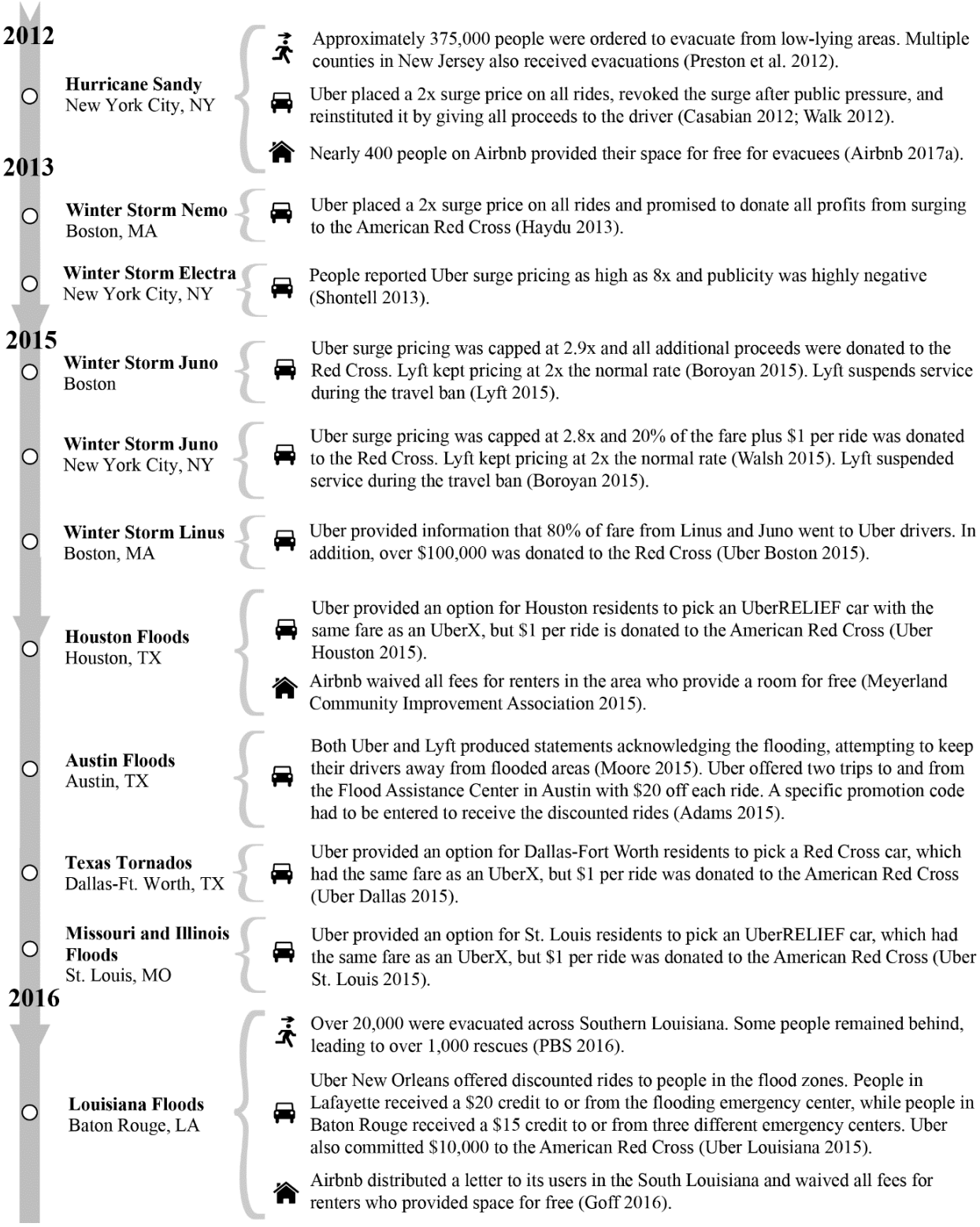
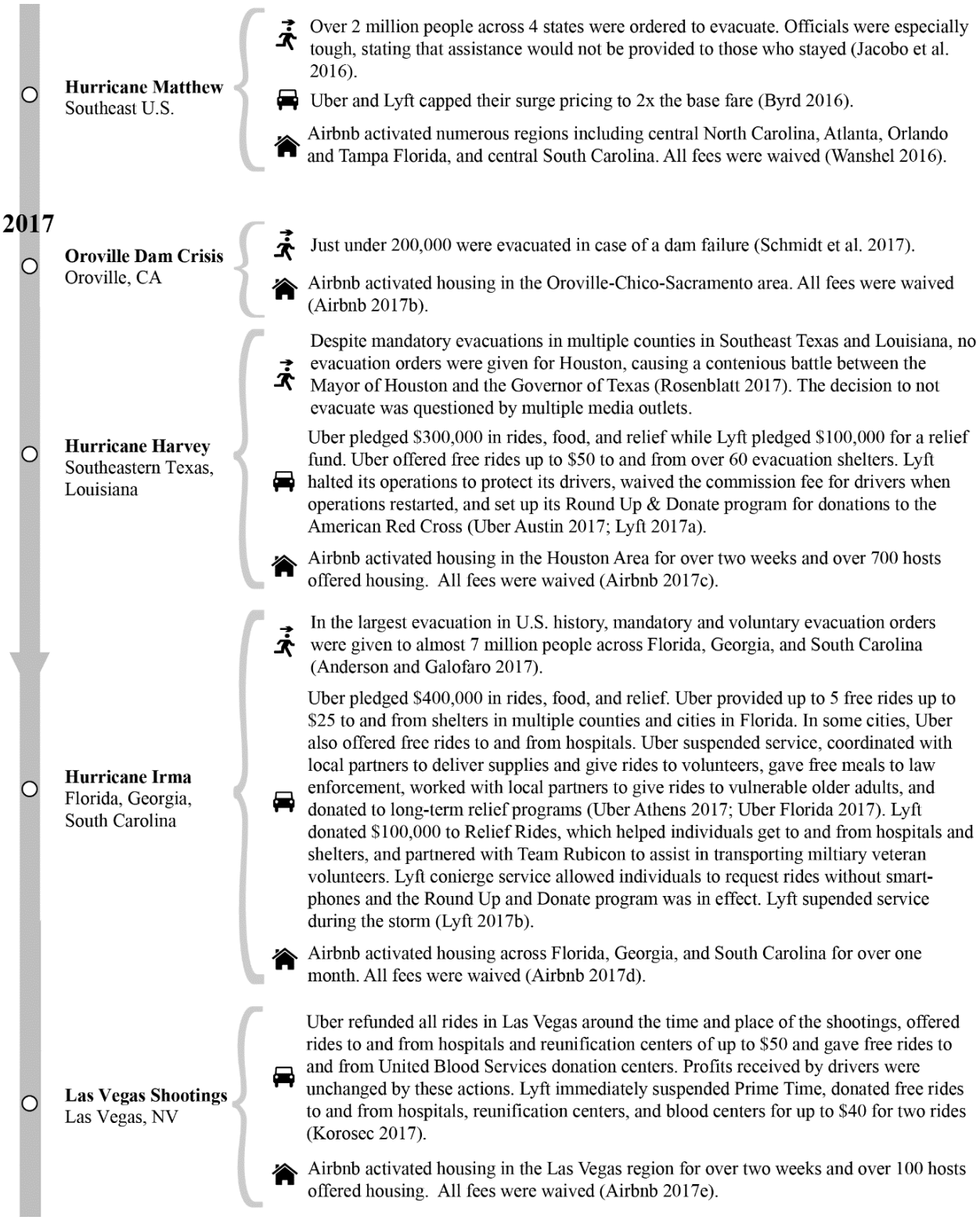
CONFLICT OF INTEREST STATEMENT

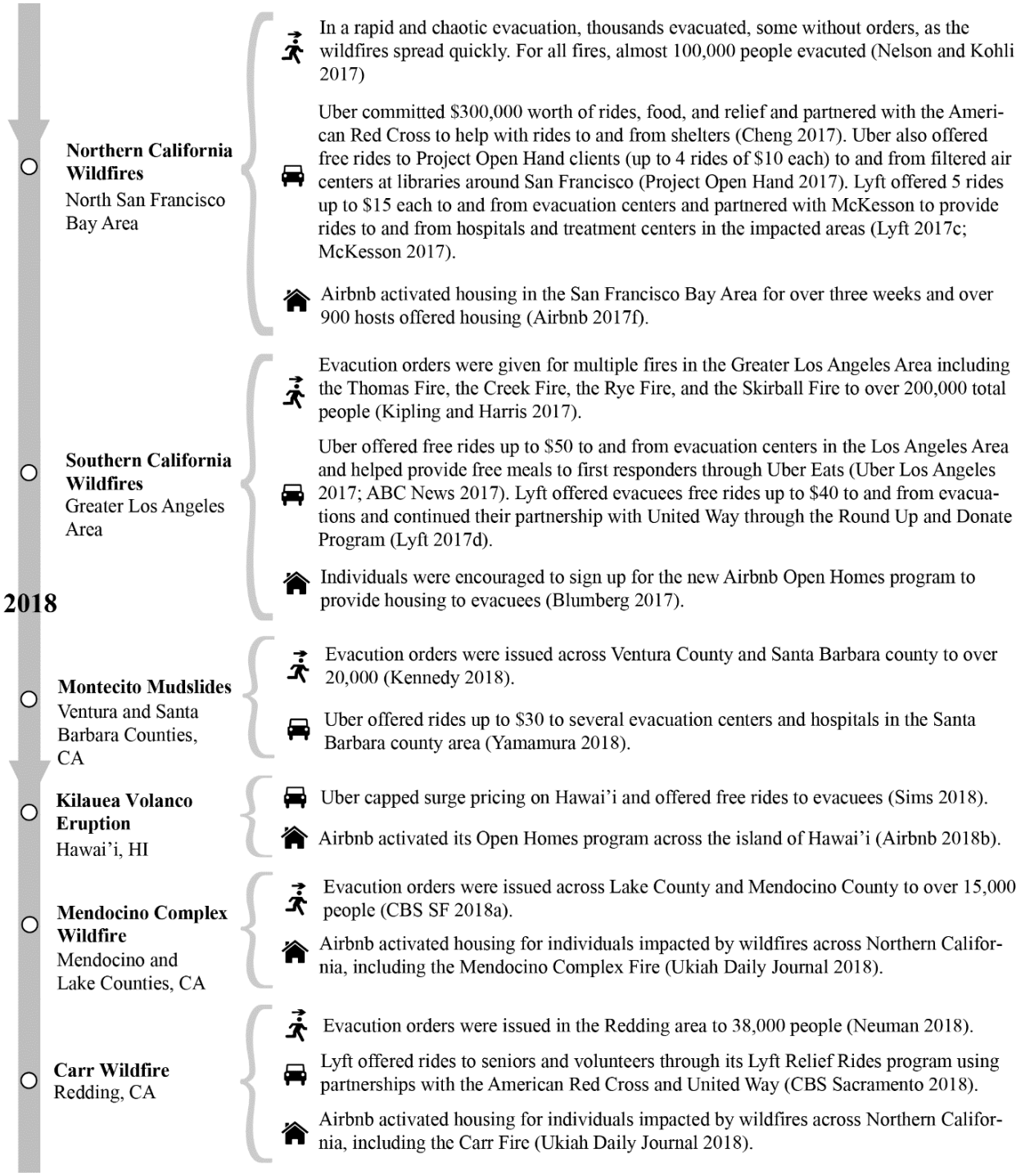
On behalf of all authors, the corresponding author states that there is no conflict of interest.

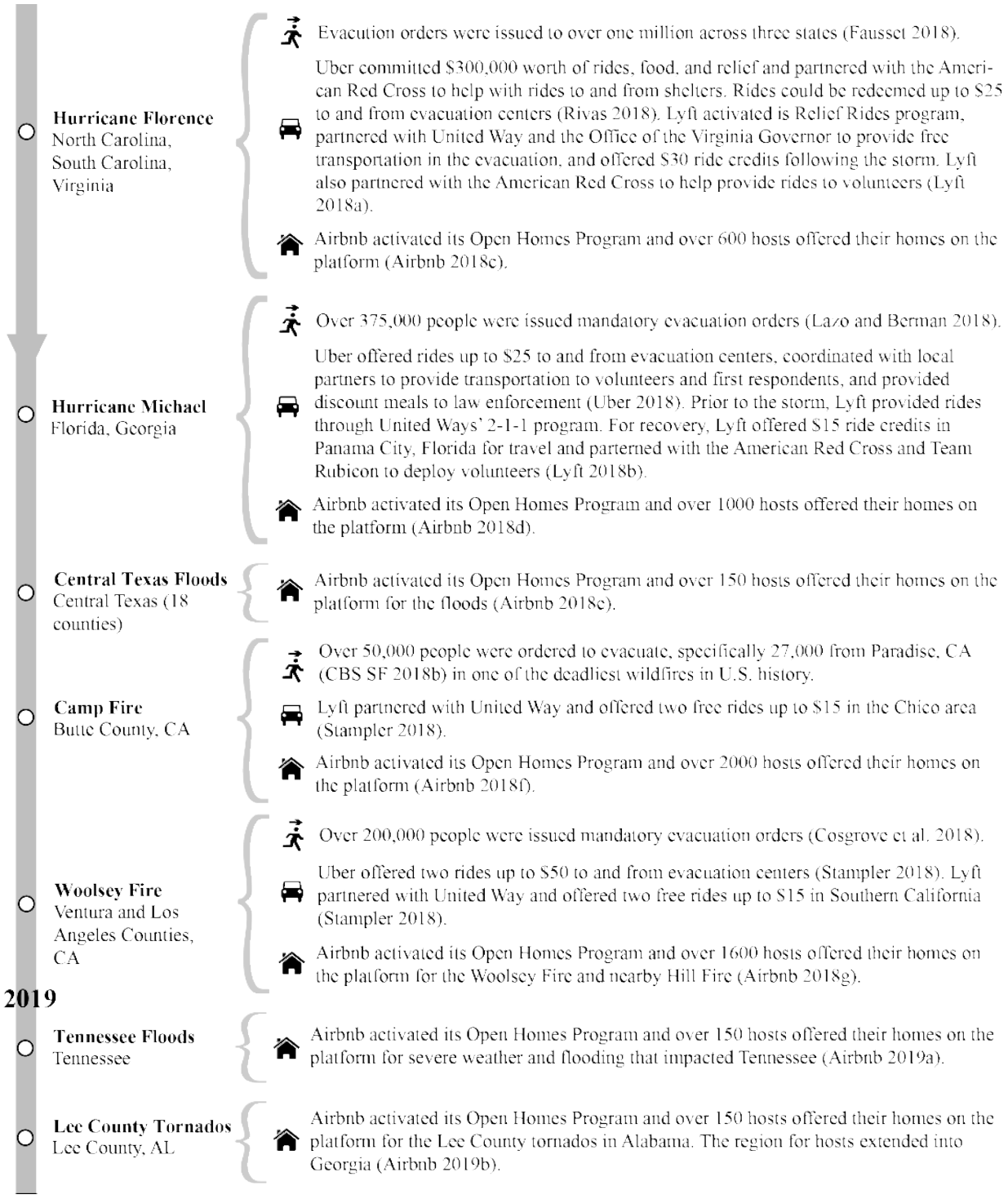
APPENDIX

Figure A1 Actions of Sharing Economy Companies During Disasters in the U.S.




2016
Hurricane Matthew
Southeast U.S.
Over 2 million people across 4 states were ordered to evacuate. Officials were especially tough, stating that assistance would not be provided to those who stayed (Jacobo et al. 2016).
Uber and Lyft capped their surge pricing to 2x the base fare (Byrd 2016).
Airbnb activated numerous regions including central North Carolina, Atlanta, Orlando and Tampa Florida, and central South Carolina. All fees were waived (Wanshel 2016).
2017
Oroville Dam Crisis
Oroville, CA
Just under 200,000 were evacuated in case of a dam failure (Schmidt et al. 2017).
Airbnb activated housing in the Oroville-Chico-Sacramento area. All fees were waived (Airbnb 2017b).
Hurricane Harvey
Southeastern Texas, Louisiana
Despite mandatory evacuations in multiple counties in Southeast Texas and Louisiana, no evacuation orders were given for Houston, causing a contenious battle between the Mayor of Houston and the Governor of Texas (Rosenblatt 2017). The decision to not evacuate was questioned by multiple media outlets.
Uber pledged $300,000 in rides, food, and relief while Lyft pledged $100,000 for a relief fund. Uber offered free rides up to $50 to and from over 60 evacuation shelters. Lyft halted its operations to protect its drivers, waived the commission fee for drivers when operations restarted, and set up its Round Up & Donate program for donations to the American Red Cross (Uber Austin 2017; Lyft 2017a).
Airbnb activated housing in the Houston Area for over two weeks and over 700 hosts offered housing. All fees were waived (Airbnb 2017c).
Hurricane Irma
Florida, Georgia, South Carolina
In the largest evacuation in U.S. history, mandatory and voluntary evacuation orders were given to almost 7 million people across Florida, Georgia, and South Carolina (Anderson and Galofaro 2017).
Uber pledged $400,000 in rides, food, and relief. Uber provided up to 5 free rides up to $25 to and from shelters in multiple counties and cities in Florida. In some cities, Uber also offered free rides to and from hospitals. Uber suspended service, coordinated with local partners to deliver supplies and give rides to volunteers, gave free meals to law enforcement, worked with local partners to give rides to vulnerable older adults, and donated to long-term relief programs (Uber Athens 2017; Uber Florida 2017). Lyft donated $100,000 to Relief Rides, which helped individuals get to and from hospitals and shelters, and partnered with Team Rubicon to assist in transporting miltiary veteran volunteers. Lyft conierge service allowed individuals to request rides without smart-phones and the Round Up and Donate program was in effect. Lyft supended service during the storm (Lyft 2017b).
Airbnb activated housing across Florida, Georgia, and South Carolina for over one month. All fees were waived (Airbnb 2017d).
Las Vegas Shootings
Las Vegas, NV
Uber refunded all rides in Las Vegas around the time and place of the shootings, offered rides to and from hospitals and reunification centers of up to $50 and gave free rides to and from United Blood Services donation centers. Profits received by drivers were unchanged by these actions. Lyft immediately suspended Prime Time, donated free rides to and from hospitals, reunification centers, and blood centers for up to $40 for two rides (Korosec 2017).
Airbnb activated housing in the Las Vegas region for over two weeks and over 100 hosts offered housing. All fees were waived (Airbnb 2017e).


2018
Northern California Wildfires
North San Francisco Bay Area
In a rapid and chaotic evacuation, thousands evacuated, some without orders, as the wildfires spread quickly. For all fires, almost 100,000 people evacuted (Nelson and Kohli 2017)
Uber committed $300,000 worth of rides, food, and relief and partnered with the American Red Cross to help with rides to and from shelters (Cheng 2017). Uber also offered free rides to Project Open Hand clients (up to 4 rides of $10 each) to and from filtered air centers at libraries around San Francisco (Project Open Hand 2017). Lyft offered 5 rides up to $15 each to and from evacuation centers and partnered with McKesson to provide rides to and from hospitals and treatment centers in the impacted areas (Lyft 2017c; McKesson 2017).
Airbnb activated housing in the San Francisco Bay Area for over three weeks and over 900 hosts offered housing (Airbnb 2017f).
Southern California Wildfires
Greater Los Angeles Area
Evacution orders were given for multiple fires in the Greater Los Angeles Area including the Thomas Fire, the Creek Fire, the Rye Fire, and the Skirball Fire to over 200,000 total people (Kipling and Harris 2017).
Uber offered free rides up to $50 to and from evacuation centers in the Los Angeles Area and helped provide free meals to first responders through Uber Eats (Uber Los Angeles 2017; ABC News 2017). Lyft offered evacuees free rides up to $40 to and from evacuations and continued their partnership with United Way through the Round Up and Donate Program (Lyft 2017d).
Individuals were encouraged to sign up for the new Airbnb Open Homes program to provide housing to evacuees (Blumberg 2017).
Montecito Mudslides
Ventura and Santa Barbara Counties, CA
Evacution orders were issued across Ventura County and Santa Barbara county to over 20,000 (Kennedy 2018).
Uber offered rides up to $30 to several evacuation centers and hospitals in the Santa Barbara county area (Yamamura 2018).
Kilauea Volanco Eruption
Hawai'i, HI
Uber capped surge pricing on Hawai'i and offered free rides to evacuees (Sims 2018).
Airbnb activated its Open Homes program across the island of Hawai'i (Airbnb 2018b).
Mendocino Complex Wildfire
Mendocino and Lake Counties, CA
Evacution orders were issued across Lake County and Mendocino County to over 15,000 people (CBS SF 2018a).
Airbnb activated housing for individuals impacted by wildfires across Northern California, including the Mendocino Complex Fire (Ukiah Daily Journal 2018).
Carr Wildfire
Redding, CA
Evacution orders were issued in the Redding area to 38,000 people (Neuman 2018).
Lyft offered rides to seniors and volunteers through its Lyft Relief Rides program using partnerships with the American Red Cross and United Way (CBS Sacramento 2018).
Airbnb activated housing for individuals impacted by wildfires across Northern California, including the Carr Fire (Ukiah Daily Journal 2018).


Hurricane Florence
North Carolina, South Carolina, Virginia
Evacuation orders were issued to over one million across three states (Fausset 2018).
Uber committed $300,000 worth of rides, food, and relief and partnered with the American Red Cross to help with rides to and from shelters. Rides could be redeemed up to $25 to and from evacuation centers (Rivas 2018). Lyft activated is Relief Rides program, partnered with United Way and the Office of the Virginia Governor to provide free transportation in the evacuation, and offered $30 ride credits following the storm. Lyft also partnered with the American Red Cross to help provide rides to volunteers (Lyft 2018a).
Airbnb activated its Open Homes Program and over 600 hosts offered their homes on the platform (Airbnb 2018c).
Hurricane Michael
Florida, Georgia
Over 375,000 people were issued mandatory evacuation orders (Lazo and Berman 2018).
Uber offered rides up to $25 to and from evacuation centers, coordinated with local partners to provide transportation to volunteers and first respondents, and provided discount meals to law enforcement (Uber 2018). Prior to the storm, Lyft provided rides through United Ways' 2-1-1 program. For recovery, Lyft offered $15 ride credits in Panama City, Florida for travel and parterned with the American Red Cross and Team Rubicon to deploy volunteers (Lyft 2018b).
Airbnb activated its Open Homes Program and over 1000 hosts offered their homes on the platform (Airbnb 2018d).
Central Texas Floods
Central Texas (18 counties)
Airbnb activated its Open Homes Program and over 150 hosts offered their homes on the platform for the floods (Airbnb 2018e).
Camp Fire
Butte County, CA
Over 50,000 people were ordered to evacuate, specifically 27,000 from Paradise, CA (CBS SF 2018b) in one of the deadliest wildfires in U.S. history.
Lyft partnered with United Way and offered two free rides up to $15 in the Chico area (Stampler 2018).
Airbnb activated its Open Homes Program and over 2000 hosts offered their homes on the platform (Airbnb 2018f).
Woolsey Fire
Ventura and Los Angeles Counties, CA
Over 200,000 people were issued mandatory evacuation orders (Cosgrove et al. 2018).
Uber offered two rides up to $50 to and from evacuation centers (Stampler 2018). Lyft partnered with United Way and offered two free rides up to $15 in Southern California (Stampler 2018).
Airbnb activated its Open Homes Program and over 1600 hosts offered their homes on the platform for the Woolsey Fire and nearby Hill Fire (Airbnb 2018g).
2019
Tennessee Floods
Tennessee
Airbnb activated its Open Homes Program and over 150 hosts offered their homes on the platform for severe weather and flooding that impacted Tennessee (Airbnb 2019a).
Lee County Tornados
Lee County, AL
Airbnb activated its Open Homes Program and over 150 hosts offered their homes on the platform for the Lee County tornados in Alabama. The region for hosts extended into Georgia (Airbnb 2019b).

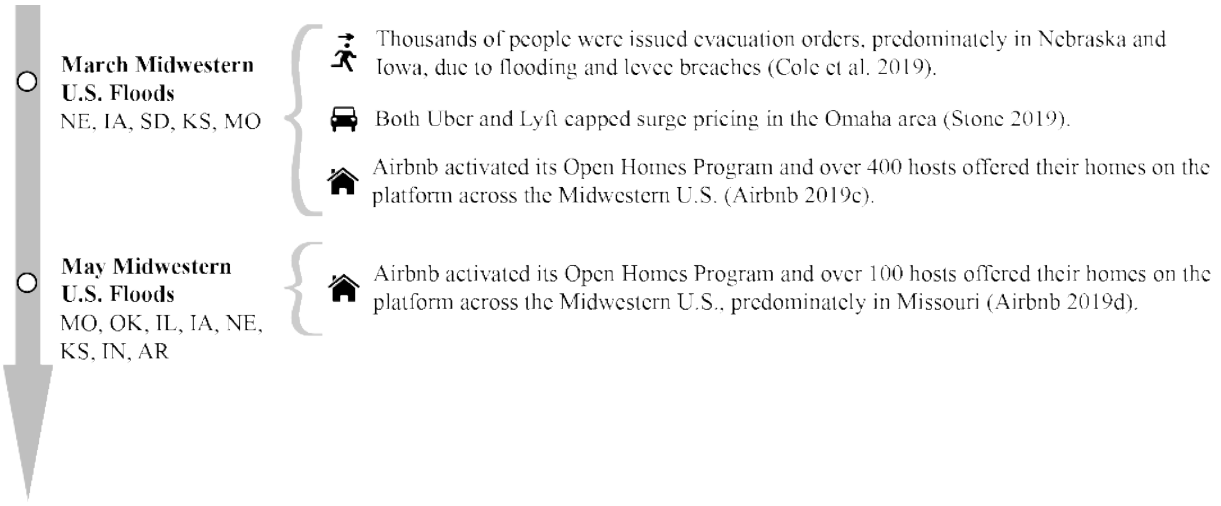


Table A1 Demographic Characteristics of Hurricane Irma Survey Respondents (n=645)

Evacuation Choice	
Received Mandatory Order, Evacuated	69.5%
Received Mandatory Order, Stayed	30.5%
No Mandatory Order, Evacuated	46.4%
No Mandatory Order, Stayed	53.6%
County of Residence	
Brevard	53.2%
Lee	17.2%
Collier	13.3%
Miami-Dade	3.7%
Pinellas	2.9%
Monroe	2.6%
Broward	2.5%
All other counties	4.5%
Live in FEMA* Flood Risk Area	
Yes	39.5%
No	47.9%
I don't know	12.6%
* Federal Emergency Management Agency	
Residence Structure	
Site build (single home)	76.6%
Site build (apartment)	19.1%
Mobile/manufactured home	4.3%
Homeownership	
Yes	69.3%
No	30.7%
Household Income	
Less than $20,000	4.7%
$20,000 - $49,999	19.8%
$50,000 - $69,999	13.9%
$70,000 - $99,999	19.7%
$100,000 - $149,999	17.7%

Gender	
Female	81.9%
Male	18.1%
Age	
18-24	3.1%
25-34	26.0%
35-44	28.7%
45-54	21.7%
55-65	14.9%
65+	5.6%
Race	
White	94.0%
Black or African-American	1.6%
Mixed	1.1%
Asian	0.9%
Pacific Islander	0.2%
Native American/Alaska Native	0.2%
No answer/Prefer no answer	2.2%
Ethnicity	
Not Hispanic	89.5%
Hispanic	6.7%
No/prefer no answer	3.9%
Education	
High school graduate	6.5%
Some college	18.6%
2 year degree	12.9%
4 year degree	32.1%
Professional degree	26.4%
Doctorate	3.6%
Employment	
Employed full time	65.7%

More than $150,000	12.4%
No/prefer no answer	11.8%
Length of Current Residence	
Less than 6 months	9.5%
6 to 11 months	7.9%
1 to 2 years	22.6%
3 to 4 years	18.6%
5 to 6 years	9.8%
7 to 8 years	6.4%
9 to 10 years	4.0%
More than 10 years	21.2%
Household Characteristics	
Household with Disabled	16.4%
Household with Children	44.8%
Household with Elderly	15.0%
Households with Pets	77.1%
Access to Internet at Home	
Yes	98.3%
No	1.7%
Mobile Phone Type	
Own a smartphone	96.3%
Own a non-smartphone	3.4%
Do not own a cell phone	0.3%

Employed part time	10.2%
Unemployed	9.6%
Retired	8.7%
Disabled	2.3%
Student	2.2%
No answer/Prefer no answer	1.2%
Primary Transportation Mode for Work/School	
Drive alone using automobile	94.3%
Work from home	1.7%
Carpool/vanpool	0.9%
Bus	0.8%
Bicycle	0.6%
Motorcycle/scooter	0.3%
Walk	0.3%
Shared mobility	0.2%
Rail	0.0%
Other	0.9%
Previous Hurricanes Experienced	
0	3.6%
1 or 2	31.3%
3 or 4	17.5%
5 or more	47.6%
Previous Evacuations Experienced	
0	46.4%
1 or 2	39.4%
3 or 4	8.8%
5 or more	5.4%

Decision Making Role	
I am the sole decision maker	18.6%
I am the primary decision maker with input from another household member	22.3%
I share equally in making decisions with another household member(s)	56.4%
I provide input into the decisions, but I am not the primary decision maker	2.0%
Another person is the sole decision maker	0.6%

Table A2: Number of Spare Beds and Spare Seatbelts by Income

	0 Beds	*1 Bed*	*2 Beds*	*3 Beds*	*4+ Beds*	*N*
Under $20,000	16.7%	26.7%	33.3%	13.3%	10.0%	30
$20,000-$39,999	37.5%	26.3%	16.3%	13.8%	6.3%	80
$40,000-$59,999	20.2%	33.3%	26.3%	10.1%	10.1%	99
$60,000-$99,999	11.4%	22.9%	32.5%	18.7%	14.5%	166
$100,000 and More	11.3%	20.6%	32.0%	18.0%	18.0%	194
No answer	9.2%	28.9%	23.7%	23.7%	14.5%	76

Income	*0 Seatbelts*	*1 Seatbelt*	*2 Seatbelts*	*3 Seatbelts*	*4+ Seatbelts*	*N*
Under $20,000	15.4%	0.0%	7.7%	23.1%	53.8%	13
$20,000-$39,999	10.2%	6.1%	22.4%	18.4%	42.9%	49
$40,000-$59,999	12.5%	6.3%	9.4%	23.4%	48.4%	64
$60,000-$99,999	8.8%	6.9%	18.6%	14.7%	51.0%	102
$100,000 and More	8.2%	12.2%	11.2%	18.4%	50.0%	98
No answer	21.4%	11.9%	7.1%	9.5%	50.0%	42

Table A3: Number of Spare Seatbelts by Vehicle Ownership

Vehicle Ownership	*0 Seatbelts*	*1 Seatbelt*	*2 Seatbelts*	*3 Seatbelts*	*4+ Seatbelts*	*N*
1 Vehicle	12.1%	6.1%	12.1%	24.2%	45.5%	99
2 Vehicles	10.0%	10.5%	16.0%	16.0%	47.5%	200
3+ Vehicles	13.4%	6.0%	10.4%	11.9%	58.2%	67

Table A4: Likelihood to Share Resources by Gender

S1-Shelter-Cost

	Extremely Likely to Share	*Not Extremely Likely to Share*	*N*
Female	7.2%	92.8%	528
Male	4.3%	95.7%	117

S2-Shelter-Free

	Extremely Likely to Share	*Not Extremely Likely to Share*	*N*
Female	19.7%	80.3%	528
Male	17.1%	82.9%	117

S3-Transport-Before

	Extremely Likely to Share	*Not Extremely Likely to Share*	*N*
Female	27.2%	72.8%	302
Male	37.9%	62.1%	66

S4-Transport-During

	Extremely Likely to Share	*Not Extremely Likely to Share*	*N*
Female	23.2%	76.8%	302
Male	25.8%	74.2%	66

Table A5: Likelihood to Share Resources by Income Level

S1-Shelter-Cost (all respondents)

Income	*Extremely Likely to Share*	*Not Extremely Likely to Share*	*N*
Income			
Under $20,000	16.7%	83.3%	30
$20,000-$39,999	6.3%	93.8%	80
$40,000-$59,999	8.1%	91.9%	99
$60,000-$99,999	7.8%	92.2%	166
$100,000 and More	2.6%	97.4%	194
No answer	9.2%	90.8%	76

S2-Shelter-Free (all respondents)

Income	*Extremely Likely to Share*	*Not Extremely Likely to Share*	*N*
Under $20,000	23.3%	76.7%	30
$20,000-$39,999	21.3%	78.8%	80
$40,000-$59,999	19.2%	80.8%	99
$60,000-$99,999	22.9%	77.1%	166
$100,000 and More	16.0%	84.0%	194
No answer	15.8%	84.2%	76

S3-Transport-Before (evacuees only)

Income	*Extremely Likely to Share*	*Not Extremely Likely to Share*	*N*
Under $20,000	23.1%	76.9%	13
$20,000-$39,999	34.7%	65.3%	49
$40,000-$59,999	23.4%	76.6%	64
$60,000-$99,999	33.3%	66.7%	102
$100,000 and More	23.5%	76.5%	98
No answer	35.7%	64.3%	42

S4-Transport-During (evacuees only)

Income	*Extremely Likely to Share*	*Not Extremely Likely to Share*	*N*
Under $20,000	15.4%	84.6%	13
$20,000-$39,999	22.4%	77.6%	49
$40,000-$59,999	23.4%	76.6%	64
$60,000-$99,999	25.5%	74.5%	102
$100,000 and More	21.4%	78.6%	98
No answer	28.6%	71.4%	42

AUTHOR CONTRIBUTIONS

SD Wong: Study conception and design, data collection, literature review, analysis and interpretation of results, manuscript writing

JL Walker: Study conception and design, manuscript editing

SA Shaheen: Study conception and design, literature review, analysis and interpretation of results, manuscript development

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