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Use of Twitter in disaster rescue: lessons learned from Hurricane Harvey

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ABSTRACT

Despite the increasingly prominent role of social media in disaster events, studies analyzing its use in rescue operations remain scanty. Hurricane Harvey hit Texas with unprecedented rainfall and flooding in 2017 and was marked by widespread use of social media for rescue requests. We conducted a survey of 195 Twitter users in Houston and surrounding communities who had requested for rescue during Harvey. The objective was to investigate our targeted group's socioeconomic and flood exposure characteristics, report the effectiveness of Twitter, and highlight lessons learnt and suggestions made for its use in future rescue missions. Survey revealed that those requesting rescue on Twitter were better educated, employed (80%), and homeowners (81%). Majority of them were flooded (87%), but remained satisfied with current location and did not consider moving. Calling relatives and friends for rescue was most responsive and yielded higher assistance-provided rate than using Twitter. Our respondents found Twitter helpful, but identified issues such as not knowing when volunteers received their requests or whether they would send help. They suggested promoting Twitter accounts and hashtags that accept emergency requests. This study provides baseline information and actionable suggestions for first responders, community managers, and resilience practitioners to improve future rescue missions.

1. Introduction

In the wake of increasing incidence of natural disasters and widespread adoption of social media use, understanding the role of social media in disaster resilience has become a focused effort of many researchers and practitioners (e.g. Duffy 2012; Zou et al. 2018a, 2018b; Wang et al. 2016, 2019). Hurricane Harvey, which hit Houston, Texas, and its surrounding region in 2017, provides a vivid example of how social media use in disastrous events is changing. Hurricane Harvey approached Texas coastline near Corpus Christy Metropolitan Area as a category-4 hurricane, but as it made its landfall on 26 August 2017, the wind speeds quickly decelerated, and its trajectory made a steep turn. In the coming days, Harvey slowly lingered over Texas as a tropical storm and delivered over 60 in. of rainfall in some locations, causing widespread flooding in the region (Watson et al 2018a). The unprecedented flooding was not anticipated, and many residents in the Houston region

resorted to social media to call for rescue from flooded homes when the 911 system was overloaded and could not be connected (Zou et al. 2018b). While social media has been employed by its users to bilaterally communicate, cooperate, and facilitate rescue in previous disastrous events such as 2012 Hurricanes Isaac (Wang 2019) and Sandy (Zou et al. 2018, Pourebrahim et al. 2019, Wang et al. 2019) and 2016 Louisiana floods (Yeo et al. 2017), Harvey was among the first to be hallmarked by widespread adoption of this practice. The Time Magazine even called Hurricane Harvey 'The U.S.'s first social media storm' (Rhodan 2017).

This new use of Twitter generates many important questions, such as how effective is social media in enhancing resilience through its new role of response and rescue, what are the challenges, and how to improve social media use for future emergency rescue? This study addresses these questions by examining the pattern of Twitter use in emergency rescue in affected areas during Hurricane Harvey. We conducted a survey of Twitter users in Houston and its surrounding communities who had requested for rescue during Harvey to provide first-hand, empirical information about Twitter use in emergency rescue. We aimed to answer three specific questions: (1) what were the socioeconomic and flood exposure characteristics of the residents who requested rescue through Twitter, and how did they compare with an average Houston area resident? (2) How effective was Twitter use in Harvey's emergency rescue, and (3) what were the lessons learnt or suggestions made regarding Twitter use in future rescue operations? Answers to these questions should increase our understanding of social media use and disaster resilience, and provide valuable information for rescue organizations and responders to better plan for future emergency events.

2. Background

Social media has become an important communication platform in disaster situations. People can express their concerns, needs, and opinions on various social networking sites and receive authoritative situational updates and announcements broadcasted by disaster management agencies from their official social media accounts (Wang and Ye 2018). On the other hand, disaster response organizations can use social media to communicate with the public and gain useful human-centric information (people's perceptions, responses, and behavior) to facilitate situational awareness and disaster response (Wang and Ye 2019). A fair amount of studies have focused on analyzing disaster-related social media messages and demonstrated that social media is a useful data source for disaster management agencies in retrieving actionable information to better their decision and policymaking (De Albuquerque et al. 2015; Huang and Xiao 2015; Imran et al. 2014, 2015; Kryvasheyeu et al. 2016; Middleton et al. 2014; Sakaki et al. 2010; Wang et al. 2016; Zou et al. 2018a; 2018b).

However, few efforts have been made to investigate how effective social media use is in emergency rescue during large disastrous events. In particular, studies that conducted surveys of Twitter users to understand how social media use affects communities' disaster response are scarce in the literature. Pourebrahim et al. (2019) conducted a trifold study that included telephone and web-based surveys of Twitter users and general population, as well as Twitter data collected during Hurricane Sandy. Their study found that Twitter was a vital source of weather-related information for those affected by a power outage, and that the government agencies were not engaged in bi-directional communication. Li et al. (2019) conducted semi-structured interviews among 15 people rescued in Hurricane Harvey. The study was concerned with psychological aspects of social media use during a disaster. They found that users were exchanging not only messages of instrumental support (e.g. weather, rescue, and other practical information), but also emotional support, which might play a role in why social media use during disasters became widespread. Survey studies related to disaster resilience are useful to gain empirical knowledge on factors affecting communities' resilience to natural disasters, such as factors affecting business return in New Orleans after Hurricane Katrina (Lam et al. 2009, 2012), or people's considerations to migrate from the vulnerable Louisiana coast (Correll et al. Forthcoming). This study will be among the first to gather first-hand data on Twitter use effectiveness in rescue operations by conducting an online survey of residents in Harvey-affected areas.

3. Study area

The study area for the Twitter user survey included 374 zip code areas affected by flooding during Hurricane Harvey, which span across 37 counties in Texas and 4 Louisiana Parishes (Figure 1). The affected zip code areas were identified from the U. S. Geological Survey (USGS) Summary Peaks point locations data (2017) and their flood inundation shapefiles (Watson et al. 2018b). For the Summary Peaks dataset (USGS 2017), USGS obtained 1258 water surface elevations through averaging 2123 field surveyed high-water marks that span across the entire study area (Watson et al. 2018a). High-water marks are evidence of water surface elevations such as flood debris trapped in tree branches and water stains on sides of the walls, that were preserved shortly after the flood with more permanent marks, and then documented and surveyed using hand-held Global Positioning System (GPS) devices (Watson et al. 2018a). Additionally, Watson et al. (2018b) used the USGS streamflow-gaging stations data to create 19 inundation maps that covered several smaller areas surrounding selected rivers and water bodies. We utilized these data sets to identify the 374 zip code areas that were affected by flooding for the Twitter user survey distribution.

Hurricane Harvey made landfall near Rockport, Texas, on 25 August 2017 as a category-4 hurricane with wind speeds reaching over 150 miles per hour. As its forward motion was stalled farther inland, Harvey produced unprecedented rainfall, leading to a historic-level flooding in Houston and its surrounding region. The unexpected widespread flooding in the region caught many people off-guard, leading to a surge of 911 calls with rescue requests. When 911 was overloaded and could not be connected, many Houston residents resorted to using social media to seek help. On August 28,
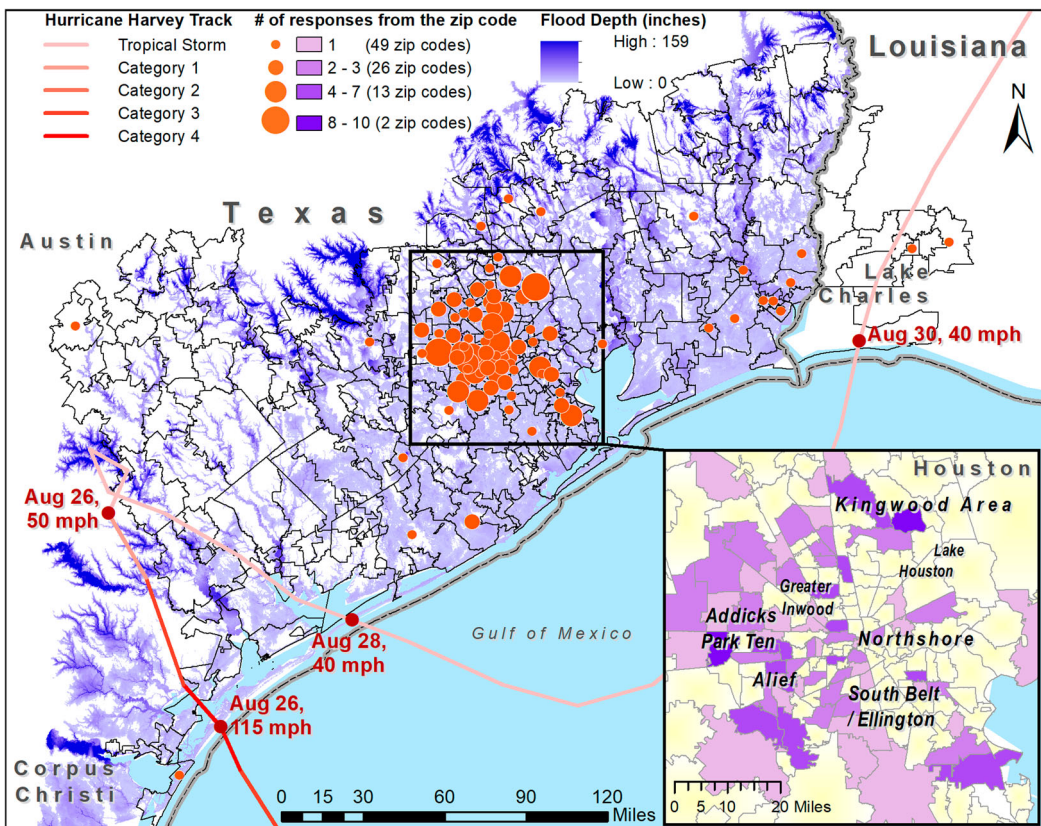

Figure 1. Study area: the zip codes selected for survey distribution overlaid with Harvey flood depths (FEMA 2018). Number of responses are depicted as orange circles (see Section 5).

Harvey headed back over the Gulf of Mexico to make its final landfall in Cameron, Louisiana on August 30, causing more flooding and damage in the area. In the aftermath of the disaster, Harvey was responsible for $125 billion in damages, with more than 300,000 structures and at least 500,000 cars were flooded. In addition, there were displacement of more than 30,000 people, 68 direct and 35 indirect fatalities (Watson et al. 2018a), and more than 17,000 rescues (Blake and Zelinsky 2018).

4. Methods

The online survey was conducted through the survey company Qualtrics (Qualtrics 2014). The study was approved by the Louisiana State University's Institutional Review Board (IRB). The survey was targeted to Twitter users in the 374 zip code areas who requested for rescue during Hurricane Harvey. As already stated above, the objectives of the survey were to find out: (1) what were the social–environmental characteristics of the respondents (i.e. Twitter users who requested rescue through Twitter), (2) how effective was Twitter use in emergency rescue, and (3) what challenges were faced and suggestions for improvements made by the respondents? The survey instrument contained a total of 32 questions, 4 of which were screening questions, 12 were general demographic questions, and 16 were directly related to the study objectives. Appendix A lists all the questions used in the survey (see Online Supplemental Materials).

We provided Qualtrics with four screening criteria to reach the target audience and desired sample size, which was set to be 200 due to our resource constraints. Qualtrics sent requests to a number of Twitter users (2082 people responded to a request), who were selected randomly from the 374 zip code areas using Qualtrics's database of Twitter users. The four screening questions were designed in such a way that a potential respondent could not 'guess the right answer' to enter the survey. The first question asked which of the several natural disasters they experienced in their area of residence, with 'hurricane' being the 'right' answer. The second question listed several recent named hurricanes out of which the potential respondent was supposed to select Hurricane Harvey. The third question asked whether they evacuated before Harvey made landfall, stayed and needed external assistance for rescue, or did not evacuate and did not ask for evacuation assistance. In this question, we were selecting respondents that did not evacuate and needed assistance. The final screening question listed 10 different ways that potential respondents could ask for external assistance and they were screened out if they did not select Twitter as one of their options.

The survey was designed to be brief and succinct to help increase the response rate within a budget limit. On average, the respondents completed the survey in seven minutes, with the fastest complete response being under three minutes and the slowest one being almost an hour.

5. Results

Because our target audience was limited to Twitter users who requested rescue during Harvey, it took a lot of attempts and screenings before reaching the desired sample size of about 200. Table 1 shows the numbers of respondents that were screened out in each step. According to Qualtrics, a total of

Table 1. Respondents' answers to the screening questions.

Screening criteria	# of responses met criteria	# of response attempts	% of response attempts that met criteria
Experienced hurricanes in area of residence	1840	2082	88%
Affected by Hurricane Harvey in area of residence	1758	1840	96%
Needed emergency rescue assistance	402	1758	23%
Used Twitter to ask for rescue	195	402	49%
Overall	195	2082	9%

2082 people attempted to enter the survey, all of which were recruited from the survey company's panels of Twitter users. First, a vast majority of people who attempted to enter the survey experienced hurricanes in their area of residence (1840 people or 88%), among which 96% were affected by Hurricane Harvey. Among those affected by Hurricane Harvey, 23% or 402 people failed to evacuate in advance and needed emergency rescue. Finally, among those in need of emergency rescue assistance, 49% of respondents or 195 people resorted to Twitter to ask for help. These 195 respondents, which amount to 9% of all attempts to enter the survey, completed the entire survey. They were from the 90 out of 374 zip code areas across Houston and surrounding region to which we distributed the survey (24%; Figure 1). The most represented zip codes were 77450 near Eldridge/West Oaks area (10 responses), 77339 in Kingwood Area (8 responses), and 77042 located west of Houston (7 responses).

Although the survey was based on the survey company's panels of Twitter users and was not necessarily proportionate to the geography or demographic characteristics of the zip code areas, the numbers of screen-outs in each step provide useful information. Two observations are notable. First, these numbers show a high percentage (23% or 402) of Twitter users needed help during Harvey. Second, only half of the sample (49%) used Twitter to ask for rescue during Harvey despite that they had already had a Twitter account. It would seem that more use of Twitter during disaster events could be cultivated to help reduce vulnerability and improve resilience.

5.1. Social–environmental characteristics of respondents

To answer the first question of what characterized the respondents in terms of their socioeconomic and environmental makeup, we collected the census statistics in the Houston area and compared them with that of the 195 sample, as shown in Table 2. Compared with an average Houston resident, our respondents were mostly employed (80% vs. 63%), had higher income (70% above $50,000 vs. 50%), were educated (96% high school diploma vs. 78%), owned home (81% vs. 43%), were mostly English-speaking (97% vs. 90%), and were mostly native or U.S. born (91% vs. 70%). This comparison further supports the notion of socioeconomic disparities in Twitter use (Zou et al. 2018a, 2018b; Wang et al. 2019). In this case, Twitter users who requested for rescue were found to be of better socioeconomic conditions than the general population.

Regarding the environmental/flooding characteristics that led to the need of rescue, we asked the respondents the flood level outside their home during Harvey (Q7, Table 2). A large majority of respondents (87%) reported that their homes were flooded, with at least 66% having a flood depth of one foot or more, or at least 22% with a flood level above three feet. These are dire flood depth statistics which to a large extent reflect the grave flooding situation in the Houston area during Harvey.

For the question of reasons to not evacuate before the flood (Q6, Table 3), the top response was that the respondents did not think it was necessary to evacuate (66%). This might be due to the fact that the lingering rainfall that caused catastrophic flooding during Harvey was not expected, thus many did not think evacuation was necessary. This response is followed by three equally important reasons, which were that they 'did not have a place to go' (38%), 'lacked financial resources to evacuate' (38%), and/or they wanted to remain with family and friends (38%) and thus did not evacuate. Lack of transportation resources was also cited as an issue by a large percentage of respondents (32%). This response is intriguing because only a small percentage of respondents (4%, Table 2) had reported to have no access to a working vehicle (4%, Table 2) in a previous question. Despite having access to working vehicles that can support their daily lives, many respondents considered resources needed for evacuation quite burdensome, especially when they were uncertain of whether evacuation was necessary. Another notable finding is that a relatively large percentage of respondents (17%) indicated that they did not receive warning information. This finding is important especially considering that this group of respondents was generally better educated and better informed. The

Table 2. Socio-environmental characteristics of survey sample in comparison with Houston residents (based on 2017 American community and housing surveys).

Category	Variable (question)	Answer	Survey respondents	Houston residents*
Socioeconomic status	Employment	Working full-time or part-time	80%	63%
		Not working (incl. not in labor force)	20%	37%
	Household income	Above $50,000	70%	50%[a]
	Education	High school diploma and higher	96%	78%
		Bachelor's degree and higher	53%	32%
	Home ownership	Owns home	81%	43%[b]
		Rents	19%	57%[b]
	House type	Single family detached house	82%	45%[b]
		Apartment or condominium	17%	54%[b]
		A mobile or modular home	1%	1%[b]
	Access to vehicles	None available	4%	9%[b]
Demographic characteristics and nativity	Age	Median (years old)	34	33
	Gender	Male	49%	50%
		Female	51%	50%
	Race/ethnicity	White, non-Hispanic	42%	25%
		African American	27%	22%
		White, Hispanic	17%	45%
		Asian	12%	7%
		American Indian and Alaska Native	2%	0%
	Language	Non-English speakers	3%	10%[c]
	Nativity	Born in Texas or US	91%	70%
	Lived in current zip	Median (years)	9	5[d]
Environmental factors and migration considerations	Satisfaction with area of residence	Extremely dissatisfied	1%	1%[b]
		Somewhat dissatisfied	6%	2%[b]
		Neither satisfied nor dissatisfied	10%	12%[b]
		Somewhat satisfied	46%	41%[b]
		Extremely satisfied	37%	42%[b]
	Do you consider moving because of the flood	No	49%	n/a
		Yes, within Houston	24%	
		Yes, within Texas	15%	
		Yes, outside Texas	5%	
		Don't know	6%	
	Moved to a new home after Harvey	Yes	17%	32%[e]
		No	83%	68%[e]
	Flood level outside home during Harvey	Wasn't flooded	13%	n/a
		Under 1 foot	21%	
		1–3 feet	45%	
		Above 3 feet	22%	

* from American Fact Finder Community Facts for Houston City, TX (2013–2017 American Community Survey 5-Year Estimates, https://factfinder.census.gov/bkmk/cf/1.0/en/place/Houston city, Texas/POPULATION/ACS_EST), and 2017 American Housing Survey for Houston-The Woodlands-Sugar Land, TX MSA
[a] of total households
[b] of total housing units
[c] population 18 years and over
[d] median year of moving into the current unit, of total households, 2017 estimate
[e] moved in the last two years, of total households, 2017 estimate.

finding implies that improving communications among governmental officials and the general public in future emergency events should help improve emergency preparedness and minimize impacts from the disaster events.

Table 3. Twitter users' motivations and experiences in Harvey rescue operations.

Question	Response	Count	% of respondents
Reasons to not evacuate (Q6)	Did not think it is necessary to evacuate	129	66%
	Did not have a place to go	75	38%
	Lacked financial resources to evacuate	75	38%
	Wanted to remain with family or friends	74	38%
	Lacked transportation resources to evacuate	62	32%
	Did not receive warning information	33	17%
Reasons to use social media to ask for rescue (Q17)	Social media was easy to use	147	75%
	Direct reach of first responders, friends, and relatives	103	53%
	Used all methods to reach people who can help	80	41%
	The telephone signal was unstable	65	33%
	The 911 system could not be connected	50	26%
Which organization(s) rescued you (Q16)	Relatives or friends	103	53%
	Individual volunteer	77	40%
	Police or fire department	54	28%
	Coast Guard/National Guard/Texas Guard	37	19%
	Texas Taskforce 1 or 2	22	11%
	Cajun Navy or Texas Navy	18	9%
How long did it take for the rescue (Q15)	Less than 2 h	52	27%
	2–5 h	79	41%
	5–10 h	43	22%
	More than 10 h	19	10%
How useful was Twitter for seeking help (Q19)	Not at all useful	3	2%
	Slightly useful	13	7%
	Moderately useful	30	15%
	Very useful	69	35%
	Extremely useful	80	41%
Problems with using Twitter during Hurricane Harvey (Q18)	No, I did not experience any problems	96	49%
	Not knowing if the tweets reached first responders	57	29%
	Not knowing if the first responders would send help	56	29%
	Not knowing how long it would take for the rescue	49	25%
	Lack of information regarding how to get help on Twitter	35	18%

We asked our respondents questions about their *actual* as well as *potential* migration considerations in the aftermath of Harvey. In terms of actual migration, most of the respondents (83%) replied that they did not move after Hurricane Harvey, whereas 17% did move but were mostly to within the Houston area (Table 2). This is a much lower percentage of actual moves compared with the average Houston statistics (32% actual moves). The lower percentage of respondents who moved after Harvey is likely due to a much larger percentage of homeowners among our respondents (81% vs. 43% of average Houston residents). When asked whether the respondents are considering moving after Harvey, half of the sample replied that they do not consider moving (49%). An additional 24% considered moving but would want to move within the Houston area. These statistics can be interpreted that Harvey flooding is unlikely to lead to out-migration, and the large group of staying residents will have impacts on the recovery and resilience of the region after Harvey.

This lack of intention for moving outside of the Houston area for a large majority of our respondents (73%) is consistent with the responses to the next question, which is 'how satisfied are you with your current location?' (Q30). Only a small percentage of respondents were not satisfied with their current location (16%), whereas about 84% of the respondents were either somewhat satisfied or extremely satisfied. Despite the severity of the flood that the respondents experienced during Hurricane Harvey (87% of homes in the sample were flooded), moving away from the flood zone was not considered as necessary. This finding implies that factors other than flood risks such as economic

opportunities may play a bigger role in migration considerations, which in turn would affect subsequent recovery and disaster resilience (Correll et al. Forthcoming).

5.2. Effectiveness of Twitter use for emergency rescue

To answer our second research question of how effective Twitter use was in emergency rescue during Harvey, we designed several questions to focus on the following: (1) which methods did the respondents use to ask for evacuation assistance (Q5); (2) which methods were the ones the respondents received responses from (Q13); (3) which methods did the respondents receive assistance from (Q14); and (4) effectiveness and problems of Twitter use in emergency rescue (Q15, Q18, Q19). Q5 was also a screening question, and only those that selected Twitter as one of their options for rescue request were allowed to enter the survey. Thus 100% of our respondents used Twitter to ask for evacuation assistance. Table 4 summarizes the responses.

Following the use of Twitter, the second and third most frequently used means of requesting rescue by respondents were by calling relatives and friends (83%) and Facebook (68%). Reaching out to voluntary organizations directly by phone or through their websites, as well as calling 911, were the fourth commonly used option by the respondents (about 40% for each method).

When asked about the reasons to use Twitter or social media to seek help (Q17), roughly three quarters of respondents (75%) indicated that social media was easy to use (Table 3). Considering all our respondents were Twitter users, it appears that in critical situations, ease of use and prior familiarity was among the most influential factors for choosing social media as a way to ask for rescue. The second most popular reason, an ability to directly reach first respondents, friends, and relatives, was selected by 53% of our respondents. About 41% of the respondents used all available tools to ask for rescue. Lastly, about one-third of the respondents indicated that they used social media because the telephone signal was unstable or because the 911 system could not be connected (33% and 26%, respectively). This result confirms what was heard over the news about the problem of not connecting to 911, which has a serious implication on emergency preparedness and response. There is a great need to ensure the robustness and reliability of the 911 system, as well as other telecommunication systems, in mass emergencies.

Regarding the effectiveness of the methods for requesting rescue as represented by their rates of responses and assistance provided (Q13 and Q14), the method that scored the highest in both categories was calling relatives and friends for help (Table 4). Facebook was the second most responsive, but calling voluntary organization was ranked second in actually providing assistance, which is a notable mismatch between the two – responsiveness and assistance provided. Since Facebook also allows communications between users and rescue organizations, and relatives or friends, the

Table 4. Frequency of use of communication modes to ask for assistance and their respective response and assistance-provided rates.

Request for rescue method	Number of respondents used method	% of respondents used this method	Method's response rate	Assistance-provided rate
Called relatives or friends	161	83%	85%	65%
Called voluntary organizations	78	40%	69%	51%
Twitter	195	100%	70%	43%
Called 911	81	42%	59%	38%
Facebook	132	68%	78%	31%
Websites of rescue organizations	83	43%	54%	25%
WhatsApp	58	30%	43%	22%
Crowdsource rescue website	19	10%	47%	0%
Zello app	18	9%	0%	0%
Nextdoor app	1	1%	0%	0%

respondents might have attributed the assistance provided directly to them, rather than to Facebook itself. Responsiveness and assistance provided by calling 911 (the police and fire department) were slightly lower than calling voluntary organizations or using Twitter, which might have contributed to why the survey respondents used social media to ask for rescue in the first place. Calling voluntary organizations had a similar response rate to that of Twitter, but it had a much higher assistance rate than Twitter, which suggests that reaching out to the voluntary organizations directly was a more effective way to get help than posting a rescue request on Twitter (51% vs. 43%). However, despite that fewer respondents attributed their rescue to Twitter than to voluntary organizations, Twitter might have been a source of information for the flood victims on the various organizations that were providing rescue assistance and how to contact them.

Additionally, we asked the respondents whether they used hashtags, and if yes, which ones (Q20). Hashtag is a keyword preceded by a hash symbol ('#') added to the message of the tweet. Twitter displays tweets with the same hashtag in a separate live feed, which can be accessed through a search query, and the most popular hashtags are highlighted as 'trending topics' which are displayed to all users of the same geographic area. Using hashtags hypothetically should improve visibility of an emergency request, as many people and organizations will be monitoring them to find information specific to the disaster event or location. Common issues with hashtags are spam and unrelated messages. In our survey, only 48 of our respondents (25%) used hashtags in their rescue requests, which add up to 21 unique hashtags. Figure 2 depicts those hashtags in a word cloud with larger fonts depicting more frequent use. The most popular hashtag among our respondents was #HurricaneHarvey, which was not specific for rescue requests, and could contain tweets from news organizations and the public on topics generally related to Hurricane Harvey but not exclusively on finding and assisting those who needed help. Several important considerations for future studies arise, such as was an infrequent use of hashtags due to low awareness or did people deem it ineffective or unnecessary? Moreover, the low percentage of hashtag use among our respondents might imply that hashtags might not be the most effective way to identify the tweets for disaster response research. Future analysis is needed to confirm such implication.

5.3. Lessons learned and suggestions for improvement

To address our third research question of what lessons learned and how Twitter use could be improved for future emergencies, we asked our respondents several questions and the results are revealing. First, regarding the issues they faced while using Twitter during Hurricane Harvey
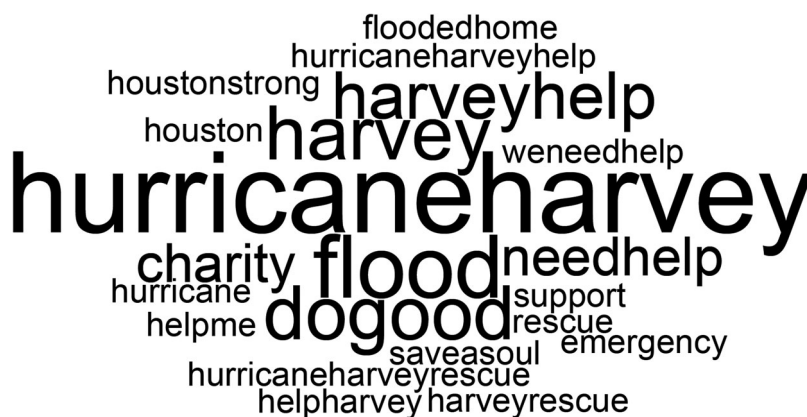

Figure 2. Word cloud of hashtags used in requests for rescue by the respondents. Larger font size depicts more frequent use.

Table 5. Ranking of usefulness of suggestions to improve future Twitter use.

How to improve Twitter use for future rescue?	Rank from least to most useful				Mean rank*
	4 (least useful)	3	2	1 (most useful)	
Spread awareness about special hashtags for emergency rescue	3%	34%	25%	38%	2.02
Spread awareness about special accounts to contact for emergency rescue	1%	27%	44%	29%	1.99
Provide information, education, and/or training on Twitter use in emergency	1%	38%	30%	32%	2.07
Other	96%	2%	2%	1%	3.93

* Lower value means the suggestion is more useful.

(Q18; Table 3), about half of the respondents (49%) indicated that they did not experience any problems. Among the remaining respondents who did experience difficulties, three issues emerged as equally relevant: not knowing if the tweets reached the addressee, if the first respondents would send help, and how soon will they come for the rescue. Lack of information on how to get help on Twitter was less concerning, suggesting that the efforts to improve future rescue operations could be better directed at reducing miscommunication between all involved parties.

Relatives and friends, individual volunteers, and police and fire department were instrumental in providing help (Q16; Table 3). However, it is noted that despite the contribution of voluntary organizations in providing help, respondents attributed this help to individual volunteers rather than the voluntary organizations they could be affiliated with. This might signal the lack of awareness among the respondents about the voluntary organizations that connected them with individual volunteers who ultimately rescued them. Respondents' answers also indicated the seriousness of circumstances surrounding their rescues: for many of them the rescue efforts took 2–5 h (41%), with many more people stuck for longer than 5 h (32%) (Q15; Table 3). Despite the long wait for rescue, the majority of respondents characterized Twitter as very useful (35%) or extremely useful (41%) for seeking help. This might be due to social media's ability to provide continuous communication, support, and information updates from many different sources throughout the rescue process, as opposed to short and periodic communications of the traditional methods.

It should be noted that despite the overall satisfactory experience with using Twitter reported by the respondents, two of them indicated that they did not receive any responses or assistance, and one of them reported that social media was not beneficial in helping their family to get rescued in an open-ended comment. This serves as an additional argument to continue investigating the role of social media in disaster resilience, people's experience with it, and ways to improve communication and ultimately resilience of the communities.

Lastly, we asked the survey participants (Q21) to rank the usefulness of four suggestions on Twitter use improvement for future events, with the fourth suggestion being an open-ended choice (Table 5). Results show that the highest ranked suggestion (based on the average score from 1 to 4 with 1 being the most useful and 4, the least useful) was to spread awareness about the Twitter accounts that were accepting requests for rescue on behalf of the volunteers. Second-ranked suggestion was to spread awareness about the hashtags. The least useful suggestion considered by the respondents was to provide education and training about Twitter use in emergency. This last response is expected because the respondents were already Twitter users. Typed-in suggestions were scarce and included: encouragement to donate, have a backup plan, provide weather information in Twitter, and make it easy to report in as safe.

6. Discussion

Conducting surveys of Twitter users remains difficult. Reaching the potential respondents through Twitter is especially challenging when the target audience is narrowed down to only those who

tweeted during a certain event or regarding a certain topic, such as disaster rescue activities. Researchers are often faced with the unpredictable and noisy nature of social media data, changes in Twitter policy regulations for the API use, as well as users' low willingness to participate in survey research due to potential privacy concerns. For instance, Mohammadi et al. (2018) surveyed Twitter users who tweeted about the academic literature to gain knowledge on scholarly related Twitter use, and found that only 1.3% of all Twitter data were useful for identifying potential respondents, and the response rate among the identified potential survey participants was very low (amounting to 3.3%). In our study, we kept the survey instrument short and direct to help minimize the time needed to complete the survey while Qualtrics provided a small incentive to those who completed the survey, which proved to be useful in recruiting participants. Qualtrics offers incentive based on the survey length and difficulty to recruit participants which may be in a form of cash or various coupons and vouchers (Qualtrics 2014).

As in many previous studies on population survey after a disaster (e.g. Lam et al. 2009, 2012), results from this study are subjected to the survival bias, meaning that those who responded to the survey in the affected areas were likely to be the ones who have survived from the disastrous event and chosen to stay. Thus their responses could be biased. Also, the results derived from this survey cannot be used to generalize to the general population including, for example non-Twitter users who requested for rescue or Twitter users who did not request for rescue using Twitter. Nevertheless, our comparison between the respondents and an average Houston resident has helped in reducing the potential bias in interpreting the results. This comparison reveals an important point: that our sample of Twitter users who requested for rescue is not considered vulnerable population in the traditional sense, instead, they represented a group that was mostly employed, owned home, and had higher income and better education than an average Houston resident.

Several implications arise from this research for policy and future rescue operations. First, many respondents have indicated that they lacked transportation and resources to evacuate beforehand, which in the future can be offset by providing transportation and resources to those in need. Second, Twitter use, ways to reach rescue organizations in case of emergency, and staying in contact with families and friends should be promoted among those planning to stay. This may allow those with fewer resources and connections to get help from a larger network with better resources, thus reducing socioeconomic disparities in social media use and their impacts on rescue and recovery. Finally, governmental, non-profit, and other organizations can benefit from utilizing social media by leveraging a community of high income, well educated, organized, and interconnected individuals to improve future rescue missions.

7. Conclusion

This study examined the new use of Twitter in emergency rescue during Hurricane Harvey through an online survey of Twitter users who requested for rescue. The survey, conducted in January 2019, was distributed in 374 and received responses in 90 zip code areas in Houston and its surrounding region. The study sought to answer three research questions: (1) what were the socioeconomic and flood exposure characteristics of the respondents who requested for rescue through Twitter, and how did they compare with an average Houston area resident? (2) How effective was Twitter use in Harvey's emergency rescue, and (3) what were the lessons learned or suggestions made regarding Twitter use in future rescue operations?

Results show that the 195 respondents who passed the screening criteria and completed the survey were of higher socioeconomic conditions than the average Houston residents. They were mostly employed, owned homes, and had higher income and education. Despite that 87% of them reported that their homes were flooded and all needed rescue, a large majority of them were satisfied with their current locations and did not consider moving away from Houston. The high satisfaction with the area of residence and low intention to migrate after the disaster among those who used Twitter to ask for help during Harvey might hint at a faster recovery and higher resilience of the region.

Calling relatives and friends for rescue was the most responsive and yielded the highest assistance rate, despite that all respondents had used Twitter to request for rescue. Three issues regarding the use of Twitter in emergency rescue emerged, including not knowing if the tweets reached the target agency or volunteer group, if they would send help, and how soon they would come for the rescue. To improve Twitter use for future emergencies, respondents found that spreading awareness about Twitter accounts or hashtags that would accept requests for rescue would be most helpful. These are concrete suggestions that would seem to be easily fixed to improve future rescue operations.

In summary, this study has generated first-hand baseline information that could be utilized by first responders, community managers, and resilience practitioners to improve future rescue operations. Moreover, findings from this study can be used to direct future research efforts to understand how Twitter use and social media connectivity is reshaping disaster rescue activities.

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