

#Sandy Tweets: Citizens' Co-Production of Time-Critical Information during an Unfolding Catastrophe

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Abstract

Social media have increasingly been used for information exchange during extreme events (EEs). Yet, until recently it had not been systematically studied how government has used and can use social media under circumstances of extreme duress. This research describes how government actually engaged citizens through social media during and in the aftermath of an EE. It also highlights the potential benefits of using social media for both governments and affected communities. Hurricane Sandy struck the US East Coast in 2012, during which both government agencies and citizens actively engaged in Twitter conversations, exchanging 132,922 tweets. The case study shows the critical contributions of citizens' information sharing with government agencies and their roles in (re-)distributing information to their Twitter followers. This specific form of co-production of public information services under duress seems to be essential for effective catastrophe response. It also demonstrates the potential benefits of government social media use.

1. Introduction

The frequency and impact of catastrophic incidents (also known as extreme events) have dramatically increased in recent years [33], which has been attributed to the global trends toward climate change and extreme weather events [30, 40, 42]. Extreme events (EEs), such as the 2004 Indian Ocean Tsunami, 2005 Hurricane Katrina, 2010 Haiti Earthquake, the 2011 Eastern Japan catastrophe, and 2012 Hurricane Sandy, overwhelm the response capacity of local government agencies [16, 33]. Timely and actionable information is critical for disaster response agencies and affected communities alike to mobilize agile and

adaptive responses during and in the immediate aftermath of an EE [32, 33].

Since the participatory 'Open Government' policy in the US [39] and similar policies in other nations were implemented, the use of social media channels in government has been accelerating to facilitate active forms of citizen engagement [1, 43]. Moreover, the literature shows that the use of social media channels for sharing time-critical information in EEs, especially via Twitter, has been emerging over the past five years [3-5, 27, 31, 37]. As of July 30, 2012, Twitter had 517 million users worldwide and 140 million users in the United States alone [34]. Worldwide, New York City ranks fifth among the top 20 cities by the number of posted tweets. Another five US cities also rank among the top 20, Los Angeles, Chicago, Miami, Atlanta, and Houston [34].

Despite these global trends, however, very little has been published about how actually government has engaged citizens through social media channels during and in the aftermath of EE situations, and how effectively government has realized the potential benefits of social media use during EEs. This research is motivated to help narrow the gap in academic knowledge with regard to the use, citizen interaction, and overall potential of social media channels during and in the aftermath of an EE. We use the case of Hurricane Sandy, which devastated the North-eastern United States in late October of 2012. When the Hurricane's devastating impact spread widely, both US government agencies and local citizens engaged in Twitter conversations through #sandy. We used the trail of tweets with #sandy as the keyword to collect a total of 132,922 tweets exchanged during the evolving Hurricane Sandy, namely from October 23, 2012 to November 10, 2012.

Drawing on social network analysis theory [22] and public administration theory on citizen coproduction [44] we analyzed and interpreted the tweet data. The tweets were generated by both government agencies

responsible for disaster response management and by citizens who were engaged in #sandy conversations.

The remainder of this paper is structured as follows: the next section presents a review of the relevant literature followed by research background on Hurricane Sandy. Then, we present two research questions and describe the methodology used: the tweet data collection using #sandy, and the social network analysis method. Then, we detail the results of the analyses followed by the discussion of citizens' Twitter-based information co-production during this EE. We conclude that in the case studied Twitter-literate citizens played a critical role in the timely diffusion of EE-related information to their followers, and hence co-created public information of high value by complementing and enhancing government's response and information management, which provided affected communities with much needed information. In the final section, we also discuss the limitations of this study and future research directions.

2. Literature Review

2.1. Social media use during EE

Early social media-related research appeared in the context of the 2007 Southern California Wildfire [27]. Since then the use of social media channels in government for disaster management has been widening across different disaster response agencies and emergency services in the growing number of both developed and developing countries, which frequently experience disasters. Table 1 below shows a selective but representative sample of empirical studies of social media in EE situations for the period from 2007 to 2012.

So far empirical studies have focused on the use of social media for different types of disasters and for the four phases of the disaster management cycle of (a) preparedness, (b) response, (c) recovery, and (d) risk mitigation with the exception of the latter phase (see Table 1). While the type of social media use studied varies from Facebook, Twitter, Ushahidi, blogs, web forums, photo sharing, micro-blogging and SharePoint uses, it appears that Twitter is the most frequently used social media channel in EE. In fact, in twelve of fourteen of recent EE (or 85 %) listed below, Twitter played a significant role. No other social medium even comes close.

In general, however, empirical and analytical research on social media use for disaster response management seems to be still lagging behind practice.

Table 1. Social media use during EE

Disaster/Year/ Country	Type of Social Media Used	Phase(s) of Disaster Management Cycle
Southern California Wildfire / 2007 / USA	Blogs, forum, Flickr, Twitter	Response, Recovery [27]
Wenchuan Earthquake / 2008 / China	Baidu Bar	Response, Recovery [43]
	Web Forum	Recovery [21]
	Web Forum	Recovery [29]
Red River Flooding / 2009 / USA	Twitter	Preparedness, Response [37]
Oklahoma Fire / 2009 / USA	Twitter	Preparedness, Response [37]
Yushu Earthquake / 2010 / China	Microblog	Recovery [29]
Ului Tropical Storm / 2010 / Australia	Twitter	Preparedness, Response [45]
Brisbane Storm / 2010 / Australia	Twitter	Preparedness, Response [45]
Haiti Earthquake / 2010 / Haiti	Forum	Response, Recovery [13]
	MS SharePoint	Response, Recovery [43]
	Twitter	Response [2]
	Ushahidi	Response, Recovery [10, 23, 26]
Mount Merapi Eruption / 2010 / Indonesia	Facebook, Twitter	Preparedness, Response, Recovery [25]
Queensland Flood / 2011 / Australia	Twitter	Preparedness, Response [7, 29, 45]
Christchurch Earthquake / 2011/ New Zealand	Twitter	Preparedness, Response [45]
Thai Flood / 2011 / Thailand	Twitter	Preparedness, Response [18]
Eastern Japan Catastrophe / 2011 / Japan	Twitter	Preparedness, Response, Recovery [15] Response, Recovery [31]
Sumatra Earthquake / 2012 / Indonesia	Twitter	Response [3, 4]

2.2. Benefits of social media use during EE

On the one hand, the e-government literature concerns itself with the realization of benefits from social media use in government under the 'normal'

conditions of routine government operations: accountability, transparency, better service, integration with planning, policy dissemination, effective programs and policies, adequate regulatory and improved decision making [1, 6, 19, 28].

Table 2. Classification of Social media benefits in EE

		Benefit Types	
		Tangible	Intangible
Benefits (Categories)	Not realized/Potential	Timely accurate information on resources available [38]; Timely accurate information for first responders [35]	Better collaboration [32]; Better evacuation plans and strategies, detailed situation reports on ongoing disasters [16]; Better response to early warning [16]
	Realized	Immediate information to mainstream medias, timely situation awareness to ground officers [29]; Timely Information dissemination on relief activity, timely situation awareness [15]; Timely hazard monitoring, situation awareness, faster risk dissemination [45]; Speed and reach of early warnings [3, 4] Shared situational awareness through crowdsourcing [31]	Citizen trust and situational awareness, clarification on rumor and immediate feedback to crowdsourced information [29]; Better collaboration through crisis map sharing [11] and information sharing [13]; Closer social ties and community resilience through crowdsourcing [31]

On the other hand, in EE situations, the literature shows mixed results with regard to the realization of social media benefits in government (see Table 2). The disaster-related literature has identified two kinds of benefits from social media use: Potential (or, promised/postulated) benefits and materialized, measured, or realized benefits. However, when studying the literature, we discovered another important tangible/intangible dimension, which in our view needs to be added to the existing considerations about benefits from the use of social media.

EE-related uses of social media observably have both tangible and intangible aspects, which provide discernible and meaningful distinctions for analysis and evaluation. The provision of timely and actionable

information, for example, represents tangible benefits from use of social media during an EE, while enhanced trust, reputation, and authority, for example, would refer to intangible benefits from social media use.

In summary, the benefits from social media use during EE identified in the literature can be classified into any of the four cells: (1) potential tangible benefits, (2) materialized/realized tangible benefits, (3) potential intangible benefits, and (4) materialized/realized intangible benefits as shown in Table 2's 2 by 2 matrix above.

3. Background: Hurricane Sandy

In the fall of 2012, hurricane Sandy ('superstorm' or 'frankenstorm' by the US mass media) devastated part of the Caribbean and the Northeastern United States. As of October 29, 2012, the impacts of Sandy (rated Category 1, down from the Category 2 earlier near the Caribbean) included a total of 88 human casualties in the US alone and affected 24 federal states.

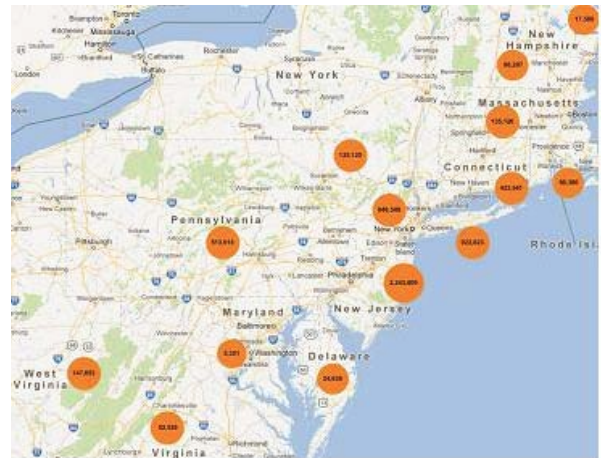


Figure 1. Northeastern US power outages

The superstorm caused flooding of streets, tunnels, and subway lines and stations in New York City and the surrounding area. Hurricane Sandy caused power blackouts affecting hundreds of thousands of citizens (see Figure 1). Moreover, the city's 911 call system was overwhelmed with 20,000 calls per hour, because it was designed to process 30,000 calls a day [9]. In consequence, citizen calls to non-emergency 311 also increased, resulting in the peak traffic of 274,000 calls in a single day and the increased average wait times to speak with a 311 call-taker [12]. Southern New York State and New Jersey were the most devastated areas, with US\$42 billion for New York and US\$29.4 billion for New Jersey in estimated damage cost [24]. Among

others, the 2013 Hurricane Sandy After-Action Report (AAR) recommends improved access and clearer disaster communication about the risk of severe weather [12].

4. Research Methodology

4.1. Research Questions

As the literature review revealed, government use of social media during EE has not been systematically analyzed, and, in consequence, it has not become clear whether or not the uses of social media by government during EE are benefitting the efforts during the various phases of the disaster management cycle, and if so, how beneficial they are. Therefore, this research aims to address two research questions:

(RQ#1) How does the government actually engage citizens through social media channels during and in the aftermath of EEs?

(RQ#2) How does the government realize the potential benefits through the use of social media during EEs?

4.2. Data Collection

In its strategy to offset the 140-character limit of tweets, Twitter introduced the hashtag symbol (#) to direct the focus of tweets and categorize tweets by keyword, facilitating greater efficiency in Twitter search. While a tweet can contain several hashtags to show that it has many foci to highlight, Twitter suggests a tweet to have no more than 2 hashtags. Hashtags then have a link to a search result with the hashtag as the keyword.

We have collected the Twitter data under the #sandy hashtag, which was used by both US government agencies at various levels and the public for storm-related communications during and in the immediate aftermath of Hurricane Sandy's landfall. Our data collection, analysis and interpretation were guided by extant relevant theories: social network analysis theory [22] and citizen coproduction theory [44].

During the data collection process we discovered other storm-related threads in the tweet logs, which concurred with the #sandy tweets. We decided to also investigate these related threads and exchanges among and between the government agencies and citizens that were related to the #sandy tweets. By exploring these other trending topics, we aimed to particularly capture citizens' experiences and concerns during the hurricane's landfall. From a public administration and responder perspective, the situational awareness in a

disaster has to include citizens' concerns and issues [41]; problems, sometimes minor, not addressed in a timely fashion can escalate into a problem during the dynamically changing EE [32].

The #sandy tweet data reflect *multi-directional interactive conversations* among public and private Twitter account owners. From an e-government research perspective, we were interested in investigating the active involvement of government agencies and citizens in the multi-directional interactive conversations and, therefore, we conducted a social network analysis of tweets issued by the government agencies responsible for disaster response management.

Since Twitter limits access to its REST API, we used Topsy at <http://www.topsy.com> to search the entire tweet data using #sandy as the keyword. We collected a total of 132,922 tweets for the selected period from October 23, 2012 to November 10, 2012.

5. Findings

5.1. Citizens' engagement via Twittersphere for disaster conversations

The #sandy tweets rapidly increased in the Twittersphere when the hurricane evolved near Jamaica during October 22 to 24, 2012. The time series graph of #sandy tweets from October 23 to November 10 (see Figure 2). As the graph shows, the #sandy tweets were gaining momentum and peaked on October 30, a day after the Northeastern region was devastated by massive flooding and wide-area power outages. The #sandy tweet conversations remained actively engaged at a higher-level (vis-à-vis the first day of our data collection on October 23) until a large decrease was observed on November 10, 2012.

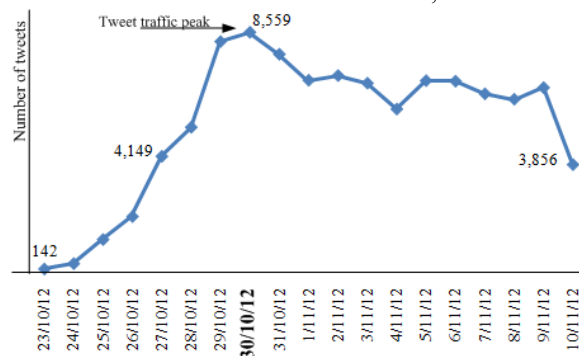


Figure 2. Time series graph: #sandy tweets

During the period studied, #sandy was used together with other hashtags to further specify the central focus of tweeted conversations. Therefore, we

identified other hashtags that were used together with the #sandy to address our research questions, that is, how Twitter was used, and what citizens discussed during and in the immediate aftermath of the Hurricane Sandy's landfall (see Figure 3 below).

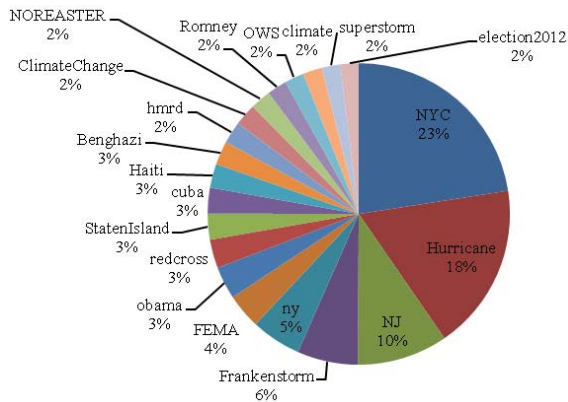


Figure 3. Trending topics related to #sandy

Among the 20 trending topics (most popular hashtags) which are shown in the pie chart, we classified the trending topics into five categories:

- (1) Locations affected by Hurricane Sandy (New York City-NYC, New Jersey-NJ, New York-ny, Staten Island-StatenIsland, Cuba-cuba and Haiti);
- (2) Perceived devastating power of Sandy (hurricane, frankestorm, NOREASTER and superstorm);
- (3) Perceived cause for extreme disaster event (climatechange, climate);
- (4) Disaster response agency/organization (Federal Emergency Management Agency-FEMA, Red Cross-redcross, Humanity Road-hmrdr) and
- (5) Other newsworthy topics/events of public interest during the same period (obama, Benghazi, Romney, OWS and election2012).

5.2. Government engagement via Twittersphere for disaster conversations

In this section we identify government agencies' engagement in the wide discussion of #sandy in order to have a good understanding of how the government agencies were interactively engaged in the Hurricane Sandy-related Twitter conversations. We identified the top five Twitter users who were actively sending their tweets with the #sandy hashtag, as of November 22, 2012. The results are shown in Table 3. The top-five Twitter accounts involved in #sandy can be classified into government agency, mass media, and weather information provider. The number of tweets sent during the period we studied ranges from 380 to 634 with a mean of 472 tweets sent (median of 478 tweets). The number of the Twitter account followers ranged

from 48,834 to 2,295,233 with a median of 100,213 followers.

Table 3. Most active users of #sandy

Twitter Account	Number of Tweets Sent	Twitter User	Number of Followers
nygovcuomo	634	Governor of New York State	65,998
nbcphiladelphia	484	Mass media	48,834
huffingtonpost	478	Mass media	*2,295,233
twc_hurricane	382	The Weather Channel	114,603
nydailynews	380	Mass media	100,213

* The number is the worldwide huffingtonpost followership.

As shown in Table 3 above, the office of the Governor of New York State led the group in terms of the number of tweets followed by two large mass media, NBC Philadelphia and Huffington Post. In terms of the number of followers, the office of the Governor of New York had far fewer followers in comparison to Huffington Post's almost 2.3 million followers (nearly 35 times as many). Overall, mass media dominated the top-five most active Twitter conversations with regard to #sandy. The three active mass media had a combined total of 2,444,280 followers.

Hence, via this Twittersphere, a critical mass of Twitter followership was reached and informed about the dynamically changing trajectory and impact of the hurricane. Furthermore, the active presence of mass media means that the media Twitter channels and their traditional channels such as television and radio might have been integrated for sharing disaster-related information to also reach non-Twitter users, including television viewers and radio listeners without access to the Internet.

Table 3 suggests that Twitter-savvy citizens had access to three different disaster information providers with whom they engaged in #sandy conversations. Without a comprehensive content analysis, however, we cannot determine whether or not the #sandy conversations led by the Governor, mass media, and the Weather Channel were complementary or redundant.

Next we identified the top fifteen government agencies that were actively engaged in #sandy tweet conversations during the period we studied. We classified government Twitter users into levels of government (local, state, and federal), and found that

all levels of government had involved themselves with #sandy tweeting as shown in Table 4.

Table 4. Most active government users of #sandy

Twitter Account	# of Tweets Sent	Government Twitter User	Number of Followers
nygovcuomo	634	State: Governor of New York State	65,998
nycmayorsoffice	188	Local: NY Mayor Office	127,734
govchristie	151	State: Governor of New Jersey	305,789
femaregion2	148	Federal: FEMA areas NY, NJ, PR, VI	7,487
fema	142	Federal: FEMA	181,604
mikebloomberg	134	Local: Mayor of New York City	391,328
911buff	114	Local: 911 Operator	11,333
govmalloyoffice	94	State: The Governor of Connecticut	15,911
dhsgov	73	Federal: Department of Homeland Security	114,500
femaregion3	69	Federal: FEMA areas DC, DE, MD, PA, VA, WV	8,132
nhc_atlantic	65	Federal: National Hurricane Center Atlantic	105,847
noaa	57	Federal: National Ocean Service	119,986
femaregion1	48	Federal: FEMA areas CT, ME, MA, NH, RI, VT	6,785
nycgov	45	Local: New York City	51,612
fdny	34	Local: NYC Fire Department	57,880

The number of tweets ranges from 34 (New York City Fire Department) to 634 (The office of the Governor of New York), with the mean of 133 tweets

and a median of 94 tweets being sent. The number of followers ranges from 6,785 (FEMA areas CT, ME, MA, NH, RI, VT) to 305,789 (The Governor of New Jersey) with a mean of 104,795 followers and a median of 65,998 followers.

Among the 15 most active government agencies analyzed, the Governor of New York Twitter account sent the largest number of tweets. In the federal agency category, FEMA regional (NY, NJ, PR, VI) and FEMA head office Twitter accounts were very active, especially because the jurisdictions were severely affected by Hurricane Sandy. Also, federal agencies responsible for issuing early hurricane warnings, such as the National Hurricane Centre (NHC), a unit of the National Oceanic and Atmospheric Administration (NOAA), and the National Ocean Service, were actively tweeted. Finally, we found the active engagement of local emergency first responders such as the 911 operator and the New York City Fire Department. The top-15 active government Twitter accounts' statistics were found to be far lower than the top-five active Twitter accounts' statistics (mean of 133 tweets/median of 94 tweets and mean of 104,795 followers/median of 65,998 followers versus the mean tweets of 472/median of 478 tweets and the mean of 524,976 followers/median of 100,213 followers). Since the huffingtonpost followership expands far beyond the Hurricane Sandy-affected area, it appears more appropriate to consider the medians in this comparison.

In summary, government agencies issued about a fourth the amount of tweets compared with other major information providers, and they reached a regional followership of about two thirds the size of other major information providers' followership.

5.3. Government agencies' Twitter use and the disaster management phases

Based on the disaster management cycle concept, we can classify government agencies' Twitter activities into one of four inter-related phases: disaster preparedness, response, recovery and mitigation. For each phase we identified the most representative tweets, except for the risk mitigation phase. During the period of data collection, mitigation activities had not yet been activated.

During the preparedness phase, government agencies issued many tweets containing warnings and preparation reminders with regard to the imminent landfall of Hurricane Sandy. The warnings and reminders were continuously released and informed about adequate preparation measures before the impact including a specific government website for hurricane preparedness such as <http://www.ready.gov/hurricanes>. Even specific instructions were released repeatedly to

increase citizens' situational awareness. For example a tweet released by @fema on 10:19 AM 25 October 2012 read:

25 Oct 12 1:41 pm Hurricane #sandy tip: Bring in outdoor furniture, decorations, garbage cans; anything else not tied down <http://t.co/YpTeigA8>.

Citizens expect an immediate response from government agencies after a disaster has struck. For example, among State governments' first actions during a disaster in the response phase include the formal declaration of the state of disaster or catastrophe. Based on its Twitter timeline, @nygovcuomo announced that the Governor asked for the declaration of disaster at 1:17 PM on October 26, 2012. When the federal government approved the request, the Governor also used Twitter to post the emergency declaration tweet at 4:35 PM on October 28, 2012.

Finally, during the recovery phase, Twitter was also used for announcing disaster aid distributions such as heaters, food, and available evacuation shelters for the citizens affected by Hurricane Sandy. The first responders also leveraged Twitter to communicate with citizens who were concerned about homeless victims in need of shelters. The New York City Fire Department gave a very quick response immediately sharing the shelter location and transport services through Twitter. As the disaster happened in the fall, the need for warm shelters was a crucial issue for the affected communities. A couple of Tweets below illustrates the very quick response by the New York City Fire Department.

5 Nov 12.01 pm @FDNY How do the homeless victims get there? That's the problem besides getting this info to them.

5 Nov 12.04 pm @SaveLongIsland There are bus pickups from 4-9 pm. The locations are listed underneath each shelter location.

In summary, in the affected regions government agencies at all levels used Twitter for sharing and receiving information in disaster-related preparation, response, and recovery.

5.4. Citizen co-production and time-critical information sharing

By its ubiquitous nature, Twitter offers the ease of use in forwarding and diffusing information rapidly in real time to other Twitter users. By its sheer number of users, for example, 140 million users in the US alone

as of July 1, 2012, Twitter also provides the potential for wide reach. Here we provide a sample tweet to describe how the government agency leveraged the power of networked citizens with Twitter accounts to diffuse information on warm shelters during the disaster recovery phase. The tweet was issued by the FDNY (New York City Fire Department) on November 4, 2012.

4 Nov 12 1:32 pm Warm shelters will open tonight. Please share this list with anyone you know without power: <http://t.co/eFJM3ia1> #NYC #sandy

The tweet was retweeted by many of its 57,880 followers and the information diffusion reached people in the affected communities far more quickly and comprehensively than the agency with its limited human resources could have done on its own via traditional channels of communication. Other government agencies, including @nycmayoroffice, also retweeted the FDNY tweet.

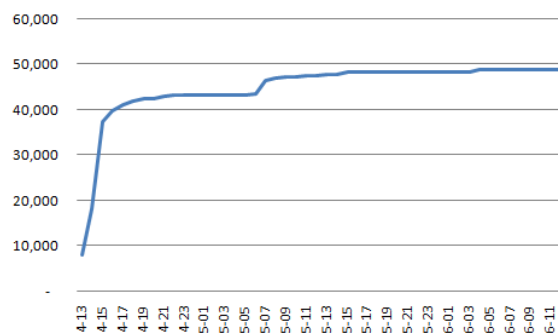


Figure 4. Citizen co-production impact on reach

The impact of active citizen engagement and co-production on having reached people in the affected communities far more quickly and comprehensively can be demonstrated by the reach within the #sandy Twittersphere. The x-axis of Figure 4 above shows date-time (November 2012), whereas the y-axis shows the number of Twitter users who can be reached by the citizens' coproduction in retweeting the FDNY tweet. Figure 4 was generated through a social network analysis of the timestamp of the 468 retweets of the "4 Nov 12 1:32 pm" FDNY tweet discussed above. Hence, the line graph shows the reach and the speed of the government information diffusion through citizen co-production. As Figure 4 shows, the reach increased sharply within the first two hours, which was on the rise for the next two days.

In other words, citizens did not wait for the government to propagate disaster-related information, but rather actively involved themselves in providing an

essential public service to a wide audience of citizens who were affected by the hurricane.

Since this tweet was re-tweeted only 1,818 times, the social network is relatively small in size with a network diameter of 13, as shown in Figure 5. The figure also gives a general overview of the FDNY Twitter network with big nodes. The big nodes in this FDNY social network represent the two government agencies (@fdny and @nycmayoroffice) and the eight citizens with large Twitter followers, all of whom have influenced the speed and reach of the FDNY information diffusion. The lines show actual links (connected Twitter users) within this Twittersphere created by the November 4th FDNY tweet.

The FDNY social network shows the average degree of 1.197, which represents an attractiveness level of each node (that is, a Twitter account). In general, tweets travel within a social network and can reach different social groups, to which any given Twitter user belongs, suggesting that FDNY tweets could reach larger audience, once the number of followers increases.

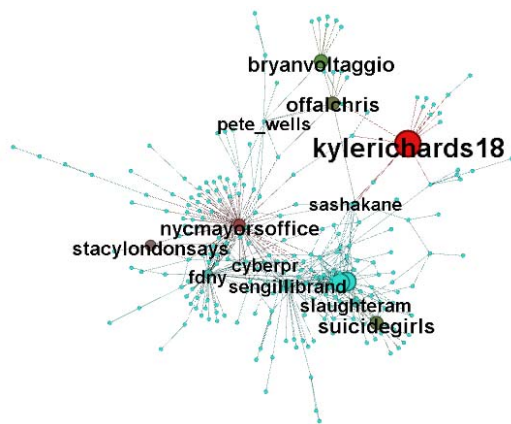


Figure 5. FDNY social network with big nodes

The FDNY tweet of November 4 has created an active Twittersphere in which the multi-directional interactive conversations among public and private Twitter account owners were made possible. Net-savvy citizens appreciated FDNY for providing this Twittersphere and enabling active information sharing. Unlike the citizens who were frustrated by the two-way communication channels such as 911 and 311 call systems, net-savvy citizens seem to have appreciated the agile disaster communication and response of NYFD via Twittersphere. It can be demonstrated by a selective but representative sample of such affirmative and affective tweets.



Whoever is doing the tweeting for @fdny you are a total hero. Inspiring! Thank you



.@FDNY Let me just say that your work has been amazing. One of the best responses by a gov't agency to an emergency situation. Thank you.



While we need further investigation, this Twitter use by FDNY shows both tangible and intangible benefit realized, especially timely accurate information for the first responders and better collaboration as mentioned in Table 2, are realized.

6. Discussion

6.1. Social media's role during an EE when information infrastructures are overwhelmed (addressing RQ#1)

When government agencies, communities, businesses, and citizens on the Northeastern coast prepared for the landfall of Hurricane Sandy in late October of 2012, New York city government's Office of Emergency Management (OEM) sent Notify NYC alerts via landline, mobile, text, email, and Twitter to reach more than 165,000 citizens [12] and, for the first time, adopted the Commercial Mobile Alert System (CMAS). While most communication channels, which government agencies used, provided for top-down one-way broadcasting capabilities, other channels such as 911 and 311 call systems had the capacity of two-way communications. However, as discussed earlier, these call systems were overwhelmed by the unprecedented surge in citizen calls during the unfolding EE. The sustained power outages meant that citizens could not access severe weather information via TV.

In stark contrast, Twitter channels used by government agencies provided the capacity of *multi-directional interactive* communications, enabling feedback, updates, and original information acquisition *in real time*. Furthermore, Twitter did not suffer from the service over-load problems reported about traditional information infrastructures such as the city's 911 and 311 call systems, both of them were facilitated through the city's call centers which could not handle the sustained surge in citizen calls [9]. While we need

further study of other agencies, our results show that citizens responded to the NYFD use of Twitter in real time affirmatively and appreciatively in contrast to the general public's expressed frustration to the increased average wait times for the city government's traditional two-way communication channels.

Furthermore, through Twittersphere, agencies were able to collect critical information in real time directly from communities, businesses, and individuals that would otherwise not have been available. In consequence, the overall operational picture became clearer much sooner and much more comprehensively than without the use of social media producing both intangible/realized and tangible/realized benefits (see Table 2).

However, government agencies were not the only organizations benefitting from citizens, businesses, and communities' engagement in the multi-directional interactive conversations and information co-production. Internet-based mass media, such as the Huffington Post, also added to the rapid information collection and exchange mechanisms enabled through social media. This in turn helped reach a wider audience than relying on the top-down and government-generated information-only approach observed during previous EE.

In summary, even though the percentage of Twitter or Facebook users relative to the affected population at large was marginal, the thousands of citizens using Twitter co-produced a significant amount of timely and detailed EE-related information, which would have otherwise not been available to responders. As a result, response efforts could be better targeted and resources used in areas, where they were needed the most.

6.2. Clear communication and information flows still a key challenge (addressing RQ#2)

While social media, in general, and Twitter, in particular, provided additional EE-related information during Hurricane Sandy's landfall to both responders and the public at large, the clear disaster communication and seamless flows of information between and among jurisdictions and communities during response and early recovery has remained a key challenge [12, 36] as known from previous EEs [8, 17, 20]. Major disasters and catastrophes present a particular challenge to jurisdictions and communities, since they transcend the jurisdictional and communal borders, and at the same time the extent of their impact overwhelms the local jurisdictional and communal resources. In other words, while the enormity of the response challenge would require cross-jurisdictional and cross-communal joint operations and unimpeded

communication and information flows, the lack of an effective infrastructure for such purpose is only developed and operational in part.

At the very least, social media and social networks inside and outside government can help fill gaps, which the traditional organizational and federated structures in government have created by design. For example, the City of New York issued more than 2,000 tweets, gaining over 175,000 Twitter followers (over 70 percent increase) during the unfolding catastrophe [12]. The Mayor's YouTube broadcasts were clicked a million times, and the City website at nyc.gov had some 4 million visitors between October 26 and November 9, 2012 [12]. Twitter with its parsimonious message sizes and low bandwidth requirements appears as a capable carrier of critical information, particularly when other channels have gone dark due to power outages and other disruptions.

In our view, cross-jurisdictional and cross-communal information integration, which includes crowdsourced information, has the capacity to more rapidly share information among stakeholders as well as to further reduce informational ambiguities and the dissemination of incorrect information. While mass media aggregate and consolidate information on regional and national levels, such effort might best and most authoritatively be coordinated at regional and national level (for example, FEMA, in the USA). FEMA's Hurricane Sandy-related rumor control website (<http://www.fema.gov/hurricane-sandy-rumor-control>) provides a prime example for such information integration efforts along with setting the record straight in an authoritative fashion. However, an ongoing information integration and verification process, which includes crowd sources, which constantly updates, makes actionable, and disseminates the most recent EE-related information, would put this approach further and beyond the current jurisdictional and communal borderlines providing a wider area view and would better take advantage of citizens, businesses, and communities' co-production of time-critical information. Such approach would in fact produce both tangible/potential and intangible/potential benefits (see Table 2).

In summary, while government agencies in Hurricane Sandy-affected areas frequently used multiple information dissemination and communication channels including social media, the integration and verification of information still presented a major challenge across jurisdictions and communities, and in particular, with regard to jurisdictional borders. However, it appears that the full potential of multi-directional interactive social media uses in real time during EE is still underestimated.

Although at this point in time it is only speculative to state, but social media and social networking might have the capacity to deeply influence the structural transformation of 'the public sphere' [14] with their ubiquitous users, common platforms, and the ability to transcend jurisdictional and technological boundaries.

7. Conclusion

This paper's stated purpose is to understand to what extent governments inform and engage citizens via social media during an unfolding EE. It further aspires to understand to what extent government agencies were able to leverage the potential of social media during an EE.

For this purpose we analyzed and categorized 132,922 #sandy tweets issued during the unfolding of Hurricane Sandy. We also performed several social network analyses of the tweets and found that communities and citizens can make a difference, at least during the immediate response to the catastrophe. While an active engagement of citizens may also have some unexpected negative effects on government response operations, it can greatly extend the reach and facilitate government agencies' efforts, for example, via Twitter, to provide critical and essential public information services in a timely fashion.

The social network analysis provided some evidence for the critical roles of citizen co-production and message amplification when sharing EE-related information with friends and followers, which was originally provided through government agencies' Twitter channels. This specific form of citizen co-production appears as a valuable extension in the provision of essential public services and needs to be further explored also with regard to information quality, information integration and verification for a cross-jurisdictional and cross-communal purposes and uses.

Our research has methodological limitations related to data collection for social network analysis. The use of Topsy as a tweet trackback source potentially introduces research limitations with regard to reliability and completeness of the data set, and hence, we cannot exclude sampling skewness. We would have favored collecting the entire #sandy tweet data set for the respective period of time directly from Twitter.com; however, that was unavailable due to that company's data sharing policy. Our future research will include extended content analyses of #sandy and other catastrophes' tweets and the conceptual development of types of Twitter categories for classifying trending topics' content areas and the exploration of potential information

integration/verification scenarios relevant during major disasters and catastrophes.

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