Rapid Emergence of Communications Networks: April 20, 2013 Lushan, China Earthquake

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Abstract: We employ a theoretical framework drawn from prior research on complex adaptive systems to analyze the rapid mobilization of multi-organizational response operations following the Ya'an Earthquake. We base this analysis on data collected in China from Sina Weibo, coded by students at Nanjing University, and validated by researchers at the Center for Disaster Management (CDM), University of Pittsburgh. The validated data were further analyzed using network analysis to identify the centrality measures for the interacting groups. Change in communications technologies has facilitated the rapid spread of information among the citizenry, and altered relationships between citizens and governmental agencies at the local level. This change is markedly evident in urgent situations that require rapid response, such as earthquakes. This analysis documents the changing context of actions in response to hazards at the community level, and indicates a pattern of rapidly evolving inter-organizational practice among levels of government in China, facilitated by user-initiated communications via social media. Based on findings from the network analysis, policy recommendations are offered to increase adaptation in emergency management systems in the changing, sociotechnical context of China.
Keywords: Complex Adaptive Systems, Emergency Management, Social Media, Earthquake, China

1. Introduction

In the context of global climate change, dealing with frequent extreme disasters is a policy issue to be explored in both practice and academia in emergency management worldwide. Extreme disasters overwhelm routine emergency management systems and require adaptive response in complex environments (Drabek et al., 1981; Comfort et al., 1990; Comfort, 2002; Tierney and Trainor, 2003; Kendra et al., 2003).

China has developed a new emergency management system to respond to all types of disasters since the SARS epidemic in 2003. These intervening years have coincided with the rapid adoption of information technologies in China, and increased usage of cell phones and access to the internet by the citizenry. Particularly, with its rising use in disaster management, social media play a bigger role than traditional information systems in facilitating adaptation of emergency response to extreme disasters.

Employing the theoretical framework of complex adaptive systems in emergency response, we seek to explore how social media facilitate the adaptation of the new emergency management system in China. Based on an analysis of the communication network that emerged via social media following the April 20, 2013 Ya'an Earthquake in Lushan County,

China, we address five questions. First, what roles do social media play in responding to extreme disasters in China? Second, how do social media contribute to adaptation of emergency response? Third, why are social media able to facilitate adaptation of emergency response? Fourth, what are the drawbacks in the use of social media in facilitating adaptation in Ya'an Earthquake in emergency response? Fifth, how do we improve the performance of social media in emergency response in China in the future?

2. Social Media in Emergency Management

If social media are strictly defined as new information technologies used in managing the content of conversation or interaction in online environments, they are different from traditional internet and communication technologies (Yates and Paquette, 2011). According to this definition, social media mainly refer to wikis, Google Docs, YouTube, Flickr, Facebook, and Twitter. We adopt this strict definition of social media. In this sense, how social media facilitate emergency management in extreme disasters is a new area of research that has emerged in recent years.

Broadly, studies on the uses of social media in extreme disasters explore two major questions: how are social media used as communication tools in disseminating information, and how are applications designed to detect earthquakes, warn the public regarding threats, and estimate damages. To date, most research studies focus on the former, and a wide consensus has been reached on the power of social media as a communication tool for disseminating information in emergency management (Fugate, 2011). For this purpose, relevant empirical studies can be classified into two categories.

The first category is how social media facilitate citizens' adaptation in responding to extreme disasters. A study on the 2007 Southern California Wildfire suggested that community information resources and other backchannel communication activity enabled by social media were gaining prominence in the disaster arena (Sutton et al., 2008). In this case, social media filled critical information gaps and facilitated social cohesion by enabling geographically dispersed people to find community (Shklovski et al., 2008). A cross case study on eyewitness photo sharing in Flickr suggested the emergent role of social media in searching for the bigger picture of disaster situations (Liu et al., 2008). A cross case study on the 2009 Oklahoma Grassfire and 2009 Red River Floods revealed that information generated in Twitter contributed to enhancing situation awareness (Vieweg et al., 2010).

Similar findings were found in other countries which suffered from extreme disasters in recent years. In China, a case study of the 2010 Yushu Earthquake found that Weibo had four major purposes: 1) situation updates, 2) opinion expression, 3) emotion support, and 4) calls for action (Qu et al., 2011). A study on 2010 Haiti Earthquake analyzed how Twitter facilitated self-organizing by "digital volunteers" in times of crises (Starbird, 2011). A study on the 2011 Great East Japan Earthquake documented the significant role played by social media in disseminating vital information during the disaster in conditions where other communication technologies were inaccessible and unavailable (ICHIGUCHI, 2011; KAIGO,

2012), as well as facilitated the development of social capital (KAIGO, 2012). A recent study on 2012 Hurricane Sandy showed the critical contributions of citizens' collaboration in generating time-critical information to serve the public during an unfolding catastrophe (Chatfield et al., 2014). These studies documented the exchange of information among individuals via social media and the co-production of shared knowledge regarding risk.

The second category of studies examines how organizations engage citizens to respond to extreme disasters adaptively. By interviewing 25 Public Information Officers (PIOs) positioned in the National Incident Management System (NIMS), Hughes and Palen (2012) found that the perception of the PIOs has been transformed from gate keeper to translator. Chatfield et al. (2013; 2014) employed the method of social network analysis to demonstrate how governmental agencies engaged citizens in the 2012 Indonesia Earthquake and in the 2012 Hurricane Sandy, and found that social media greatly extended the reach of governmental agencies and facilitated their efforts, particularly in providing critical and essential public information services in a timely fashion.

However, there is also evidence to suggest that organizations were not as adaptive as citizens in adopting social media in disaster situations. Based on the study of the February 27, 2010 Hawaii Tsunami, Sutton et al. (2011) discovered that social media still played a backchannel role. Observations on how social media were used in the 2008 Democratic Convention revealed the tendency to fall back upon standard operating procedures that limit institutional responders from adopting social media in actual response (Sutton, 2009). The lack of followers has also limited the information dissimilation capacity of public agencies and nonprofit organizations (Wukich and Steinberg, 2014).

In summary, most of these research studies were based on data from Twitter in different political contexts; few have explored data collected from social media in the political context of China. To fill in this gap, we seek to identify what roles social media play in facilitating adaptation in extreme disasters in China. Further, informed by these studies, we distinguish citizen users from organization users to determine how organizations engage citizens to respond adaptively and how organizations communicate with each other in responding to extreme disasters in the context of China.

3. Perspective of Complex Adaptive Systems in Emergency Response

In emergency response, a complex adaptive system is defined as a sociotechnical design enabling individuals and organizations to interact with, and adjust to, each other through information search, exchange, and sharing in disaster situations (Stallings and Quarantelli, 1985; Comfort, 1999). This process has been widely recognized as a phenomenon that emerges following the occurrence of disasters, returning from chaos to order (Drabek et al., 1981; Stallings and Quarantelli, 1985; Comfort et al., 1990; Comfort, 1994; Comfort, 1999; Comfort, 2002; Kendra et al., 2003; Kapucu, 2009; Comfort and Okada, 2013). In the sociotechnical context, a complex adaptive system in emergency response consists of two dimensions: organization structure and information processes that build collective capacity

(Comfort, 1999).

In the first dimension, public organizations are more likely to respond in a mixture of plans-based and feedback-based performance (Dynes, 1979; Kendra et al., 2003). Private sector, nonprofit organizations, and massive numbers of individuals are all self-organized, because they are largely not included in the institutional response system (Stallings and Quarantelli, 1985; Kapucu, 2007). In actual response to extreme disasters, these components create a multi-centered network to respond adaptively to threats.

In the second dimension, information capacity highly depends on core information, which is defined by both structure and context (Comfort et al., 2004; Jaeger et al., 2007). In structure, core information moves among critical nodes or bridges in the response network (Comfort et al., 2004). In context, core information is highly related to the Emergency Support Functions (ESFs). Social media can create a sociotechnical structure to support the exchange of information essential to drive a complex adaptive system. Organizations may engage citizens to respond adaptively to extreme disasters and enable them to communicate with organizations based on on-line information exchange and sharing.

Employing the theory framework of complex adaptive systems in emergency response, we seek to document how organizations engage citizens in response operations and how organizations communicate with each other to facilitate adaptation under rapidly changing conditions.

4. Evolution of Emergency Management and Social Media in China

Since the SARS Epidemic in 2003, China has reformed its emergency management to approach a comprehensive response system. Four major institutional changes have been adopted (Zhang, 2012):

(1) Unifying response. Previously, the governmental agencies managed disasters separately based on institutional responsibilities. Now, it has been changed to mobilize response operations ranging from natural disaster, accidents, epidemics, and social riots under the unified command and coordination of the government at various levels.

(2) Reclassifying responsibilities at different levels. Disasters are divided into four levels according to severity, and the central government only engages in emergency response and recovery at the most severe level.

(3) Improving coordination. The Emergency Management Offices (EMOs) have been set up from state to county. They are not independent agencies, but are placed in charge of coordination.

(4) Enhancing preparedness. Millions of response plans have been made from central to local levels of government.

However, all of these policy changes were implemented only in the public institutional response system. The result is that the change is not inclusive enough to allow the participation of private and nonprofit organizations, and massive numbers of individuals.

Social media use has risen in China since 2009. With an explosive development in five years, Weibo has become the most popular social media platform in China. According to the 2014 Annual Report of China Internet Development, the user size of Weibo has reached 275 million, and active users have reached 120 million (43.64%). The number of users accessed by mobile phones has reached 189 million (68.73%), and active users have reached 67.76 million (35.85%) (CNNIC, 2014). Sina, Tencent, Sohu, and Netease are the major Weibo service providers in China, and among them Sina Weibo is the largest one and most influential. According to the official report by Sina Company, by the end of 2013, the user base has reached 129 million, and 61.4 million of them have been active (Sina Company, 2013).

The first time that the use of social media coincided with emergency management in China was during the 2010 Yushu Earthquake. Sina Weibo was identified as serving four major purposes, including situation updates, opinion expression, emotional support, and calls for action (Qu et al., 2011). In the 2011 Wenzhou High Speed Train Crash, Sina Weibo was extremely active, and primarily proved useful in changing the governmental response strategies in comparison to a similar type of railway accident in 2008 in Jiaoji Railway lines, China (Zhang, 2013).

Unlike Twitter, Sina Weibo has an extra feature in taking the form of V [username]. It means this user is verified by the service provider. The verified users can be either organizations or individuals with public influence. The comparison between the common accounts and the verified accounts in information dissemination in the 2010 Yushu Earthquake in China has proven that the Weibo messages generated by the verified accounts had many more retransmissions than those generated by the common accounts (Qu et al., 2011).

5. Methods and Data

We use the method of case study to document the role that social media plays in a rapid changing, disaster environment and address the five questions posed earlier (p. 2) in reference to an actual event. The relation between social media and emergency management is an emerging area, and the case study method is appropriate for this area still in an exploratory phase. Particularly, a case study is a preferred method when the relevant behaviors cannot be manipulated and the understanding of a real-world case involves important contextual conditions pertinent to the case (Yin, 2014). In this sense, case study methods are useful in exploring the complex adaptive nature of social media in the distinctive context of China. However, this method is weak in generalizing to wider applications, so we do not generalize the conclusions drawn from this single case.

5.1 Case summary

The Ya'an Earthquake occurred in Lushan County, Sichuan Province, China, on 8:02 am, April 20, 2013. It registered a 7.0 magnitude on the Richter scale, leaving 196 people dead, 21

people missing, 11,470 people injured, and over 2.3 million people affected (Xinhuanet, 04/24/2013). According to the new emergency management system initiated after the 2003 SARS Epidemic, China's Central Government launched response at the top level, and Sichuan Provincial Government, Ya'an Municipal Government, and Lushan County Government all initiated response operations at their respective levels of authority. Chengdu Military, one of the seven regional military command centers, also sent military forces to participate in search and rescue operations. The Ya'an Earthquake was a typical extreme disaster, although it was less severe than the Wenchuan Earthquake that occurred in the same area five years earlier on May 12, 2008.

In the initial response state, social media played a dominant role in citizen communication, given the conditions that traditional communication systems were severely damaged and the emergency communication system was insufficient. According to the situation report by China State Council, there were 16 of 33 townships located in Lushan County, Tianquan County, and Baoxing County, as well as the downtown area of Baoxing County that were inaccessible through standard communication means (China State Council Website, 04/23/2013). The citizenry and organizations in these areas could not make calls or be reached through their telephones or mobile phones. By contrast, internet channels were robust, so China Telecom, China Mobile, and China Unicom, the three major communication service providers in China, all used their Weibo accounts to declare temporary free internet access policies to allow the rescue forces and citizens in the affected areas to communicate through social media. Consequently, Sina Weibo was extremely active in the first day. According to data from Sina Weibo, by 15:00 pm, April 20, the number of messages related to the Ya'an Earthquake reached 65 million in Sina Weibo alone. There were 1,277 governmental agencies, 2,086 mainstream media, 9,290 companies, and 31, 273 persons with public influence that used Sina Weibo to disseminate information related to the earthquake.

5. 2 Data collection and coding

Immediately after the Ya'an earthquake occurred, data regarding response to the earthquake were extracted daily from four Weibo sites for three weeks during the period from April 20 to May 10, 2013. This data collection process created a daily record of disaster operations as an empirical basis for content analysis to identify the number of organizations participating in response operations, the interactions among them, and the types of transactions they performed. There were many different hashtags related to this earthquake, so we used "Ya'an Earthquake" as a general keyword to search for messages through the APIs of Sina Weibo, Tencent Weibo, Sohu Weibo, and Netease Weibo. Sohu Weibo and Neteasy Weibo returned only 1,171 messages and 3,921 messages respectively to our request, so we did not include them into the analysis. Tencent Weibo returned 64,128 messages, but only 4,707 (7.34%) have at least one retransmission, and the highest retransmission frequency was 4,420. Sina Weibo returned 69, 427 messages from the search, and 8,092 messages (11.66%) have at least one retransmission, with the highest number of retransmissions at 506,924. Finally, to avoid duplications, we selected only the dataset extracted from Sina Weibo for the analysis in this paper. Qu et al. (2011) has shown that the verified accounts were much more influential in

disseminating information, so only 4, 203 (51.94%) of the 8,092 messages with at least one retransmission were selected for data coding.

The data were first analyzed by a team of ten Chinese graduate students at the Center for Social Risk and Public Crisis, Nanjing University, and then checked and recoded by two bilingual researchers at the Center for Disaster Management, University of Pittsburgh to ensure the coherence of data coding and inter-coder reliability. Figure 1 indicates the time series of the extracted data.

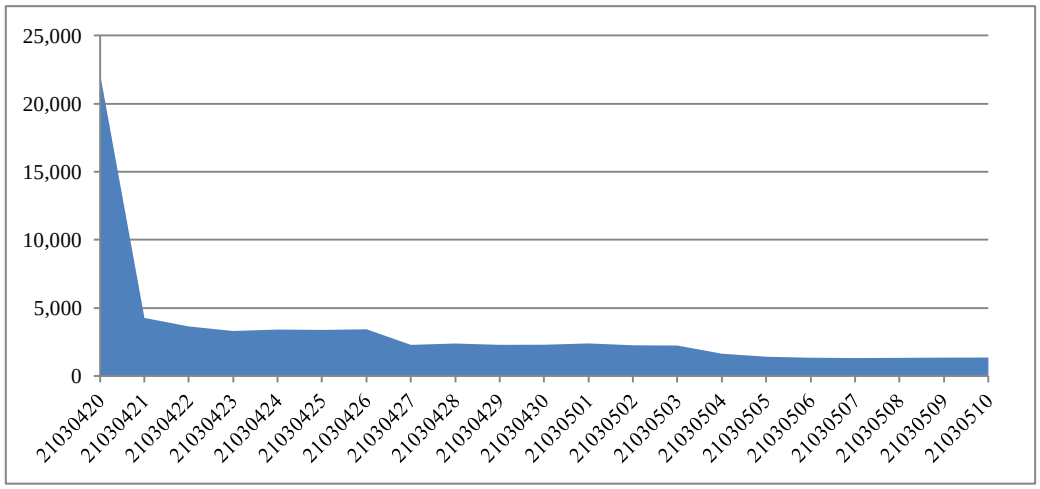


Figure 1 Times series of the data extracted

Notably, due to the Intellectual Property restrictions set by Sina Weibo, the dataset we extracted was not based on random sampling. Although it might cause bias in conclusions (Morstatter et al., 2013), most research studies based on social media data have to take this risk before a satisfactory solution is found.

5. 3 Content analysis

We used content analysis to assess how organizations engage citizens in responding adaptively and to identify the core information in the context of operations. First, we excluded information irrelevant to emergency response. Adopting the classification schema developed by Qu et al. (2009) and Vieweg et al. (2010), all Weibo messages were classified into six categories: (1) information related; (2) action related; (3) emotion related; (4) opinion related; (5) technology related; (6) others (irrelevant to the earthquake). Only information related and action related messages were treated as the core information in emergency response.

In the second step, information related and action related messages were further classified into 12 categories according to the ESFs, which had been defined in the updated National Earthquake Emergency Response Plan (NEERP) after the 2008 Wenchuan Earthquake (China Earthquake Administration, 08/28/2012). The 12 categories and examples of actual messages from our database are listed below:

ESF1: **search and rescue**. Example: # recruit volunteers # A big earthquake occurred in Sichuan at eight o'clock this morning, we recruit veteran, experienced volunteers, if you want

join the on-site rescue, please contact me.

ESF2: command and coordination. Example: Chengya Highway opens the emergency lane, and vehicles not engaged in emergency response take other routes.

ESF3: relief and settlement. Example: # Ya'an Earthquake # China Telecom has set up a hotline for those searching for relatives: (0835) 2220000, Call this number, if you need.

ESF4: medical care and disease control. Example: # Ya'an Earthquake # a barrier lack has appeared in Baoshen Town; apparatus and personnel for medical care are urgently needed.

ESF5: information release. Example: # Lushan Earthquake # those who will donate medical resources, please visit the website of Sichuan Health Department (http://www.scwst.gov.cn/) to obtain the procedures and specific needs (demands); telephone: medical resources group (028-86240701); supervision group (028-86240772;86240607).

ESF6: social mobilization. Example: # Reasonable Relief # from the summarizing information, food, water, tents, medicine, and toilet paper are in heavy shortage, please retransmit this message to volunteers and prospective donors.

ESF7: secondary disaster prevention. Example: # Sichuan Ya'an Earthquake # Barrier lakes have appeared in the Baoshen Town and Jinji canyon, and cracks have appeared in Dongmo reservoir, Miaoxi reservoir, and Tianquan reservoir, @ China Territory Resources News those who were on site, watch out.

ESF8: assessment. Example: if your mobile phone works, please tell me your location, feelings and any damage that you see.

ESF9: infrastructure restores. Example: # Weibo Tips# those friends who are in confirmed safety, please avoid calls to preserve the limited communication capacity for rescue operations.

ESF10: recovery. Example: "the Wulong Town in the affected area is famous for its cherries, please help the fruit farmers, call (028)96111 to order.

ESF11: social order keeping. Example: please confirm validity before you retransmit photos; your efforts are needed to avoid panic.

ESF12: foreign affairs. Examples are not found.

5. 4 Network analysis

We used network analysis to identify the communication network and core information in its structure. In messages that were generated by verified organization accounts, two types of situations were coded as communications between the reporting organizations and other organizations:

(1) Re@ [organizational username]. Term appeared in the beginning of the message, and meant that this message was sent from another organization.

(2) @ [organizational username]. Term appeared at the end of the message, and meant that this message was to another organization.

Attributes of funding source and jurisdiction as well as the real identity of the verified accounts and numbers of followers were also coded from the web pages of the verified accounts. In the political context of China, we classified funding sources into five categories: public, private, nonprofit, state-owned, and public institution. For example, companies such

as China Telecom are a part of the institutional response system, but it is not completely public or private; the China Central Television (CCTV) is also a part of the institutional response system, but it is not completely public or nonprofit.

If two or more verified accounts stand for the same organization, they will be treated as one organization.

We compared this network with the response network defined in emergency response plans to see how social media expand the response network to adapt to the disaster situation, and with the response network on the ground to find out to what extent social media facilitate adaptation of organizations.

6. Data Analysis and Findings

6.1 Roles of Organizations in information dissemination

Table 1 indicates that the verified accounts are much more capable of disseminating information than the unverified accounts at a 99.99% significance level. Further, although the highest retransmission of the unverified accounts reaches 454,783, it was actually a funny story telling how a student evacuated with his tortoises. Four messages by the unverified accounts were retransmitted more than 100,000 times, and the one with highest retransmissions was actually irrelevant to the ESFs. By contrast, among the messages by the verified accounts, there were 25 messages with retransmissions higher than 100,000 times and all related to the ESFs.

Table 1 Comparison of transmissions between verified accounts and unverified accounts

	N	Maximum	Minimum	Sum	Average
Verified Accounts	4,203	506,924	1	15,538,044	3,697
Unverified Accounts	3,889	454,783	1	3,155,394	811
Mean Test	F=66.601, DF=1, Sig=0.000				

Among the verified accounts, Table 2 shows that there is no a significant difference in capacity of information dissemination between the verified organizations accounts and the verified persons accounts; although the average number of retransmissions by the latter is a little higher than the former.

Table 2 Comparison of retransmissions between organization accounts and person accounts

	N	Maximum	Minimum	Sum	Average
Organization Accounts	2,339	506,924	1	8,384,932	3,838
Person Accounts	1,864	494,743	1	7,153,112	3,584
Mean Test	F=0.162, DF=1, Sig=0.687				

Finding 1: Organizations played an important role in disseminating information in Sina Weibo

immediately after the Ya'an Earthquake.

6.2 How do organizations engage citizens to respond adaptively?

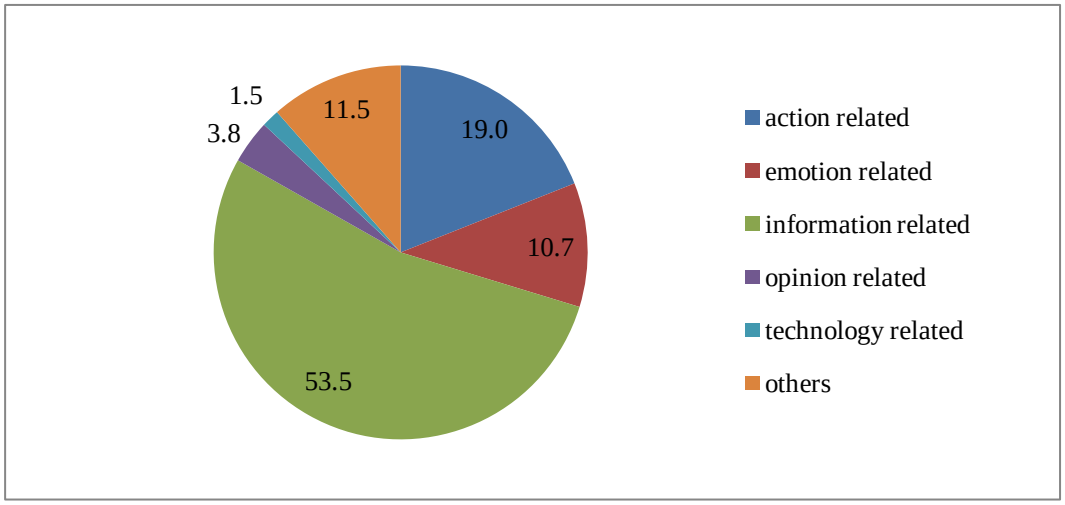


Figure 2 Information Categories

Figure 2 shows the categories of information generated by the verified organization accounts. There are 53.5% of the messages are information related, 19.0% are action related, and 72.5% of the messages are related to emergency response in total.

Among the messages related to emergency response, Figure 3 indicates that 43.8% are about information release, 12.6% are about social mobilization, 5.1% are about command and coordination, 5.0% are about relief and settlement, 4.8% are about search and rescue, and 4.4% are about assessment. In total, among the messages of information related and action related, 75.7% of the messages are core information significantly related to the ESFs.

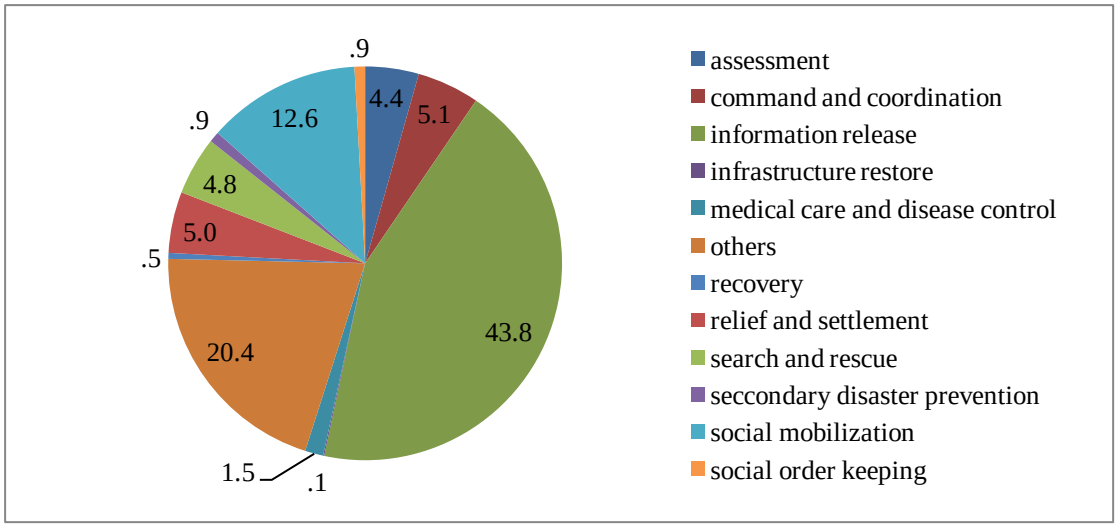


Figure 3 Core information of organizations engaging citizens

Table 3 summarizes the sub-topics of the core information and their percentages. The sub-topics demonstrate how the core information facilitates the adaption of individuals and organizations.

Table 3 Sub-Topics of the major ESFs

Major ESFs	Sub-Topics
Information Release	(1) Situation Update (54.0%); (2) Response Strategies (37.5%); (3) Rumors Clarifying (2.2%); (4) Contact Information (2.0%); (5) Others (4.3%)
Social Mobilization	(1) Donation Mobilization (63.5%); (2) Volunteer Recruitment (29.0%); (3) Others (7.5%)
Command and Coordination	(1) Transportation Coordination (58.1%); (2) Volunteer Coordination (23.3%); (3) Communication Coordination (10.5%); (4) Others (8.1%)
Relief and Settlement	(1) People Searching (90.6%): (2) Others b (9.4%)
Search and Rescue	(2) Rescue Knowledge (56.8%); (2) Help Seeking (35.8%); (3) Others (7.4%)
Assessment	(1) Living situation (51.8%); (2) Call for feedback (37.0%); (3) Others (11.2%)

In an information release, "@ Ya'an Lushan Earthquake Response V", on behalf of the Chengdu Military Earthquake Response Command Headquarters, informed their followers of the strategies that the military had adopted. This was the first time that the military forces disclosed information of responding to earthquake through social media in China. This account had 180,218 followers, which facilitated retransmissions of one of its messages to reach 46,548. Similarly, both private sector and nonprofit organizations updated their response strategies on-line. All of these strategic information messages are essential for individuals and other organizations to adopt or adjust their own response strategies.

In social mobilization, messages were published and retransmitted for not only calling for donations, but also stopping donations if some kinds of resources were sufficient. It significantly facilitated the efficiency of managing donations, as well as ensuring that donations met urgent needs.

In command and coordination, inexperienced volunteers were advised not to participate in on-site rescue for their own safety and difficulties in coordination. In particular, because the Chengya Highway (from Chengdu to Ya'an) was the only transportation lifeline for the affected areas, its traffic situation was given extra attention. Many messages were generated or retransmitted to advise nonessential vehicles not to enter the Chengya Highway to prevent it from becoming overcrowded and impassable. Also, people were asked not to make phone calls to save bandwidth on the damaged telecom system for rescue communications.

In relief and resettlement operations, information technology companies including Sina, Baidu, Google, Sohu, and 360 all set up their own on-line people searching information

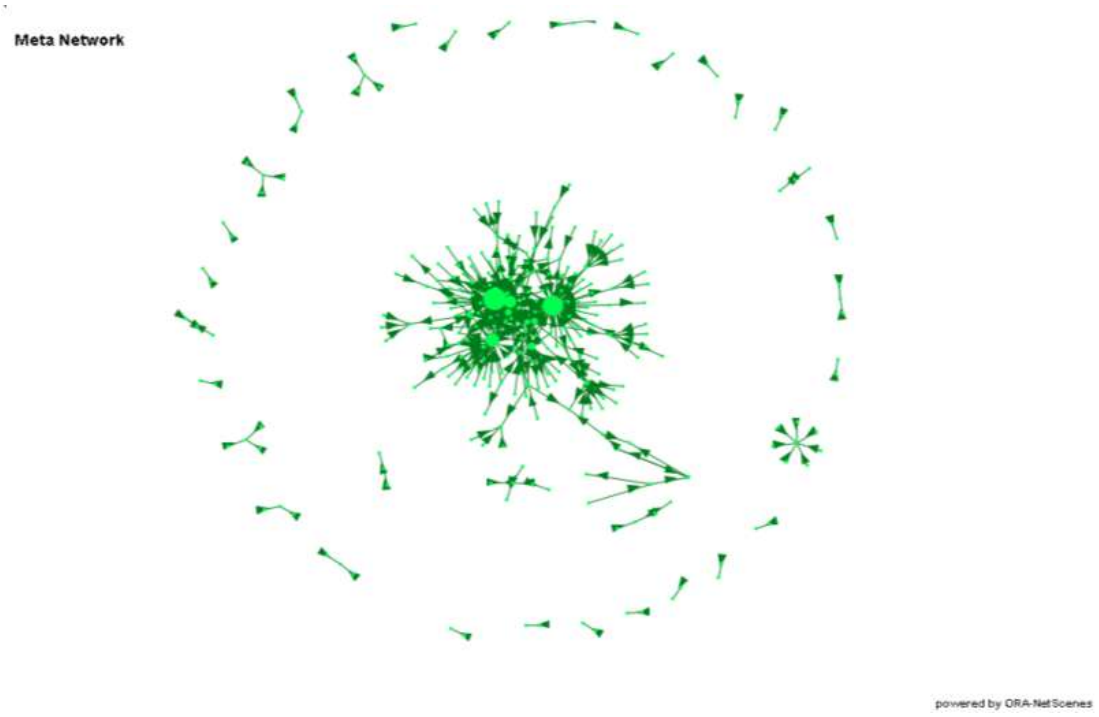
systems and allowed access to sharing data for the first time. It was more convenient than traditional methods of missing persons search and reduced the workload of institutional organizations in charge of relief and settlement.

In search and rescue, Baoxing County, which had been ignored in the initial stage of response, was given attention for its heavy damage in Sina Weibo. It was helpful to allocate search and rescue forces more effectively.

In assessment, "@ China Rescue V", the official account of China international Search and Rescue Team, sent the first message on occurrence of the Ya'an Earthquake on 8:02 am, April 20, 2013 to mobilize its followers to report locations, feelings, and damage. This message was retransmitted 506, 924 times ranking as the highest. Feedback from local residencies and organizations would be greatly helpful for the governments to assess the damage and distribute resources according to the degree of damages and specific locations.

Finding 2: 1) Sina Weibo provided core information in the disaster context so that organizations could engage citizens to respond adaptively to needs for information release, social mobilization, command and coordination, relief and settlement, search and rescue, and assessment. 2) The percentage of core information is not very high.

6.3 Emergence of communication networks among organizations



Note: Node sized by total degree centrality

Figure 4 Communication network among organizations

Figure 4 visualizes the communication network among organizations in the database. It

represents 344 links among 289 nodes. There are 38 (13.2%) public organizations, 73 (25.3%) private companies, 61 (21.1%) nonprofit organizations, 101 (34.9%) state-owned companies, and 16 (5.5%) public institutions.

Key links emerged between Sina Company and China Earthquake Administration (link value=20.00), Chengdu Municipal Government and China Earthquake Administration (link value=11.00), Chengdu Business Daily and China Earthquake Administration (link value=9.00), Huaxi City Daily and China Earthquake Administration (link value=8.00), and China Central Television and China Earthquake Administration (link value=5.00). These links emerged between government agencies and private sector, state-owned companies and nonprofit organizations.

Table 4 summarizes the key nodes in the communication network ranking by total degree centrality, betweenness centrality, and eigenvector centrality. These nodes are all types of organizations.

Table 4 Key nodes of the communication network

	Total Degree Centrality		Eigenvector Centrality		Betweenness Centrality	
	Organization	Value	Organization	Value	Organization	Value
1	China Earthquake	0.008	China Earthquake	0.911	Sina Company	0.040
2	Sina Company	0.007	Sina Company	0.720	People Daily	0.027
3	People Daily	0.004	Chengdu Government	0.375	China Central Television	0.027
4	China Central Television	0.004	People Daily	0.324	China Earthquake	0.022
5	CD Business Daily	0.002	CD Business Daily	0.312	Xinhua News Agency	0.013
6	Chengdu Government	0.002	China Central Television	0.300	China News Agency	0.009
7	Huaxi City Daily	0.002	Huaxi City Daily	0.291	Chengdu	0.008
8	Xinhua News Agency	0.002	Xinhua News Agency	0.212	Guangzhou Daily	0.004
9	One Foundation	0.001	China News Agency	0.082	Sohu	0.004
10	China News Agency	0.001	Chongqing Times	0.072	Sichuan Telecom	0.004

(1) Total degree centrality is calculated on the number of connections a node has. (2) Betweenness centrality measures the potential influential of a node that connects nodes that are otherwise not connected in the network. (3) Eigenvector centrality measures the key nodes in a network that link to other nodes that have many connections.

Figure 5 indicates that, among 435 communications in the network, organizations

communicate with each other for the ESFs of information release (62.29%), social mobilization (13.19%), command and coordination (8.49%), relief and settlement (6.43%), assessment (3.21), and search and rescue (3.21%).

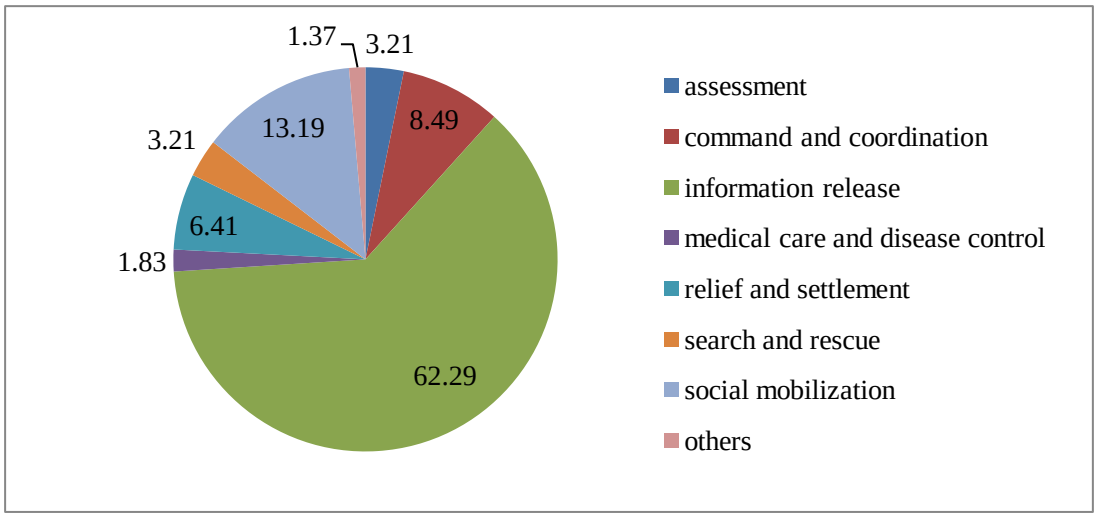
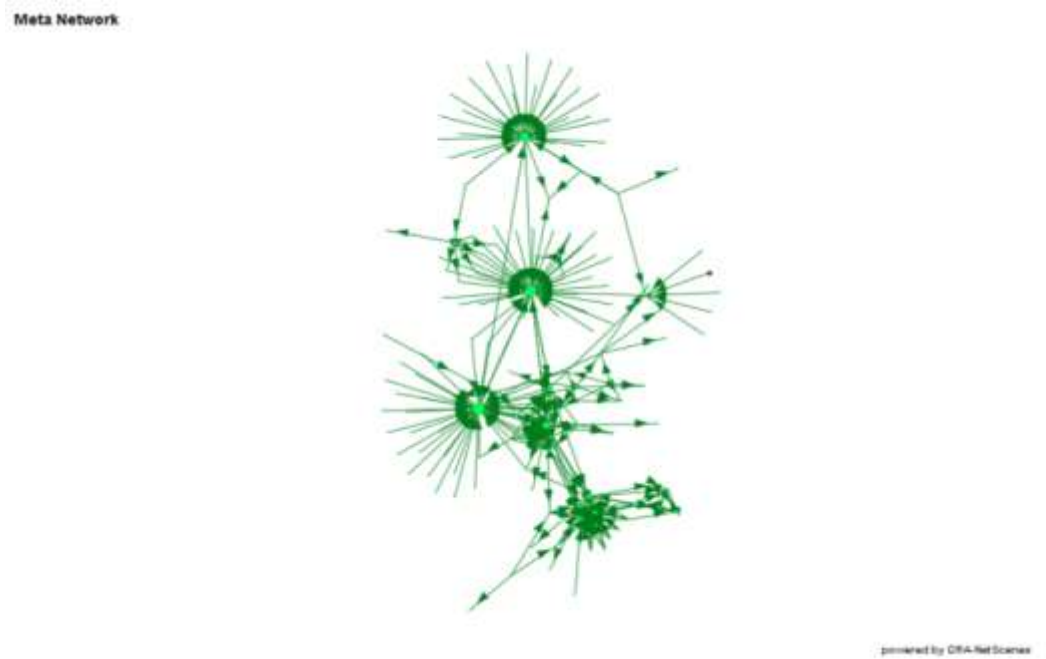


Figure 5 Core information in the communication network

Figure 6 visualizes the response network defined by the relevant emergency response plans. It represents 279 links among 155 nodes.



Note: Based on the NEERP (revised on August 28, 2018); Sichuan Earthquake Emergency Response Plan (revised on April 9, 2012); Ya'an Earthquake Emergency Response Plan (revised on March 15, 2012); Lushan County Emergency Response Plan (Revised on October 14, 2012).

Figure 6 Response network defined by the earthquake response plans

Key links emerged between China State Council and China State Administration (link value=3.00), China Earthquake Administration and China National Emergency Rescue Team (link value=2.00), Sichuan Provincial Government and China Earthquake Administration (link value=2.00), Sichuan Provincial Government and Sichuan Command Headquarters (link value=2.00), Sichuan Civil Affairs Department and Sichuan Earthquake Administration (link value=2.00), Sichuan Provincial Government and Sichuan Earthquake Administration (link value=2.00), and Ya'an Municipal Government and Ya'an Earthquake Administration (link value=2.00). All links emerged among governmental agencies.

Table 5 summarizes the key nodes in the response network defined in the emergency response plans by total degree centrality, betweenness centrality, and eigenvector centrality. Key nodes are all governmental agencies.

Table 5 Key Organizations identified in the emergency response plans

	Total Degree Centrality		Eigenvector Centrality		Betweenness Centrality	
	Organization	Value	Organization	Value	Organization	Value
1	Sichuan Command	0.055	Sichuan Command	0.651	Ya'an Government	0.071
2	Ya'an Government	0.053	Sichuan Government	0.524	Sichuan Earthquake	0.039
3	Lushan Government	0.038	Sichuan Earthquake	0.405	China Earthquake	0.031
4	Sichuan Government	0.028	Sichuan Civil Affairs	0.379	Sichuan Government	0.030
5	China Earthquake	0.025	China Earthquake	0.305	Lushan Government	0.030
6	Sichuan Earthquake	0.020	Ya'an Government	0.266	China Armed Police	0.006
7	Sichuan Civil Affairs	0.018	Sichuan Transportation	0.260	Ya'an Earthquake	0.005
8	China State Council	0.014	Sichuan Water Resources	0.249	China Fire Fighting	0.004
9	China Police	0.014	Sichuan Construction	0.248	Sichuan Transportation	0.003
10	China Civil Affairs	0.013	Sichuan Safety	0.247	Sichuan Civil Affairs	0.002

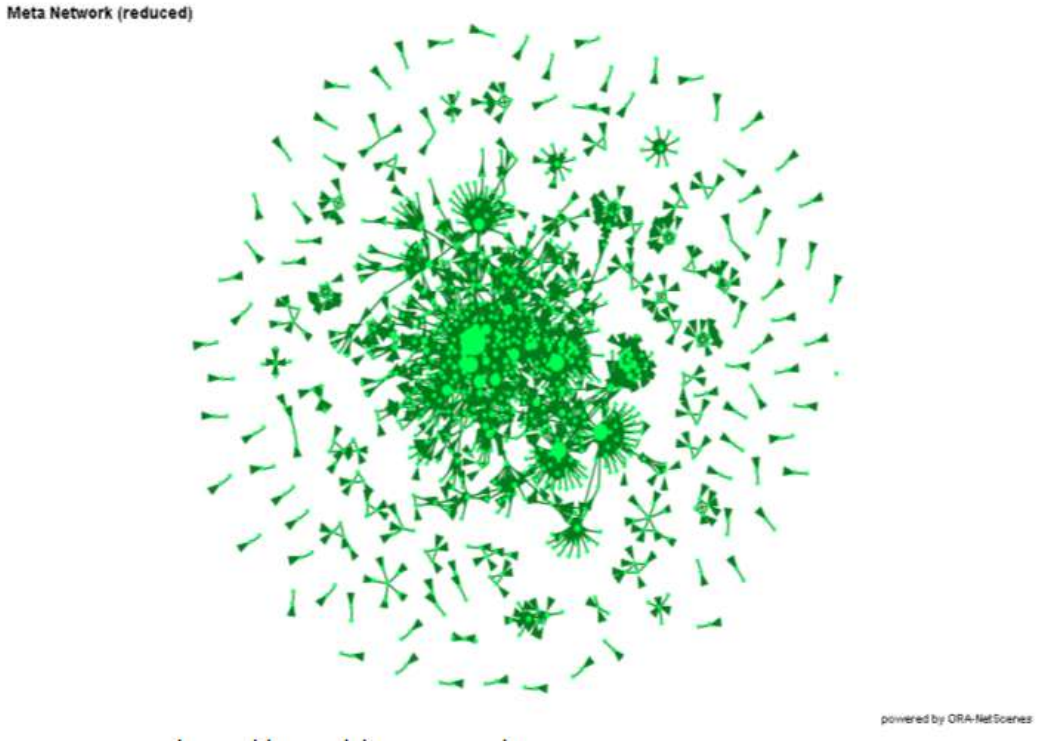
Finding 3: 1) By comparing these two networks, Sina Weibo expanded the response network from institutional organizations to non-institutional organizations including private sector, state-owned companies, and nonprofit organizations, and traditional media were very adaptive in using social media disseminate information. 2) The percentage of core information in the context in the communication among organizations is also not very high. 3) The percentage of public organizations in the communication network is low.

6.4 To what extent social media does facilitate the actual response network?

Figure 7 visualizes the response network on the ground. It represents 1,543 links among 981

nodes.

Key links emerged between Sichuan Provincial Government and Sichuan Civil Affairs Department (link value=6.00), China Mobile and China Industrial and Information Technology Ministry (link=value=5.00), China Meteorology and Sichuan Meteorology, Sichuan Provincial Government and Sichuan Command Headquarters (value=4.00), Sichuan Provincial Government and Sichuan Health Department (link value=4.00), PLA Chengdu Military Regional Command Center and Chengdu Military Air Force (link value=4.00), Sichuan Provincial Government and Sichuan Armed Police (link value=4.00), and China Earthquake Administration and Sichuan Earthquake Administration (link value=4.00). All key links are between governmental agencies.



Note: Node sized by total degree centrality

Figure 7 Response network on the ground

Table 6 summarizes the key nodes in the actual response network ranking by total degree centrality, betweenness centrality, and eigenvector centrality. Key nodes include governmental agencies, privates sector, and nonprofit organizations.

Table 6 Key organizations in the response network on the ground

	Total Degree Centrality		Eigenvector Centrality		Betweenness Centrality	
	Organization	Value	Organization	Value	Organization	Value
1	Sichuan Government	0.009	Sichuan Government	0.743	Sichuan Government	0.052

2	One Foundation	0.005	Sichuan Civil Affairs	0.454	Sichuan Health	0.039
3	China Health	0.005	Sichuan Command	0.404	Tencent Foundation	0.026
4	China Poverty Alleviation Foundation	0.005	Sichuan Armed Police	0.328	China Poverty Alleviation Foundation	0.023
5	Sichuan Command	0.004	Sichuan Health	0.323	One Foundation	0.018
6	Sichuan Civil Affairs	0.004	Sichuan Communication	0.321	China Health	0.014
7	Ya'an Government	0.003	Sichuan Transportation	0.253	Ya'an Government	0.011
8	China Red Cross Society Foundation	0.003	Sichuan Construction	0.244	Sina Company	0.011
9	Sichuan Health	0.003	Sichuan Fire Fighting	0.244	China Youth Development Foundation	0.010
10	China Earthquake	0.003	Sichuan Land Resource	0.232	Sichuan Armed Police	0.010

Finding 4: 1) Although so far we don't know exactly how the communication in Weibo facilitates the actual collaborations on the ground, we may infer from the comparison of key nodes and key links among these three networks to draw the conclusion that Sina Weibo may foster trust among governmental agencies, private sectors, and nonprofit organizations, and then contribute to collaboration among them. As a result, private sector and nonprofit organizations are also important nodes in the response network on the ground. 2) However, the core information defined in the structure in Sina Weibo was very different from the core information defined in the structure in the response network on the ground, and it limited the leverage of the core information in context in Weibo and the role of Weibo played in facilitating adaption.

7. Conclusions and Discussions

Returning to the five questions stated above (p. 2), we summarize our findings from this analysis regarding the emergence of social media in disaster response operations in China.

1. *What roles do social media play in responding to extreme disasters in China?* In general, social media can be complementary to institutional response system in extreme disasters: First, in the centralized political system of China, governmental agencies still play the dominant role in the emergency response network. Second, social media are complementary at two levels: at the community level, social media can facilitate organizations to engage citizens to participate in response adaptively; at the organization level, social media expand response

operations to private sector and nonprofit organizations. Third, the complementary role of social media that play is particular important in the initial stage when the traditional communications system failed.

2. *How do social media contribute to the adaptation of emergency response in China?* First, at the community level, social media can improve the self-organization of citizens' participation in emergency response. Citizens' participation brings resources, which the institutional response system may not provide in the urgent situation; a massive number of individuals responding to a disaster are very difficult to coordinate. In the centralized political system of China, civil society is weak. The strict regulation on registration limits the development of nonprofit organizations. As a result, citizens' participation is mostly isolated and disorganized. This lesson has been found in the response operation of the 2008 Wenchuan Earthquake and the 2010 Yushu Earthquake.

According to China State Council (2009), in the 2008 Wenchuan Earthquake, volunteers involving ground response exceeded three million and the volunteers working on remote support service reached ten million. How to organize these volunteers posed a huge challenge to the institutional response system in urgent situations. In the 2010 Yushu Earthquake, the government had to rescue a large number of volunteers because they did not have the equipment or skills for operations in high altitude regions. Now, social media offer a solution capable of both leveraging the participation at community level and enabling volunteers to become more self-organized. It is particularly important in the context of China, given the condition that nonprofit organizations are not yet strong in improving citizens' self-organization.

Second, at the organization level, social media greatly expand the response network from the institutional system to the non-institutional system in extreme disasters. It increases the diversity of the response network and contributes to the adaptation. In the context of China, the state owned companies and public institutions were originally separated from the government, so they were actually included in the institutional response system that has been initiated since the 2003 SARS Epidemic. However, private sector and nonprofit organizations have been excluded. Now social media provide a platform to allow the governmental agencies, private sector, and nonprofit organizations to communicate with each other across sector boundaries. This on-line interaction builds trust among them and may contribute to collaboration on the ground.

3. *Why are social media able to facilitate adaptation in emergency response in China?* First, social media are more robust than traditional communication systems. Internet is technically resilient from earthquake damage because it has many routes to bypass damage, even when some optical cables are disconnected. This has been observed in the 2011 Great East Earthquake in Japan (ICHIGUCHI, 2011; KAIGO, 2012) and the 2012 Hurricane Sandy in the US (Chatfield et al., 2014). Second, social media constitute more powerful communication tools in contrast to other communication technologies. They enable real time information exchange and data sharing on a large scale. Third, the feature of verified accounts

facilitates organizations as influential as public figures such as film stars in disseminating information. This is an interesting finding in the context of China. It is different from findings that the lack of followers limits the governmental agencies' capacity of information dissemination base on the data from twitter in other contexts (Miyabe et al., 2012; Wukich and Steinberg, 2014).

4. *What are the drawbacks in the uses of social media in facilitating adaptation of emergency response?* First, the percentage of core information in the context, either at the levels of community or organization, is not very high. It limits the leverage of the core information. Second, the governmental agencies are not as adaptive as traditional media, private sector and nonprofit organizations. As a result, the core information is not being used among critical nodes and bridges of the network. It restrains social media contributions in facilitating adaptation of the response network on the ground. Third, information overload also limits the efficiency in using social media in emergency operations (Hiltz and Plotnick, 2013).

8. Policy Recommendations

1. Users' training. It would be helpful to increase the percentage of core information in the context at both the community and organization level. Users need to know what the ESFs are, what messages are useful for the ESFs, and how to send messages related to the ESFs.

2. Government involvement. Although many public agencies have registered accounts in social media, only some of them are as active as private sector and nonprofit organizations. Particularly the public organizations, which are the critical nodes that are defined in the emergency response plans and the response network on the ground, should be more active in Weibo. This strategy can increase the percentage of core information in the structure and contribute to actual collaboration among organizations on the ground.

3. Applications popularizing. More applications should be designed via social media to facilitate adaptation to extreme disasters. These applications should aim not only at teaching users how to disseminate core information in both the context and the structure, but also in filtering information to reduce the information over load and leverage the core information more effectively.

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