Social Media in Emergency Management: Twitter as a Tool for Communicating Risks to the Public

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Abstract

One of the main challenges of emergency management lies in communicating risks to the public. On some occasions, risk communicators might seek to increase awareness over emerging risks, while on others the aim might be to avoid escalation of public reactions. Social media accounts offer an opportunity to rapidly distribute critical information and in doing so to mitigate the impact of emergencies by influencing public reactions. This article draws on theories of risk and emergency communication in order to consider the impact of Twitter as a tool for communicating risks to the public. We analyse 10,020 Twitter messages posted by the official accounts of UK local government authorities (councils) in the context of two major emergencies: the heavy snow of December 2010 and the riots of August 2011. Twitter was used in a variety of ways to communicate and manage associated risks including messages to provide official updates, encourage protective behaviour, increase awareness and guide public attention to mitigating actions. We discuss the importance of social media as means of increasing confidence in emergency management institutions.

1. Introduction

When Hurricane Sandy hit the east coast of the United States in late October 2012, the popular microblogging application Twitter was extensively used as a hub of timely information provision to help people stay informed and safe. Public authorities such as the New York Fire Department were able to provide essential support and even target the rescue of victims through the effective use of their Twitter account (CNN, 2012). This is only one of the highly visible cases where the immediacy of Twitter has proven valuable in emergency communication; others include tsunamis, floods and man-made violent incidents like terrorist attacks or food contamination (Al-Saggaf and Simmons, 2014; Gaspar et al., 2016; Heverin and Zach, 2012; Oh et al., 2013). Twitter Alerts (2015), the network's official warning system launched in 2013, helps users

receive official emergency alerts from registered authorities such as police forces, ambulance services, meteorological and environment agencies.

As a major technological innovation of recent years, social media applications have reshaped the nature of digital information sharing and networking. As part of this, they have come to function as spaces where both officials and citizens seek to interpret emergency situations and intervene accordingly (e.g. Macias et al., 2009; Neubaum et al., 2014; Palen et al., 2010). The relevance of social media has become evident in different aspects of communication before, during and after emergency events with Comfort et al. (2012, p. 547) noting that channels like Twitter and Facebook 'are being rapidly integrated into disaster environments and warrant systematic study of their viability in support of improved public response'. Compared to previous work in information and knowledge management applications for emergency support (e.g. Dorasamy et al., 2013), social media have created much more open and ubiquitous information flows between authorities and the public. This is one of the reasons why Turoff et al. (2013) more specifically suggest that social media merit further attention with regard to their potential to engage with the public during emergencies.

This paper focuses on the role of social media in communicating risks to the public during emergency events. Management of risk to the public is one of the main major challenges in emergency communication. It involves diverse strategies in terms of gathering information, setting standards and enforcing or suggesting particular behaviours to mitigate risks (e.g. Lodge, 2009; Mileti, 1999; Sellnow and Seeger, 2013). Risk communication requires providing timely and reliable information to signal that authorities have the situation under control. Using this information, community members interpret emergency risks and make decisions about their own actions (Comfort, 2007; Kapucu, 2008). As a result, on some occasions, risk communicators might seek to increase awareness over emerging risks and alert the public, while on others the aim might be to reduce uncertainty and avoid escalation of reactions (Smith and McCloskey 1998; 't Hart, 2013).

This challenge is increasingly addressed using social media platforms like Twitter. Within the technical confines of the particular social media platform being used, planning is required that attends to, anticipates and integrates increased levels of public engagement as well as framing risk messages that are attuned to public perceptions of the issue. Although studies have shown the importance and relevance of social media in emergencies, there is much to learn about how social media technologies enable – or constrain – risk communication and how they might best be deployed at different stages in the development and management of a crisis.

To situate our consideration of how social media can be used to communicate during emergency events, we draw on two theoretical perspectives in risk and emergency communication: the Social Amplification of Risk Framework (SARF) (Kasperson et al. 1988) and the Crisis and Emergency Risk Communication model (CERC) (Reynolds and Seeger 2005). The combination of these perspectives facilitates an integrated consideration of risk communication themes and

message framing (SARF) with the different emergency stages and risk reduction strategies suggested by CERC.

The empirical part of the study focuses on the use of Twitter by local government authorities in the UK during the heavy snow of December 2010 and the summer riots of August 2011. These two high-impact emergencies of national reach required different types of responses from local government authorities (LGAs: known as councils in the UK). In December 2010, adverse weather over a long period of time required constant alertness to increase and maintain awareness of a range of risks. In the 2011 riots, authorities had to deal with uncertainty while actively attempting to reduce the effects of public disorder. Following an analysis of 8,274 LGA tweets from the 2010 snow and 1,746 from the 2011 riots, we identify the risk communication strategies that were used to influence public perception and actions as events unfolded during the two emergencies. On the basis of this analysis, we identify the scope and limitations of communicating risks to the public using social media. First, we outline the relevant literature and theoretical perspectives on emergency and risk communication.

2. Emergency management, risk communication and social media

Emergency management deals with a wide range of events that are unexpected, undesirable, disturb everyday life and affect a large number of people (Boin and 't Hart 2010). Examples range from weather-related incidents (e.g. floods, fires) to transportation accidents, intentional events and civil disorders. Emergency management research has focused on issues such as inter-organisational coordination, integrated planning risk mitigation, response and recovery, as well as how community resilience can be developed and sustained (Comfort et al., 2012, 2010; Zulean and Prelipcean, 2013).

Relevant to several of these areas, communicating with the public during emergencies is a research domain in its own right. When unexpected events occur, there is high demand for information from the media, and from publics that may be affected, engaged or simply observing. Channels of timely, actionable and reliable information are of vital importance, especially in situations that involve high fear and uncertainty (Horsley and Barker 2002; Ansell et al. 2010). For information flows and high transparency to be established during emergencies, an open and flexible approach to communications is required (Harrald 2006; Somers and Svara 2009). However, lack of time, limited resources, inter-organisational barriers and coordination difficulties commonly hinder organisations' ability to meet the challenge (Hale 2005; Ansell et al. 2010). Alongside dealing with the actual events of an emergency, public organisations are increasingly required to exhibit transparency in the use of resources and manage expectations about how they are dealing with a situation (Henstra, 2010). It is in this context that social media have become increasingly part of the armoury of communication practitioners.

2.1. Social amplification of risk

Organisational communication in emergencies in part will be shaped by the imagined characteristics and requirements of those to whom communications are directed (Barnett et al., 2012). Such perceptions influence responses by authorities and the framing of risk messages. For example, one characteristic often attributed to the public - for which in fact there is little evidence - is that people are likely to panic in response to a warning (Mileti and Peek, 2000). The Social Amplification of Risk Framework (SARF) focuses on the discrepancies between public, stakeholder and organisational appraisals of risk events. The frequent lack of alignment between expert assessments of the situation and those of key actors constitute one of the major challenges in risk communication that SARF seeks to explain (Kasperson et al. 1988; Pidgeon et al. 2003).

SARF was developed in order to systematise the findings of a disparate risk perception and communication literature and in particular to help explain why patterns of socio-political attention that surround a risk event are often of a different order (both in terms of the focus of that attention and its scale) than experts consider to be warranted. Thus, hazard events may attract considerable social attention and expressions of concern by publics, media or stakeholders yet experts may consider them to present a low risk (risk intensification) and, conversely, hazards designated as serious by experts might receive comparatively little attention (risk attenuation). SARF makes it clear that both individuals/experts, organisations as well as informal interactions can serve as 'stations of amplification' as they communicate in ways that may intensify or attenuate risk signals (Brenkert-Smith et al., 2013) or may indeed simply 're-present' them (Breakwell and Barnett, 2003). Although organisations, viewed within SARF as social stations of amplification, cannot predict the impact of a risk message during emergencies, they need to accommodate diverse communication needs. They may view the nature of public concern and behaviour to warrant alerts about what are seen as emerging risks, seek to raise concern and generate action or seek to reduce uncertainty and avoid the escalation of reactions (Smith and McCloskey 1998; 't Hart, 2013). Renn (1991) notes that in seeking to communicate risk, institutions frame messages using a combination of factual (simple information dissemination), inferential (inferring or directly mandating particular behavioural responses) and other more specialised components (e.g. value-related or symbolic that have particular meanings within a community).

SARF provides a broad backdrop against which to consider organisational preparedness, highlighting the often wanted consequences of risk amplification (i.e. intensification or attenuation), and the required adaptation in the communication strategies of risk managers that are required as the flow of public and stakeholder actions are seen to exemplify amplification processes. However, SARF does not specify what characteristics of the information flow around an event are indicative of managerial competence, even though it is recognised as a major determinant of both public behaviour and of the broader impacts of the event (Burns et al. 1993; Rickard et al. 2013). To more fully consider these indicators of competence, we turn to a second framework: the Crisis and Emergency Risk Communication model (CERC) (Reynolds and Seeger, 2005).

2.2. The Crisis and Emergency Risk Communication model

The Crisis and Emergency Risk Communication (CERC) model was developed by the Centers for Disease Control and Prevention as a tool to structure and manage risk communication activities during public health emergencies (Reynolds & Seeger 2005). CERC is a crisis communication model that provides good connection to practice, even though it assumes a rather straightforward approach to how a crisis unfolds (Sellnow and Seeger, 2013). The strength of CERC as a guide for risk managers is evident in the links it makes between the common stages of a crisis and elements of good practice for communicating risks during each stage. The model also emphasises the importance of activities to transfer lessons from each individual emergency to the improvement of crisis response capabilities and public confidence in them. Table 1 shows the model's stages and associated elements of good practice, adapted from Reynolds and Seeger (2005, p.52). It is an essential adjunct to SARF in framing the research perspective in this paper as it provides a set of indicators of good communication and managerial competence that are structured in relation to the stages of a crisis.

In a further development and elaboration of the model, Veil et al. (2008) emphasise that since crises affect a wide variety of publics with diverse needs and resources, CERC is useful because it allows for flexibility in which risk reduction strategies a particular situation at a particular time might demand. Rickard et al. (2013) more explicitly contend that the combination of SARF and CERC can be helpful for considering not only the origin of risk management crises but also how using appropriate risk reduction strategies may help to resolve these. Here SARF offers a useful frame to understand which risk events may result in intensification or attenuation and why, while CERC offers guidance on how organisations can influence the course of a risk event. An early assessment of what might affect patterns of risk intensification or attenuation and appropriate management actions may limit the extent of crises or at least facilitate their smooth resolution (Rickard et al., 2013).

Emergency stages	**Communication aims and good practice**
Precrisis	– Monitoring and recognition of emerging risks – Warnings regarding eminent threats and precautionary messages – Changes in behaviour to reduce likelihood of harm – Development of recommendations by experts and first respondents
Initial event	– Reduce uncertainty and emotional turmoil – Establish official sources of information – Announce anticipated outcomes – Improve understanding of self-efficacy and personal response activities (what to do and how to get more information)
Maintenance	– Facilitate more accurate understanding of ongoing risk, background factors and issues – Support and cooperation with response and recovery efforts

Emergency stages	Communication aims and good practice
	– Feedback from the public and correction of any misunderstandings/rumours – Ongoing uncertainty reduction, re-iteration of self-efficacy and personal response activities from the previous stage
Resolution	– Inform about recovery and rebuilding efforts – Improve public understanding of new risks and risk avoidance behaviours – Facilitate discussion and resolution of issues regarding responsibility, blame and adequacy of response – Promote the activities and capacities of emergency organisations to reinforce positive identity and image
Evaluation	– Assess responses and communication effectiveness – Document, formalise and communicate lessons learnt – Create linkages to precrisis activities – Determine actions to improve crisis response capabilities

Table 1: Crisis and Emergency Risk Communication model (Reynolds & Seeger, 2005, p.52).

2.3. Social media in emergency and risk communication

Empirical work framed in terms of SARF or CERC has barely attended to the role of social media in communicating and managing risks. Within SARF, traditional media are a key social station of risk amplification and there is broad agreement as to which characteristics of an issue are most likely to attract media attention (Pidgeon and Barnett, 2013). However, the use of social media represents a step change in how organisations can communicate about risk and in crisis situations. Although it has long been emphasised that risk communication is a two-way process (e.g. Pidgeon, et al., 2003), the advent of social media turns this principle into clear practical reality: organisational messages can be supplemented, contested and reproduced (or not) far beyond their original intended audience.

Indeed, early assessments of social media in risk communication have noted that new issues can be uncovered and quickly result in intensification or attenuation before organisations are able to react or guide to desired actions (Chung, 2011; Veil et al., 2011). Jung and Park (2014) map the dynamic evolution of risk communication networks where intermediary actors clearly act as stations of amplification in terms of diffusing information and mitigating the impact of an outside attack. Al-Saggaf and Simmons (2014) further show how amplification on social media can even escalate from crisis incidents to issues of political accountability and blame.

Incorporating a consideration of the deployment of social media around risk and crisis communication by stakeholders and publics represents a considerable research agenda. This would need to attend to, for example, how social media enable organisations to communicate directly with citizens and the impact of doing so, the role of individual citizens in communicating

risk (perhaps requiring a more differentiated picture of individual stations of amplification), how traditional media interacts with social media, and, of particular interest to this paper, how particular features of social media platforms enable – or constrain – risk communication and how they might best be deployed at different stages in the development and management of a crisis.

There has been a great deal of work that focuses on the role of social media and crisis communication more generally as noted in early reviews of this area (Rains et al., 2014; Veil et al., 2011; Wendling et al., 2013) and the role of microblogs in this has received sustained attention with Twitter being highly influential and distinctive. Twitter started in 2006 as a brief announcement service where users could follow others (with 'following' not being a reciprocal relationship). Twitter's conversational features were gradually established to support user interactions and the structuring of information (e.g. Marwick and Boyd, 2011). First, users are enabled to directly address other users or refer to them in conversations using the symbol '@ (e.g. @XXX). Second, users can 'retweet' or reproduce another user's message in its original or modified form. Third, users can follow streams of updates through keywords which are thematically organised around the symbol '#' (hashtag), which is self-assigned to messages by users themselves (e.g. #LondonRiots). In addition, tweets often contain media content or hyperlinks to other material.

Due to these features, Twitter has radically changed the way emergency information is socially distributed. Without replacing traditional media sources, Twitter has become a virtual space where many Internet users turn to seek emergency details; tweets might even come from users from the epicentre of disasters such as earthquakes (Murthy, 2013). During events that draw attention, tweets can be propagated on the ad hoc networks of users and quickly reach outside previously established relationships (Marwick and Boyd 2011). Network effects are facilitated by one-click actions like replies and retweets, or evolve around unmediated conversations enabled by hashtags. As a result, large scale computational techniques applied on Twitter data can be useful to detect unexpected incidents and overview public reactions or the mobilisation of emergency response networks (Burnap et al., 2013; Jung and Park, 2016).

Despite warnings that such interactions might be simply about rapid distribution of factual information (Helsloot and Groenendaal, 2013), the relevance of Twitter in emergency and risk communication has been evident. For example, Twitter can be used for collective sense-making during civil unrest incidents (Heverin and Zach 2012), as a warning tool in natural disasters (Chatfield et al., 2013) or as means of coping with the stressful effects of a food contamination incident (Gaspar et al., 2016). Emergency activity on Twitter that starts with factual information can involve waves of public reaction that directly impact ongoing events, especially when they involve high uncertainty. Despite assumptions that the spreading of rumours might lead to intensified risk perceptions, most emergency information on Twitter has been found to be of high quality; untrue rumours are likely to be dismissed by other users and not spread disproportionally (Guardian, 2012). Using rumour theory, Oh et al. (2013) established that it is not ambiguity in the content of tweets that results in rumours but rather ambiguity about the source or the context. Rumour may also be associated with unwanted attenuation of risk perceptions if, for example it

drew attention away from officially sanctioned positions like the cause of food contamination or the treatment of subsequent illness (Gaspar et al., 2016). If faced with an inappropriate lack of concern, authorities would then wish to correct this analysis and intensify, or perhaps more accurately, de-attenuate, by ensuring that proportionate attention and concern was linked to appropriate actions and levels of vigilance.

Therefore, from the perspective of SARF, the use of Twitter by those responsible for risk management can have a role in the intensification or attenuation of risk-related messages and are aimed at encouraging officially sanctioned actions. Previous studies have mainly looked at these effects using tweets, the relevance of which is assigned in respect of the presence of keywords or hashtags (e.g. Gaspar et al., 2016; Heverin and Zach, 2012). Such evaluations can shed light on public perceptions of risk and risk amplification processes during major events like pandemics (Chew and Eysenbach, 2010). The approach in the current study has been to analyse all the Twitter communications made by particular actors and, in line with CERC, the focus of attention is on how Twitter is used to communicate, the nature of this communication and how this varied at different stages of a crisis.

3. Research approach

To empirically investigate the use of social media to communicate risks to the public, we focus on local government emergencies in the UK. In many countries like the UK, local governments have the main responsibility for planning and response even for emergencies that concern large areas and are of national reach (Henstra, 2010). In many cases, UK councils are expected to take a leading role in emergency coordination and communicating risks on behalf of several agencies involved (e.g. police or fire services) [1]. Kavanaugh et al. (2012) suggest that social media might be used in local government emergencies on a relatively ad hoc basis without clear appreciation of the risk communication challenges. Many local governments are likely to be in the process of developing expertise of monitoring reactions on social media and intervening accordingly.

The methodology used in this study broadly belongs to digital research methods, which encompasses different techniques for the collection and analysis of data produced via the Internet (Fielding et al., 2008). Following data collection, we classify tweets according to their thematic and risk communication content and then discuss the findings by considering the CERC stages of good practice given the different nature of the two emergencies.

3.1. Data collection and case selection

Twitter is very popular in the UK with over 15 million users (rising from 10 million in 2012), most of which are active via mobile devices. Twitter has been extensively used by government

[1] More details can be found in the UK government's (2013) emergency response and recovery guidance.

authorities at different levels, including councils, mainly since 2008. To identify UK councils using Twitter, the @Directgov/ukcouncils was consulted, which was an official list aggregating 187 general Twitter accounts of UK councils at the time of the study [2]. A large dataset of over 300,000 posts made by those accounts was retrieved within 2012 via the Twitter's Application Programming Interface (API) [3]. For the scope of this study, a total of 10,020 tweets were selected and analysed in relation to the heavy snow of December 2010 and the summer riots of August 2011. These two national emergencies were selected due to their high impact and distinct characteristics; this corresponds to the diverse and influential case selection criteria for exploratory research recommended by Seawright and Gerring (2008).

The UK winter of 2010, also known as the Big Freeze, was a meteorological event that started at the end of November 2010 and lasted until the end of December 2010 (Met Office 2011). Those five weeks involved a long period of extreme weather that demanded continuous alertness and action by councils as the principal emergency authority. Emergency information had to raise awareness over weather conditions and, in a situation where risk managers may wish to avoid people's over-familiarity with the issues, seek to de-attenuate public reactions to ongoing and yet often unpredictable and invisible risks such as driving on icy roads (Breakwell and Barnett 2003). In contrast, the 2011 riots were a largely unfamiliar civil disorder situation marked by high uncertainty about its causes and effects over a period of five days in August 2011 (Riots Panel 2011). Emergency communicators had to use all available information channels to manage public perceptions of events, to reduce uncertainty about the extent of disorders, discourage rioters from taking part and both to warn and reassure. Although dealing with public disorder is mainly the responsibility of police authorities, affected councils took an active role in managing the riots.

3.2. Data analysis

The filtering, selection and analysis of tweets were carried out using MS Excel and NVivo. From all tweets posted by LGAs during November/December 2010 and August 2011, only the emergency-related ones were selected for further analysis in each case respectively. For the 2010 snowfalls, due to the high volume and duration of events, the number of tweets had to be further narrowed down to the period 1-23 December 2010, which included the escalation of snowfalls around the beginning and middle of December 2010 (Met Office 2011). This led to a total of 8,274 tweets emanating from the majority of LGAs across the UK. The investigation of the 2011 riots focused on 1,746 messages mostly from London councils and other metropolitan areas in

[2] The 187 accounts included 13 councils from Scotland, 12 from Wales, Belfast City Council from Northern Ireland and 161 councils from England including 28 London Boroughs. The list was created by the Department of Communities and Local Government and maintained as accurately as possible until 2012.

[3] Data were retrieved from Twitter's API using a customised data collection tool developed by a member of the research team. Based on the API's restriction's, the tool allowed the collection of up to the 3,200 most recent tweets by each account listed by @Directgov/ukcouncils.

England where public disorder took place. The 1,746 tweets were posted during a period of five days from the 9th to the 13th of August 2011.

The 8,274 snow tweets from December 2010 and the 1,746 riot tweets from August 2011 were coded as separate cases to systematically analyse their content and classify emerging themes in each emergency situation. An open coding approach was used, which is common for studies that examine the posting characteristics of specific Twitter users or conversations (e.g. Waters and Williams 2011; Heverin and Zach 2012). This approach comes from traditional qualitative content analysis methods (Krippendorff, 2013) and is adapted for short texts such as tweets with specific structural elements (e.g. hashtags and mentions). The open coding was implemented by two coders who identified initial patterns using keyword frequency and distribution within the messages. This gave a first indication of the tweets' content and the main patterns that are likely to be selected in the final dataset (e.g. words like "school" and "road" appeared in a large proportion of tweets from December 2010, which strongly indicated that they needed to be treated as separate categories). After several rounds of reading of the whole dataset, initial patterns were then further developed and adapted, which eventually led to seven main content categories for each case. Since this process was not based on subjective assessment of the meaning of the tweets, any ambiguities between coders were resolved by agreement before finalising the themes. The seven categories for each case are nonexclusive as tweets could contain meaning that is relevant to more than just one of them; 13.7% and 21.6% of tweets in each case had to be classified in two categories.

The frequency of tweets was examined as an indication of how the volume of messages corresponded to the nature of actual risk events (Renn, 1991, p. 296). It was expected that the volume of tweets would fluctuate according to the intensity of the crisis. As part of assigning tweets to themes we also sought to classify tweets in relation to Renn's (1991, p. 300) categories of message components. Given the context of our dataset and the brief nature of tweets, message components were mostly factual or inferential. Factual information relates to the content or the source of the message (e.g. a road is blocked). Inferential messages refer to the conclusions that can be drawn from the evidence (e.g. care is needed on road x due to ice). Messages with value-related or symbolic components were less evident in our analysis (evaluation of messages against value criteria or symbolic meanings). We relate these message components to amplification potential through the work of Sutton et al. (2013) who find that warning tweets containing clear and specific calls for actions encouraging protective behaviour are more likely to be passed on. Identifying factual and inferential tweets provides an analytic distinction that can be useful in characterising the amplification potential of messages regarding the spread of information. The next two sections present the findings of each case respectively.

4. Raising awareness: heavy snow in December 2010

Heavy snowfalls started during the last week of November 2010 and turned into relentless snow showers during the period between 29 November and 3 December. By early December, most of the UK was covered with snow; accumulations in the north and east of Scotland and England were over 50cm in places, with over 1m of snow lying on much of the Scottish mountains. Indicatively, on the 2nd of December, over 100 motorists were stranded on the north motorways, two teenage girls died in a car crash caused by ice and more than 7,000 schools remained closed (BBC 2010). On that day, an extremely heavy belt of snow affected Southern England and resulted in the closure of three main motorways. Exceptionally low temperatures were recorded in major towns and cities (e.g. -18 °C in Aberdeen, Scotland). The heavy snowfalls and record low temperatures during this period resulted in major transport disruptions, school closures, power failures, the postponement of events, and even several casualties across the country. International airports were also heavily affected, particularly London Heathrow, which remained closed for four consecutive days from the 18th of December. Snowfalls continued during most of the month, with milder weather pushed across the UK only from the 26th to the 27th.

From the end of November 2010, councils in England, Wales, Scotland and Northern Ireland initiated emergency procedures to monitor the situation, improve awareness among the public and ensure the safety of local communities. Activity on Twitter increased accordingly to the local significance and intensity of events. Figure 1 shows the distribution of tweets over the 24 days analysed and confirms the volume effect in line with the actual timeline of snow intensity (Met Office 2011). The peak of Twitter activity in the periods 1-3, 6-9 and 17-22 December 2010 includes the heaviest snow showers within the month when communication needs raised accordingly to provide official information and emphasise the seriousness of the situation with a combination of advice and warnings.

The 8,274 messages were examined in relation to their content in a coding process that resulted in the seven thematic categories shown in table 2 in decreasing order of frequency. Both factual and inferential components were present in most thematic categories. Reflecting on the stages and good practice activities of the CERC model, it is important to consider how the 8,274 tweets were spread across the pattern of adverse weather over a period of 24 days. Figure 2 shows how tweets from the seven thematic categories were distributed over this period. The proportion of different communication themes during each day can be read as indicative of desired reactions from the public and as seeking to convey managerial competence.

When snow waves were expected (*precrisis*), tweets emphasised the need to take precautionary measures and increase awareness, arguably to warn, to lessen attenuated public perceptions and to indicate that a heightened response was required. Strongly inferential messages devoted to advice, updates and warnings were posted at this stage (e.g. on the 4th, and within the 14-16 period). Many of these messages aimed at increasing awareness over the risk of incoming snow, including retweets of messages originally posted by police authorities, the met office, local citizens, the media and other accounts.

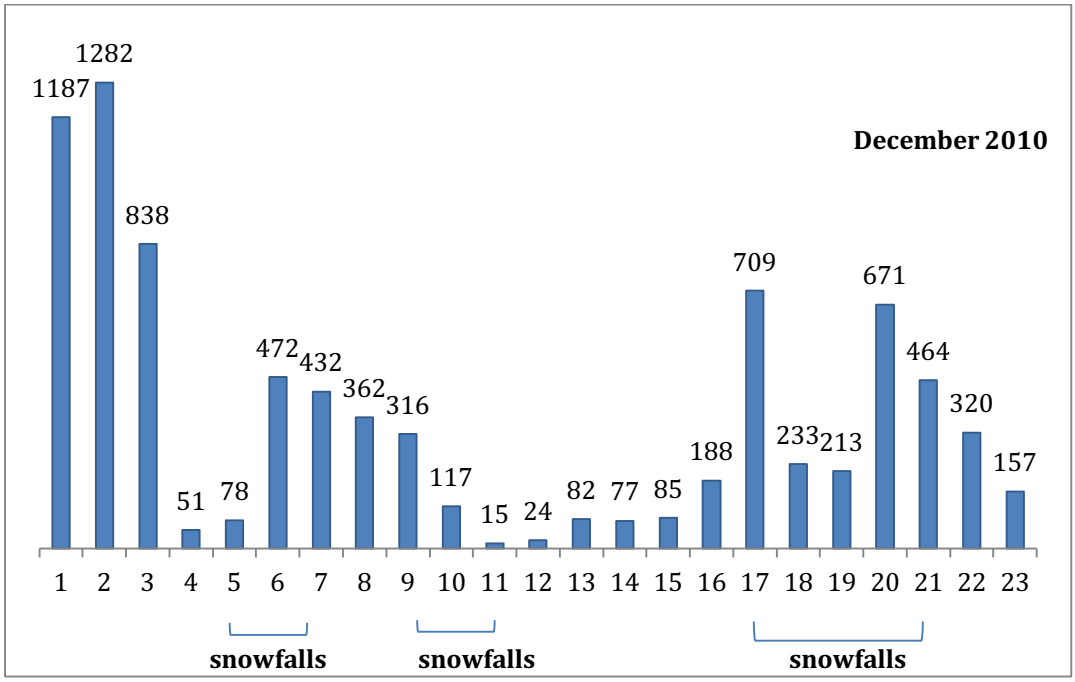

Figure 1: Distribution of tweet volumes, 1-23 December 2010

Category	Examples	Risk amplification components
School updates Updates about school openings, closures and other relevant issues. **33.4%**	*"Head Teachers continue to review the position of their individual schools. Parents will be alerted if pupils are to be dismissed early."* *"All schools and nurseries closed to pupils tomorrow Thursday 9 December. "*	Factual to announce which schools will be open or closed. Details about transportation or the state of facilities were also included.
	"Many schools are staying open in spite of the snowy conditions. Parents and pupils check yours here http://..." *"Parents should make a judgment about whether to send children to school. We understand that it may be a difficult journey for some"*	Inferential messages asked parents and school staff to make their own decisions about attending on specific days.

Cleaning activities Updates about cleaning the streets from the snow and ice. **17.6%**	*"We have used around 2800 tonnes of salt since the start of the winter. Currently we are using an average of 600 tonnes per day."* *"Priority route gritting continues throughout the night. No further snow forecast but temperature in city likely to fall to -10C."* *"Primary roads and footways gritted in advance of possible snow showers coming from the east today. Further grit this evening."*	Factual messages contained information about: (1) the availability and use of gritting (2) apologies to those affected and (3) acknowledgement of cleaning limitations (e.g. omitting smaller streets).
State of council and other local services Updates about recycling, local transportation and other services. **16.9%**	*"We apologise to all of our residents who have had disruptions to their bin and recycling collections over the last couple of days."* *"Special needs and social care transport will not run due to the risk to vulnerable passengers"* *"Service disruptions: Read the full statement on disruptions to council services due to severe weather conditions at http://..."*	Factual to announce information about services including: (1) justification of council actions to deal with the situation, (2) apologies to those affected and (3) retweets of messages by other service providers (e.g. buses).
	"Residents are also being advised to put excess household waste in their brown garden waste bin until full service is resumed."	Inferential messages asked residents to assist in waste collection, avoid specific routes or be patient until full services are resumed.
Information about roads and drivers Updates about the condition of roads and advice for drivers. **15.1%**	*"Drivers are warned of continuing treacherous conditions on Devon's roads after temperatures of -14C in places causes snow to become ice."* *"Highways advice: don't be deceived by today's blue skies & fading snow; it will stay below freezing this weekend so ice is a danger."*	Factual messages informed about the condition of roads and how traffic was affected by the weather.
	"Drivers: Be aware of pedestrians, using salted roads to walk along to avoid slippery icy pavements tomorrow." *"Please be careful on the roads this morning. Ice is likely to be the biggest danger especially on minor and residential roads #Plymouth"* *"Please if you're driving clear snow off your car roof before leaving. It could slip while moving and block your view."*	Inferential messages contained strong precautions about driving and expressions of care related to vehicle maintenance, pedestrians and deteriorating weather conditions.

Response to queries and others Replies to questions, requests for information and other direct mentions to accounts. **12.3%**	*"@*** You can see the routes on this map http://... and here's info on winter maintenance plan http://..."* *"@*** we are responsible for 5 000 miles of roads (not just Sevenoaks) and our 66 gritters and snow ploughs are doing the best they can"* *"@*** We know the situation is bad but please bear with us as we are trying our best to help as many people and areas as possible"*	A combination of factual and inferential messages in response to requests for information and other direct contacts. Mostly related to details about the actions of the council to deal with the snow and how to receive updates.
Events and venues Information about the opening/closure of facilities and cancellation of events. **9.5%**	*"All our sports pitches including pitches at leisure centres remain closed due to the ice and snow."* *"All the borough's libraries are closing at 4pm because of the bad weather."* *"The show must go on! Playhouse panto matinee and evening performances are going ahead. Oh yes they are!"*	Factual to announce information about events and the state of venues like leisure facilities and libraries.
Advice, updates and warnings General updates, advice, statements from local leaders and other situation description messages. **8.9%**	*"If you are aware of someone who is vulnerable and is at risk due to the cold weather please contact Adult Services on ***."* *"No major snow overnight but still threat of freezing rain this afternoon. Please take care when out and about."* *"Please take care. Ice or large amounts of snow falling from buildings can be dangerous."* *"As sleet/snow melts and temperatures then begin to drop overnight residents are asked to take extra care due to a very high risk of ice."*	Inferential messages with strong expressions of care and advice about how to protect public safety.

Table 2: Thematic categories and examples for the snow tweets, 1-23 December 2010.

Uncertainty reduction was more intense while snow waves were in progress (*initial event*) with several reminders before most local issues were resolved (*resolution*). During snow waves, inferential tweets related to the condition of roads, actions to support snow cleaning and other self-efficacy or precautionary measures. Depending on how critical the message was, a few tweets contained direct risk assessment propositions such as 'drive at your own risk'. Furthermore, given the long duration of events (*maintenance*), residents were likely to become familiar with risks such as driving or walking on icy roads. To address this, specifically targeted

tweets aimed at intensifying public reactions through reminders of the existence and high impact of weather conditions on individuals and council resources. Most public queries were received at this stage (12.3% of all messages), so that tweets could be used to collect information and identify areas of attention based on feedback by residents and local organisations. Following the recovery stage, there was no evidence of discussions about adequacy response and lessons learnt (*evaluation*); such reflections probably took place in less constraining and immediate spaces than Twitter's 140 characters.

Although public response to messages from different categories cannot be measured in detail, if we consider retweets as an indicator of influence (e.g. Marwick and Boyd 2011; Sutton 2013) it seems that factual information about openings and closures had the clearest impact. Probably due to the size of their population, accounts from major city councils tweeted more during the two emergencies and their tweets drew higher evidence of attention in the form of retweets (e.g. *'All schools and nurseries closed to pupils tomorrow Thursday 9 December'* by Glasgow City Councils was retweeted 145 times).

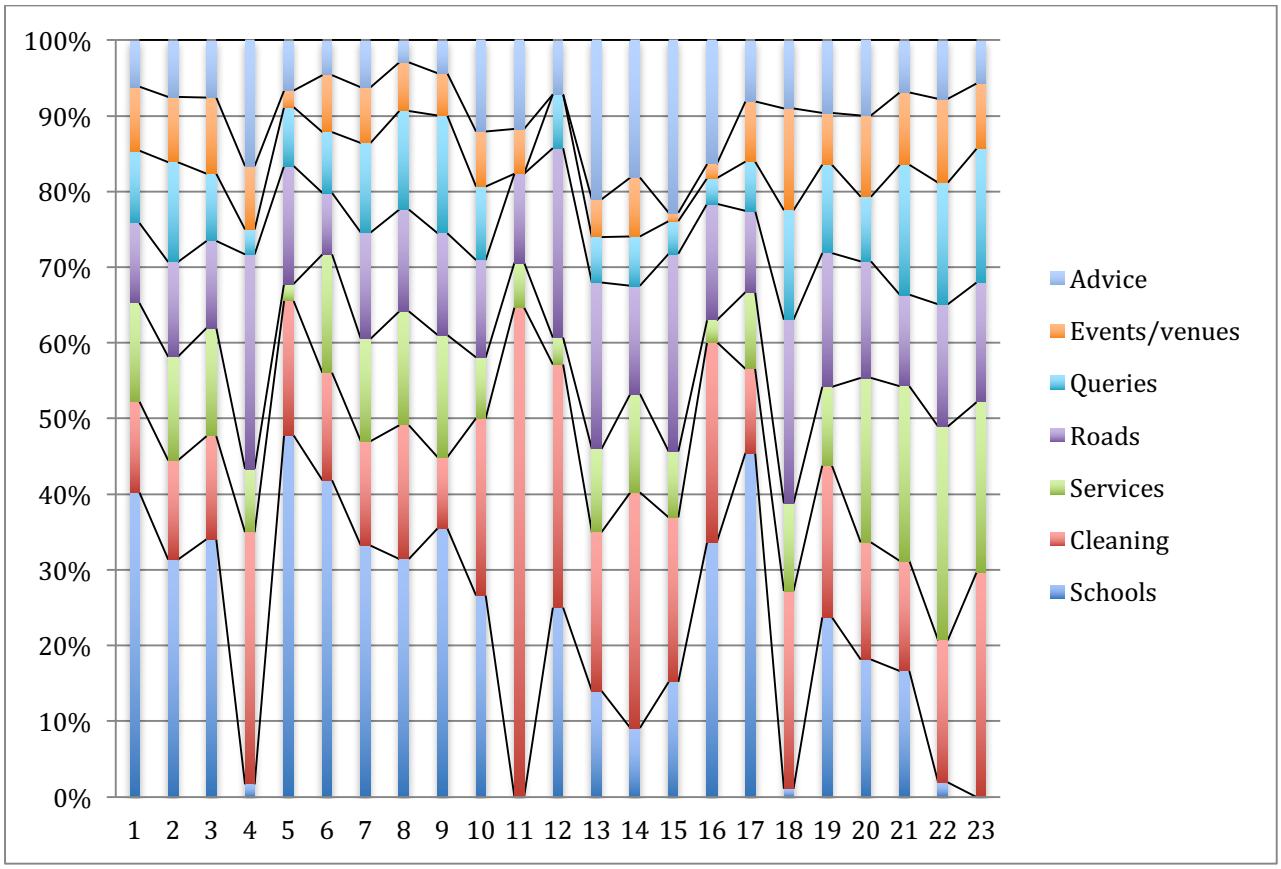

Figure 2: Distribution of thematic categories for the snow tweets, 1-23 December 2010.

5. Managing uncertainty: the riots of August 2011

The widespread public disorder for five days in August 2011 across major cities in England was an exceptional event marked by high uncertainty. The riots started in London Tottenham on Saturday 6th of August 2011, following protests caused by the death of a local man named Mark Duggan by the London Metropolitan Police two days earlier. From 8th to the 10th of August disorders spread rapidly across London and nationally leading to a total of 66 areas affected, including cities such as Bristol, Manchester and Birmingham. About 13,000 - 15,000 people were actively involved in the riots, five people lost their lives and hundreds more lost their businesses and homes in a total estimated cost of over half a billion pounds (Riots Panel 2011). The majority of crimes were committed in London (68%), including many incidents of violence against individuals, arson and criminal damages, thefts and shop looting. Riots de-escalated when 16,000 patrolling police forces were deployed in London on the 10th of August. In parallel, the London Metropolitan Police started a robust campaign to arrest suspected rioters through the monitoring of over 200,000 hours of closed circuit television (CCTV) footages. Another influential event was the peace-rally called by Tariq Jahan whose son was killed during riots in Birmingham.

Social media were extensively used during the riots by all involved parties. Twitter specifically gained a central role as part of a massive flow of information about the riots in traditional and digital media. Despite initial assumptions, mainly by media and political leaders, studies showed that social media were not used to promote illegal activities, but much more to describe the events, condemn the riots, raise donations and express solidarity to local communities (Guardian, 2012). An exception to this was the BlackBerry Messenger (BBM) which, due to its cheap cost, efficiency and security, was used by rioting groups as an organising tool (Guardian, 2011). An analysis of over 2.5m tweets by the Guardian (2012) team found that Twitter was mainly used by authorities and individuals to organise clean-up activities, which was an idea suggested by Twitter users and supported by the Mayor of London. Over 60,000 volunteers were mobilised in the most affected areas of London and other cities to clean the streets from the riots. Hashtags like #LondonRiots and #RiotCleanup used to organise these activities were estimated to have reached over 7 million Twitter users. Police forces used Twitter mainly for broadcasting purposes instead of intervening and systematically gathering information, which proved difficult due to the speed of events (Procter et al., 2013). However, the initiative to identify suspects following the release of CCTV images of rioters by the police proved to be very popular.

The 1,746 tweets analysed were posted by 81 councils from the 9th to the 13th of August 2011 while the riots were taking place across England or shortly after. Even though the initial reaction of councils to the incidents was rather late, Twitter was used extensively from the 9th. Figure 3 shows the distribution of tweets over the five days. The volume effect is clear, as this number of tweets would normally correspond to a whole month of activity instead of five days. Most tweets were posted over the first two days when riots were in progress and uncertainty was high. In subsequent days, the peak of activity around noon was due to tweets related to the events of the previous night and the organisation of cleaning activities later the same day. The different types

of messages posted by councils reveal a combination of risk communication strategies to reduce uncertainty and attempt to influence actual events. The 1,746 tweets were related to the seven categories of content described in table 3. Unlike the 2010 snow tweets, most thematic categories have a clear factual and inferential focus, both aiming at the fastest possible resolution of the emergency and the attenuation of public perceptions.

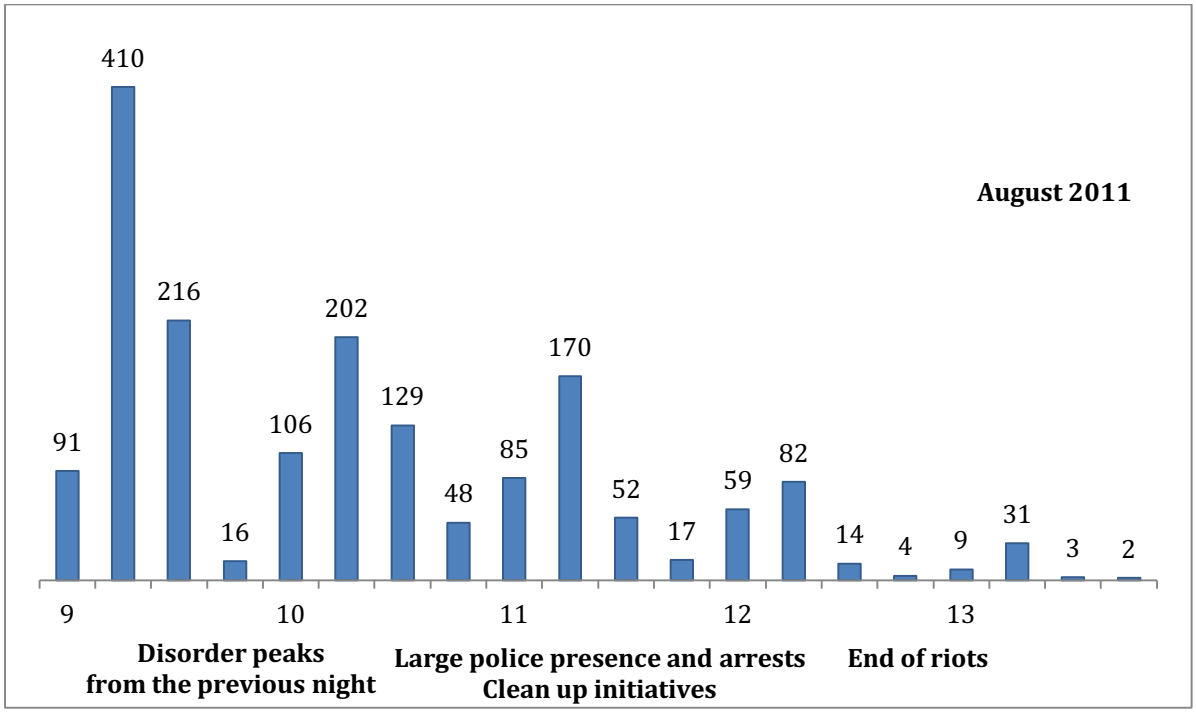

Figure 3: Distribution of tweet volumes, 9-13 August 2011

The stages and good practice activities of the CERC model can illuminate the proportion of different communication themes over the five days (figure 4). Due to the man-made nature of the riots, we can observe significant differences in the nature of Twitter communication as events unfolded. Twitter use during the riots followed the sudden escalation of disorder (*initial event*) and there was no opportunity to observe a precrisis stage. Tweets were however clearly deployed to support councils' efforts to attenuate public stress and avoid the possible escalation of the riots. To serve this purpose, a large number of factual messages included official announcements, statements from local leaders, retweets of messages from the police and replies to other accounts that sought information about the situation (situation description theme). Those messages contributed to collective sense making and provided links for further information on council websites or other original sources. Due to the uncertainty about the extent of the riots in city neighbourhoods, timely information was of vital importance to reinstate public order and prevent the spreading of panic; as shown in figure 4, tweets preventing rumours mainly appeared during the first two days.

Category	Examples	Risk amplification components
Press release, announcement or statement Press releases, announcements and statements by local leaders, officers in charge or the police. **34.9%**	*"Press release: Harlow Council leader Andrew Johnson praises young people in Harlow for tackling baseless riot rumours on social media"* *"Statement from Birmingham City Council on unrest calling or calm and business as usual in the city tomorrow http://..."* *"The leader of the council has made a statement about the disorder and the concerns of local people. Read it here: http://..."*	Factual about the situation and actions of authorities.
Situation description Information about the situation in response to queries or actions in progress. **29.7%**	*"It's business as usual in Solihull - we'll be working closely with @WMPolice to keep a close eye on things and will keep you updated"* *"West Midlands Police are reassuring communities that the situation this evening is one of calm across the region."* *"We've been dealing with an incident in Morrisons car park. Police on scene situation under control. Number of arrests ..."*	Factual, with evidence about the situation being extrapolated to inferences as to how to stay safe.
Community appraisal Public appraisal of those participating in community recovery events like cleaning actions and fundraising. **16.9%**	*"Thanks to everyone who has turned up to help with the cleanup. We've got most of it done now. Business as usual here. #salfordriotcleanup"* *"Thanks everyone for your offers of help to #cleanuptelford - we'll keep you posted"* *"Most of the clean up is now underway or has already been completed but a very big thank you to everyone who has offered to clean up"*	Community acknowledgements appear to be mostly factual but act as encouragement for more public input, especially since many of them were posted while riots were in progress.
Clean-up actions Coordinating or supporting actions to clean the streets. **12.9%**	*"The core of the city has been cleaned. We'd still welcome help with smaller streets but may be less to do than expected #Manchester"* *"All is now calm in Wellington town centre and our street cleaning operation has been completed. http://..."* *"RT @***: At the bethnal green clean up nice to see so many people ready to help in the community!"* *"Please wait for announcements about a cleanup this*	Inferential to ask people to support cleaning actions organised by councils, local citizens or other groups.

	afternoon. We need to make sure areas are safe first."	
Legal actions Information and warnings about legal actions in progress against potential offenders or those arrested on the spot. **11.7%**	*"Lots of warrants being executed this morning and people being arrested from last night."* *"We have started knocking on doors to arrest people. We arrested a total of 888 people in connection with disorders."* *"We will not take action against any parent who reports their child to police for rioting"* *"Our housing provider Salix will be taking legal action and potentially evicting tenants involved in the riots"*	Messages in this category appear to be factual but are indirectly inferential to: (1) ensure the general public that law enforcement is in progress and (2) warn offenders to stop engaging in disorder.
Preventing rumours Disproving rumours broadly or with direct reference to other users' tweets. **8.9%**	*"All is calm across Stoke-on-Trent and Staffs - ignore the rumours there is nothing to report"* *"RT @gmpolice: Rumours and gossip everywhere - NO disorder at the moment. Follow this official Twitter feed and we will keep everyone updated"* *"All quiet in Smethwick and West Bromwich this morning. Please do not spread rumours on Twitter and Facebook reliable updates from @WMPolice"*	Balanced factual and inferential as they contained updates about the situation and strongly directed individuals to stop spreading rumours using online or offline means.
Information seeking Seeking public assistance to identify suspected rioters. **6.6%**	*"#UKriots: help name the criminals and find out what you can do to stay safe http://... #stoptheriots #londonriots"* *"You can give @GMPolice info about the #salfordriots by using this web page http://.... It lets you upload videos photos + docs."* *"RT @gmpolice: Check out our pics and help us Shop a Looter. http://..."*	Inferential to seek public input in identifying offenders. Includes many retweeted messages or calls from police forces or other ad hoc campaigns.

Table 3: Thematic categories and examples for the riots tweets, 9-13 August 2011.

It is important to observe that, following this initial response, the public was seen as a resource to mitigate the impact of the riots and establish transitional actions between the *maintenance* and the *resolution* stage. Inferential tweets were posted mostly at these stages and attempted to influence public behaviour by promoting collaborative actions to clean the streets while seeking input to identify offenders and strongly warning those at the streets for the consequences of their actions. Even tweets that appeared to be informational, actually guided the public into specific actions implicitly. For example, legal actions in progress aimed to affect offenders' willingness to engage in riots on the spot, as they were likely to receive updates via their mobile devices. The proportion of tweets about legal actions increased during the five days. Together with appeals to

identify offenders from CCTV images (information seeking theme), those tweets were influential in reducing disorder and restoring faith in the ability of authorities to react effectively. Furthermore, repeatedly expressing gratitude about community mobilisation to clean the streets aimed to encourage more people to take part or promote the initiatives on their own networks. Overall, these three inferential communication themes aimed at accelerating the *resolution* stage by providing people a variety of ways to get involved, even by a single retweet for those observing the riots outside their local areas (re-iteration of self-efficacy).

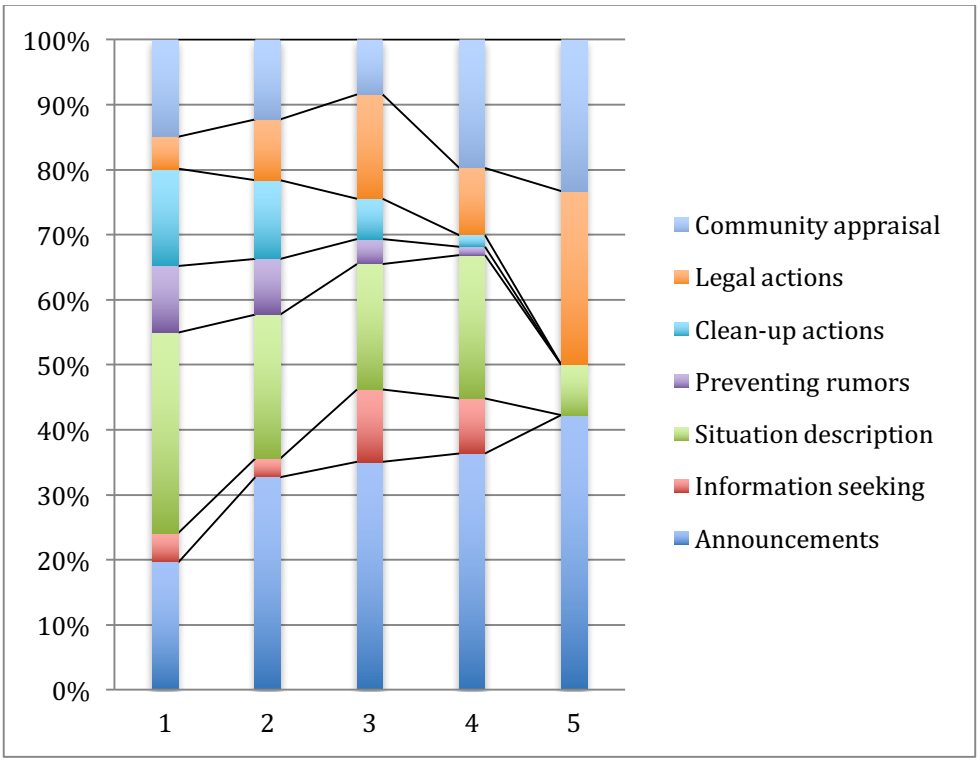

Figure 4: Distribution of thematic categories for the snow tweets, 1-23 December 2010.

6. Discussion

The analysis of the 10,020 tweets shows that LGAs used a variety of risk communication strategies related to social amplification processes. First, they significantly increased the pure volume of broadcasted information to intensify awareness and provide frequent timely updates. Second, they filtered and reproduced information from other resources to take advantage of the high visibility of their accounts (e.g. to ensure that police warnings or weather updates maximise their reach). Third, LGAs framed their own Twitter messages to lead public attention to alerts, warnings, updates and proposed actions. Original tweets produced by LGAs, together with retweets and replies, were spreading as official sources of information, hence being part of an emergency communication tool that could reach wider audiences through Twitter's network effects. Following the observation of these information flows and communication strategies, we

discuss the changing nature of emergency communication due to the new role of social media. We then expand and reflect on the study's implications for theory.

6.1. Communicating risks to the public on social media

An important starting point for consideration is the value of Twitter to improve confidence in emergency management institutions. Many tweets from both cases were devoted to information about emergency decisions, use of resources and progress of risk assessment activities. The level of detail provided by brief frequent messages can improve adaptability to emerging risks by building an informed community, for example, addressing queries from the public, sharing and promoting actions in progress by individuals and organisations (e.g. effective coordination of riot clean-up) or providing support with emotional coping (Gaspar et al., 2016). This is important since previous work has indicated that if the public does not perceive emergency management activities as adequate, there might be issues of political accountability or attempts by non-institutional actors to influence public perceptions (Al-Saggaf and Simmons, 2014).

In the case of the 2010 snowfalls, Twitter was extensively used to manage expectations over the reach and limitations of emergency resources. Tweets informed about numbers of resources used to grit and salt the streets, risks that had to be accepted such as leaving ice on secondary routes and how waste collection was prioritised when vehicles could not reach certain areas. Many tweets also directly addressed queries from the public about these issues. This function of Twitter can be of particular value in large-scale emergencies like weather conditions, when public managers face pressures to demonstrate the effective allocation of resources (Boin and 't Hart, 2010; Henstra, 2010).

In the case of the 2011 riots, there was an ongoing struggle to show that authorities had the situation under control. Most themes of Twitter communication were clearly aligned with this objective, with many of them aiming to clarify ambiguities about the source of publicly distributed information or directly disprove rumours (Oh et al., 2013). The style of tweets adapted accordingly to show the alertness of authorities and decisiveness of actions in progress (e.g. legal actions, disproving rumours). One would expect that authorities would maintain a traditionally official tone but many of the tweets deviated from this norm were informative in an informal way (e.g. "Colleague at meeting with police confirms nothing of note has happened in the borough. We and police will continue to keep our eyes open"). This is arguably one of the few cases that actions by authorities and local communities co-evolved around activities like cleaning the streets and identifying suspects (Panagiotopoulos et al., 2014).

Following from the latter, it is important to note that compared to traditional risk and emergency communications, social media interventions take place in spaces where official accounts are not isolated but act as hubs within a broader flow of information during emergencies (Jung and Park, 2014; 2016). Being able to communicate as part of a network is a major change for emergency authorities compared to traditional one-way models where public responses are neither

anticipated nor visible. In the two cases, LGA accounts occupied a central position as a trustworthy source of information in emergency flows both to inform communities about issues within their responsibility (e.g. waste collection, schools or public venues) as well as to make risk assessment propositions about the condition of roads or the state of transportation services. Good practice suggests that the public has to be made aware of how updates will be posted and which other information sources are trustworthy and relevant (e.g. transportation or utility companies) (Mergel, 2013). To a large extent, these relationships will emerge ad hoc and sustaining them can be critical to turn channels like Twitter Alerts to useful risk management tools.

6.2. Theoretical implications

The Social Amplification of Risk Framework sensitised us to considering how Twitter messages might relate to risk amplification where LGA accounts – as key stations of amplification – sought to shape and guide what they considered to be proportionate public responses. In this endeavour, they used both using factual and inferential messages. The principles of CERC as a further explanatory lens supported an understanding of how risk communication strategies were deployed at different stages of each emergency. SARF and CERC proved useful starting points to frame social media in relation to established emergency and risk communication theories (Rickard et al., 2013; Sellnow and Seeger, 2013).

Our findings regarding the different communication strategies supported by Twitter messages clearly reflect some of the good practice elements suggested by the CERC model (e.g. uncertainty reduction, self-efficacy). The application of the model illustrated the intention of LGAs to accelerate the transitions between emergency management stages whenever possible (riots) or show preparedness for next stages when transitions could not be controlled (snow). Although citizen responses to official LGA tweets were not the focus of this paper, further good practice was evident as many tweets sought to involve wider community responses; such community engagement tweets posted at the earlier stages during the riots constituted close to 30% of all messages. Hence, depending on the nature and stage of an emergency, there might be different opportunities to identify risk sources and guide public behaviour.

Another useful aspect of the CERC model is the opportunity to retrospectively evaluate a dataset of social media posts and draw lessons for the development of future emergency communication capabilities. Given that interest in social media monitoring tools is rising, the CERC model can be a useful diagnostic framework to strengthen the connection between pre-crisis and evaluation. For example, through collecting and analysing responses, it might be possible to observe how messages aiming at risk attention and re-iteration of self-efficacy were actually received by digital publics. This could allow for: (1) a more in-depth assessment of the impact of messages like tweets beyond volume effects and measures of vitality (e.g. number of retweets) as have been considered thus far (Sutton et al., 2013), and (2) an understanding of wider information

flows around an emergency in which authorities were not directly involved in (e.g. Twitter users organising the riots clean-up campaign).

Although SARF and CERC were useful as a conceptual scaffolding for the analysis of this paper, further development of risk communication models is needed to better take into account the immediacy and non-linear nature of social media interactions. SARF assigns a key role to the media in driving amplification processes but now there are many more social stations of amplification, such as the LGAs in this analysis, which are increasingly enjoined to communicate risk directly to their followers, with selective reference to traditional media sources. Furthermore, the CERC model's assumptions that emergencies evolve in a predictable and systematic way might not always fit to the blurred Twitter audiences that might be observing or engaging during an emergency without clear boundaries.

7. Conclusion

In this article, we examined how Twitter was used with the aim of increasing awareness over emerging weather risks (snowfalls) or reducing the effect of a man-made crisis (riots). Despite the fact that tweets were brief and unavoidably 'terse', they were deployed extensively in the two crisis management situations in ways that reflect a range of strategies and that are sensitive to different stages in the crisis – both in terms of volume and content of messages. As institutional learning processes with regard to social media are progressing through different levels of sophistication (Mergel and Bretschneider 2013), our findings can be informative for different public engagement contexts.

There are certain limitations that need to be acknowledged. The messages in our dataset came from LGAs with diverse communication needs, urgency, local impact of the two emergencies or available resources. As such, we are not able to fully reveal the choices involved in broadcasting specific types of content; this might obscure our understanding of the extent to which Twitter use represented a planned response or ad hoc creativity by local government officers. Since emergency management is more than the application of frameworks to inform and guide the public, we can also not be fully aware of actions taken but not communicated through Twitter's brief updates. Furthermore, our approach is based on qualitative exploration of content and risk expressions over a significant amount of tweets. We were not able to capture the full range of information flows involving mainstream and other social media or even within Twitter during the two emergencies. We also need to take into account that, despite its large user base in the UK, Twitter is not the only important source of emergency information activity and its use is not expected to reach the general public that needs to be informed during emergencies.

A final point of departure for future work is related to the observation by Turoff et al. (2013) that social media may not be as useful for effective collaboration as systems directly designed for crisis planning and response. Social media certainly entail opportunities for mobilisation like cleaning the streets during the riots, however we are not fully aware of how these activities can

be planned or encouraged more systematically and what is the relationship with emergency systems that are based on closed information flows. Understanding how social media can be integrated with back-office systems of planning and control offers an important aspect for future work.

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