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Title	Towards an online information quality model for major incidents: a naturalistic decision-making study
Authors	Planella Conrado, Silvia
Publication date	2020
Original Citation	Planella Conrado, S. 2020. Towards an online information quality model for major incidents: a naturalistic decision-making study. PhD Thesis, University College Cork.
Type of publication	Doctoral thesis
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Download date	2026-09-27 16:14:02
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Towards an online information quality model for major incidents: A naturalistic decision-making study

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for the degree of

Doctor of Philosophy

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2020

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

Acknowledgements

I would like to express my appreciation to my supervisors, Dr. Karen Neville, Dr. Simon Woodworth and Dr. Sheila O'Riordan for the time and effort you have given over the last five years. Your input and guidance have enabled me to materialise ideas into concrete actions and this into research. Thanks for all meetings and coffees.

I wish to thank all the S-HELP consortium members and workshop participants. Working as a Research Support Officer in UCC, it really made all this possible. S-HELP was the origin of everything: great ideas and great friendships. Thanks to Matt, Micheal, Michael, Andrew, Alexis, William, Maria, Marion, Alexander, Martina, for great conversations and advice over the years. Even if we are not in touch as much as I wish, I hold very good memories of the project and trips together (Austria, Israel, Ireland).

A big thank you to my fellow researchers and S-HELP colleagues: Dr. Nora McCarthy and Cian O'Brien. You always have superb advice. It has been a privilege to be part of our PhD Thesis Committee group. Always full of helpful suggestions even in the last few months when life got too messy with the COVID19.

A special thank you goes to VOST in special the VOS Oregon team who made such a difference in this research, but also on myself as a person. It is great to collaborate with you by managing social media in emergencies actively. It is a pity that VOST Ireland did not work out but maybe in the future. Who knows?

Thanks to FirstDraft initiative and Media4Sec researchers for inviting to their workshops. Inputs and informal conversations helped to shape this research in many ways.

Thank you to all of the BIS department staff for showing their support and guided me throughout the years. In special to Dr. Joseph Feller for his feedback during and after the VIVA. Also, thanks to Dr. Dan Power who provided me with an amazing feedback during the VIVA and who unexpectedly passed away on 26th of January 2021. RIP. I am honoured to be one of the many PhD candidates who had you as examiner. Your advise will guide me in many years to come.

Thank you to my parents, Valle and Jordi. This one in Spanish: *"Gracias por todo vuestro apoyo y ayuda. Gracias por estar siempre ahí, por escuchar todas mis ideas incluso las que son totalmente locas. Todo lo que he conseguido ha sido gracias a los valores y la educación que me distéis. Sóis mi modelo a seguir."*

My sister Judit who supported this PhD in so many ways. You have ensured that I didn't lose my mind through the process. Thanks for all the conversations, reviews and suggestions to get this research over the line. You are amazing! I know you will achieve whatever you set your mind on it. I admire you deeply.

Lastly, a big thanks to my husband Francis. You have always been there for me, but even more since our baby Michael was born in 2018. Becoming parents together has been amazing, and if we survived, it is thanks to your dedication and love to both of us. I promised you to finish before giving birth, sorry I didn't make it before our first boy. Thanks for the opportunity of fulfilling my promise with a second baby that will join our family in a couple of moths. For this and so many other reasons… I love you, forever.

Abstract

Decision-making is a critical skill in major incidents. During emergencies and related incidents, it is paramount to make timely sound decisions to reduce human and material losses (Kowalski-Trakofler, Vaught, & Scharf, 2003). Emergencies are dynamic, urgent, complex and uncertain environments (Aldunate, Pena-Mora, & Robinson, 2005; Comfort, 1999; Danielsson & Ohlsson, 1999; Kapucu & Garayev, 2011; Moynihan, 2008) where a large number of decisions must be taken (Helsloot & Ruitenberg, 2004). While experts may rely on their previous experience and take actions based on internal prototypes or mental models; other stakeholders involved in major incidents may not be familiar with the situation and therefore, require additional information and support from emergency experts.

One of the newest online risk communication channels and information sources is Twitter. It is a 280 characters micro-blogging platform that enables users to develop inter-personal relationships. In major incidents such as emergencies, Twitter usage presents several Information Quality (IQ) challenges to overcome, including the difficulty of finding relevant information, information shift, completeness of the information, and users' intention while creating or sharing inaccurate information. All of these complicate the decision-making process by increasing information uncertainty.

IQ is defined based on information's *'fitness for use'* which relies on the concept of meeting end-users' requirements and expectations (R. Y. Wang & Strong, 1996). The importance of IQ in emergencies is paramount to decide the best course of action. The analysis of information requirements in emergencies against existing IQ models showcased a misalignment between these. The researcher identified a gap while trying to use these solutions to implement a decision-making process using online information sources such as Twitter in naturalistic environments. What is more, little is known about the IQ dimensions available on Twitter for decision-making in emergencies.

In order to address this gap, the researcher used a three-stage process to gather evidence of decision-making using Twitter (RQ1), identify relevant IQ dimensions (RQ2) and record the decision-making steps followed by experts (RQ3) in the analysed context.

The methodology selected is aligned with the naturalistic decision-making school, which places high importance on prescriptive knowledge and the use of real-life scenarios. Hence, the researcher selected three case studies (a terrorist attack, a solar eclipse and a hurricane) combined with expert input. Through ten Critical Decision Method (CDM) interviews, a qualitative method based in real-situations, a total of 75 decision-making processes were documented from journalists, Public Information Officers (PIOs) and Virtual Operation Support Team (VOST) members.

The findings highlight that Information Quality (IQ) is context-specific. Twitter IQ for decision-making in major incidents and emergencies can be improved from a production and consumption perspective. From these findings, the researcher proposes the Evaluation of Twitter Information Quality in Incidents (ETIQI) model based on four main IQ dimensions -utility, time, reputation and comparability- which are enhanced by eleven interconnected dimensions -value-added, applicability, relevance, accessibility, accuracy, reliability, objectivity, believability, representational consistency, an appropriate amount of information and completeness – which can positively impact in the use of Twitter for decision-making in emergencies. The proposed ETIQI model is a mechanism that aids the evaluation of IQ in different steps of the decision-making process. Hence, this research presents multiple practical and theoretical contributions in the area of information quality, Twitter, user-generated content, emergencies and naturalistic decision-making. The proposed model and associated strategies can be utilised to develop more robust systems, train emergency stakeholders, and overall improve decision-making using online information when it is most needed: in major incidents such as emergencies.

List Acronyms

- **API:** Application Program Interface
- **BTA:** Barcelona Terrorist Attack (case study)
- **CDM:** Critical Decision Method[1]
- **CDM***: Classical Decision-making (see note)
- **CRISP DM:** CRoss-Industry Standard Process for Data Mining
- **EC:** Eclipse (Oregon Solar Eclipse – case study)
- **EMS:** Emergency Management Systems
- **FEMA:** Federal Emergency Management Agency (United States of America)
- **KAM:** Knowledge Audit Method
- **FASB:** Financial Accounting Standards Board
- **GDTA:** Goal-directed Task Analysis
- **GPS:** Global Positioning System
- **HH:** Hurricane Harvey (case study)
- **IQ:** Information Quality
- **IS:** Information Systems
- **ISIS:** Islamic State in Iraq and Syria
- **JDM:** Judgment and Decision-making
- **JSON**: JavaScript Object Notation
- **LOD:** Linked Open Data
- **MCM:** Mass Communication Media
- **NDM:** Naturalistic Decision Making
- **NDMS:** Naturalistic Decision Making School
- **ODM:** Organisational Decision-making
- **PIO:** Public Information Officer
- **PQI:** Perceived Quality of Information
- **RPD:** Recognition-Primed Decisions

[1] CDM, as described by Lipshitz, Klein, Orasanu, and Salas (Lipshitz et al., 2001), stands (confusingly) in the literature for Critical Decision Method and Classical Decision-making. The researcher has marked the acronym for Classical Decision-making with a * (CDM*) to differentiate both concepts as Critical Decision Method (CDM) term is more important for this research.

- **RQ:** Research Question
- **RT:** retweets
- **SA:** Situation Awareness
- **SMEs:** Subject-Matter Experts
- **OCHA:** Office for the Coordination of Humanitarian Affairs (in the United Nations)
- **UGC:** User-Generated Content
- **URL:** Uniform Resource Locator
- **VOSG:** Virtual Operations Support Group
- **VOST:** Virtual Operations Support Team
- **VTC:** Volunteer and Technical Communities

Glossary

The following terms were used operationally throughout this research:

- **Accessibility** is the extent to which data are available or easily and quickly retrievable. Information Quality (IQ) dimension.
- **Accuracy** is the extent to which data are correct, reliable and certified free of error. Information Quality (IQ) dimension.
- **Agenda-setting theory** implies that traditional media choose the topics to consider and influences in *"how to think about it''* and *''what to think''* (McCombs & Shaw, 1993, p. 65).
- **Amount of Information** is the extent to which the quantity or volume of available data is appropriate. Information Quality (IQ) dimension.
- **Believability** is the extent to which data are accepted or regarded as authentic, real, and credible. Information Quality (IQ) dimension.
- **Candidate alternatives** are alternatives course of action, a candidate solution to a problem. The different alternatives available are mutually exclusive. Decision-making element.
- **Classical Decision-making (CDM*):** Focuses on the development and study of operational decision-making methods. Decision analysis sub-discipline.
- **Completeness** is the extent to which data are of sufficient breadth, depth, and scope for the task at hand. Information Quality (IQ) dimension.
- **Concise representation** is the extent to which data are compactly represented without being overwhelming (i.e. brief in presentation, yet complete and to the point). Information Quality (IQ) dimension.
- **Control variables** are characteristics that describe a candidate alternative. A change in one control variable, constitute a different alternative. Decision-making element.
- **Critical Decision Method (CDM)** is a retrospective semi-structured interview method that uses cognitive probes (from real-life situations) stimulating the recall of information about decision-making strategy from experts (Klein, Calderwood, & MacGregor, 1989). This method provides valid results to develop training materials, identify requirements, develop expert systems, and assess

this system's effect on task performance. Naturalistic Decision Making (NDM) method.

- **Decision criteria** are each dimension of an outcome which is significantly affected by choice of alternatives, and which decision-maker considers being critical in making his decision. Decision-making element.
- **Decision-maker** is an individual or set of people who has to select an alternative. Decision-making element.
- **Decision-making** is *"a mechanism for making choices at each step of the problem-solving process"* (FEMA, 2005, p. 2.1).
- A **Disaster** is *"a serious disruption to community life which threatens or causes death or injury in that community and/or damage to property which is beyond the day-to-day capacity of the prescribed statutory authorities and which requires special mobilisation and organisation of resources other than those normally available to those authorities"* (1998, p. 33).
- An **emergency** is an extraordinary situation in which emergency stakeholders cannot meet their basic survival needs, or there are serious and immediate threats to human life and well-being and calls for immediate action (Blanchard, 2008; Emergency Management Australia, 1998; Reliefweb, 2008).
- **Emergency Stakeholder** is *"an individual who is affected by the decisions made (or not made) by emergency managers and policymakers in his or her community"* (Lindell et al., 2007, p. 33).
- **Gatekeeper figure** is the person that decides what messages reach to the 'mass' (citizens) according to the approved agenda (Sung & Hwang, 2014).
- **Goal-directed task analysis (GDTA) method** is a form of a structured interview that uses probe questions to conduct a top-down analysis of work (e.g. Endsley, 1993, 1995a, 1995b). GDTA attempts to obtain detailed knowledge of the decision-maker's goals and the information requirements for working toward those goals. Researchers focus on the information that decision-makers would *"ideally like to know to meet each goal, even if that information is not available given current technology"* (Hoffman, 2005, p. 78). Naturalistic Decision Making (NDM) method.

- **Information manager:** In an emergency, the person responsible of *"seek information, question it and, where appropriate, validate acquired information; sort it, group it, prioritise it and then display it, ensuring that what is being presented on the information management boards are both facts and safe deductions, and not suppositions."* (National Working Group, 2008, p. 6).
- **Information Quality (IQ):** information's *'fitness for use'* which relies on the concept of meeting end-users' requirements and expectations (R. Y. Wang & Strong, 1996).
- **Judgment and Decision-making (JDM):** Emphasises normative, descriptive, and prescriptive theories of human judgments and decisions. Decision analysis sub-discipline.
- **The Knowledge Audit** is a research method based on the concept of expertise but from a psychological aspect (Militello & Hutton, 1998). It attempts to understand further the difference between novice and experts in a specific domain or task within a domain (e.g. Chi, Feltovich, & Glaser, 1981; Klein & Hoffman, 1993) and identify the specific things that experts in a given domain need to know and the skills they need to possess. Naturalistic Decision Making (NDM) method.
- **Media dependency theory** predicts that individuals rely on mediated information to meet their needs. However, individuals have specific preferences related to where they will turn for information concerning a particular topic (Ball-Rokeach & de Fleur, 1976). Therefore, task complexity, decision aid familiarity and cognitive fit can play a vital role for decision-making. Researchers have revealed that media dependency increases during crises (e.g., Hindman & Coyle, 1999; Lachlan, Spence, & Seegar, 2009; Loges, 1994; Tai & Sun, 2007). According to this theory, individuals will access mediated sources during a crisis and complement them with additional information from other sources (Mazer et al., 2015).
- **Model:** A chart that shows theoretical links between different variables or relationships in or among groups (McEntire, 2004).

- **Naturalistic Decision Making (NDM):** Emphasises psychological approaches and methods in decision processes. While somewhat ethnographic, it is based on careful descriptions of how experts make choices in complex, real-world situations. Decision analysis sub-discipline.
- **Noise** is *"a competing interpretation of data not grounded in science that may not be considered scientific evidence. Nevertheless, noise may be manipulated into a form of knowledge (what does not work)"* (Data Science Association, 2016).
- **Objectivity** is the extent to which data are unbiased (unprejudiced) and impartial. Information Quality (IQ) dimension.
- **Organisational Decision-making (ODM):** Focuses on decision-making as an element of organisational behaviour, specifically decision-making behaviours in individuals when acting as a member of an organisation. Decision analysis sub-discipline.
- **Outcomes** are the consequences associated with implementing a candidate alternative given a state of nature. Decision-making element.
- **Recognition-Primed Decisions (RPD) model** defends that experienced decision-makers rarely had time to consider alternative options. Instead of generating a range of options, comparing them and selecting the best one at a specific decision point, they depend on their own experience and mix situation awareness and mental simulation (Klein, 1993; Lipshitz, Klein, Orasanu, & Salas, 2001). The model has three variations and includes four crucial aspects of situational assessment (goals, cues, expectancies and actions) but with different complexity levels (Klein, 1993; Klein & Crandall, 1995). Naturalistic Decision Making (NDM) model.
- **Relevancy** is the extent to which data are applicable and helpful for the task at hand. Information Quality (IQ) dimension.
- **Reliability** is the extent to which information is reliable or trustable. Information Quality (IQ) dimension.
- **Reputation** is the extent to which data are trusted or highly regarded in terms of their source or content. Information Quality (IQ) dimension.

- **Risk communication** is the interactive exchange of information related to a real or perceived risk (Committee on Risk Perception and Communication, 1989).
- **Social media** is a set of internet-based applications built on the collaborative concept of Web 2.0 technologies which support the creation and dissemination of user-generated content, and online social networking. Each platform presents a different level of social presence/media richness and self-presentation/self-disclosure, enabling communication and information revelation. Social media support social interaction and personal disclosure through the creation, posting, sharing and diffusion of rich user-generated content in the form of comments, documents, video, photos or audio files. Social media technology is based on seven functional building blocks: identity, conversations, sharing, presence, relationships, reputation and groups. Social media types include blogs, social networking sites, virtual social networks, content communities, virtual game worlds, news and activities feeds, location-based services and social couponing.
- **States of nature** are a set of pertinent attributes describes nature. A 'state of nature' is identified by specifying a level or magnitude for the measure of each member of this set of attributes. There is a probability associated with each state of nature where their sum equal to 1. Decision-making element.
- **Theory of Situational Awareness (SA).** There is an ongoing awareness of one's environment and not only the detection of isolated signals, stimuli, or cues, or even the perception of static objects. There is as an inverse relationship between SA and complex and dynamic environments. Situational awareness decreases during uncertain events.
- **Timeliness** is the extent to which data the age of the data is appropriate for the task at hand. Information Quality (IQ) dimension.
- **Twitter** is a micro-blog platform that allows users to create profiles, generate content and search information. It is limited to 280 characters which are mostly visual (text, photos, polls) but can include acoustic content (i.e. through recordings). Twitter enables inter-personal relationship allowing users to share information with their followers and followees in a public or private space (direct messages).

- **Uncertainty** is the magnitude of a decision criterion depends on the state of nature and the decision alternative. The magnitude of given decision criteria cannot be known with certainty when an alternative must be selected. Decision-making element.
- **Understandability** is the extent to which data can be understood and processed. Information Quality (IQ) dimension.
- **Usability** is the extent to which data can be used for the task at hand. Information Quality (IQ) dimension.
- **Utility** is used to identify the scalar measure of relative contribution to success. It may be done subjectively, intuitively or implicitly. Information Quality (IQ) dimension.
- **Value-added** is the extent to which data are beneficial and provide advantages from their use. Information Quality (IQ) dimension.
- **Web 2.0** is a term first used in 2004 and describes a new way of using the web in which all users continuously modify content and platforms in a participatory and collaborative approach.

Chapter 1. Introduction: research overview

Chapter 1 provides an overview of this research. First, the researcher outlines the rationale for this study (section 1.1). The use of online platforms (e.g. Twitter) presents multiple benefits for risk communication and information search in major incidents (e.g. emergencies); however, its usage is not exempt from challenges for decision-making in these uncertain situations. One of the most serious difficulties is the evaluation of Information Quality (IQ) in these platforms.

After surveying the literature review, the researcher found the analysis of Twitter IQ for decision-making in major incidents as an interesting avenue to explore. This research is a descriptive study about decision-making using online information (e.g. Twitter) in dynamic, complex, and uncertain naturalistic environments (e.g. major incidents). Findings in this area contribute to theory and contribute to minimising the impact of emergencies and disasters in human life and material losses by supporting decision-making processes. Thus, section 0 presents this study's research objective: "the development of a descriptive model to assist the Evaluation of Twitter Information Quality in Incidents (ETIQI) for decision-making". This objective is achieved by answering three Research Questions (RQs) related to the definition of requirements (RQ1), identification of IQ dimensions (RQ2) and understanding of experts' decision-making processes (RQ3).

Section 1.3 provides a summary of the research strategy and maps it against the organisation of this study. This research is operationalised through three phases: 1) understanding of the model requirements; 2) identification of Information Quality (IQ) dimensions; and 3) development of a descriptive model through experts' input. The chapter concludes by describing research findings' contributions and impacts on academia and practice (section 1.4).

1.1. Rationale for the study

Decision-making in naturalistic environments (e.g. non-routine incidents such as emergencies and disasters) is intrinsically different from other settings. Decision-making is defined as *"a mechanism for making choices at each step of the problem-solving process"* (FEMA Independent Study Program, 2005, p. 2.1). The decision-maker reaches a decision (outcome) after following each step of the problem-solving process. Decision-making steps involve evaluating different decision criterion established by the decision-maker in conjunction with the consideration of the utility and uncertainty (Lifson, 1972). While the elements of a decision remain the same (i.e. decision-maker, outcome, decision criteria, utility, uncertainty), decision-making in this context is so different that a new school, the Naturalistic Decision Making School (NDMS), was born in 1989 (Klein, 2008).

The importance of decision-making in major incidents and emergencies is exceptionally high. An emergency is defined as an extraordinary situation in which emergency stakeholders are unable to meet their basic survival needs, or there are severe and immediate threats to human life and well-being and calls for immediate action (Blanchard, 2008; Emergency Management Australia, 1998; Reliefweb, 2008). Hence, critical decision-making is paramount to make timely sound decisions to reduce human and material losses (Kowalski-Trakofler et al., 2003).

Decisions in this context are more difficult as they occur in naturalistic environments which are by definition dynamic, urgent, complex and uncertain situations (Aldunate et al., 2005; Comfort, 1999; Danielsson & Ohlsson, 1999; Kapucu & Garayev, 2011; Moynihan, 2008). In addition, in major incidents, all stakeholders do not have the same experience or access to the same information sources. For instance, emergency management organisations have access to more reliable information sources than citizens who must rely on Mass Communication Media (MCM) for updates. Social media, especially Twitter, is nowadays being used as an MCM and an information source before, during and after major incidents.

Twitter is a micro-blog platform that allows users to create profiles, generate content and search information. Access to Twitter and its data can support the decision-making

process in major incidents from two perspectives: risk communication channel (mass broadcasting and peer-to-peer bidirectional conversation), and information source. Twitter's features are empowering citizens to share information with their peers but also with emergency organisations. Any emergency stakeholder can post content and share it with a large population.

However, Twitter usage presents a number of Information Quality (IQ) challenges to overcome, including the difficulty of finding relevant information (big noise), information shift, completeness of the information, and users' intention while creating or sharing inaccurate information: intentional or unintentional. These challenges are translated to the malicious use of social media and sharing misinformation. There is a high interest in this topic from a knowledge development (theory) and implementation (emergency management practice) perspective. European funded projects (e.g. InVID, 2016; Reveal Project FP7, 2017; WeVerify H2020, 2018) and private companies (e.g. Facebook, n.d.; Google News Initiative, n.d.) are working together with scholars and experts' practitioners to support verification and fact-checking initiatives mostly in the area of journalism but also in emergency-related areas (e.g. crisis computing).

Over the last few years, researchers have provided suggestions to solve some of these challenges, focusing on evaluating user-generated content, users' information, network behaviour, and the support of experts, crowds, and machines (Conrado, Neville, Woodworth, & O'Riordan, 2016). After reviewing the suggested approaches, it is deemed appropriate to evaluate a more holistic approach to address the challenges outlined and evaluate Information Quality (IQ). Further analysis of these in the area of social media use in major incidents for decision-making is required to understand how it can impact Twitter IQ and reduce any uncertainty in emergencies. In summary, this research looks into how decisions are made in naturalistic environments using online information, in particular from Twitter.

1.2. Research objective and research questions

Information Quality (IQ) is one of the main challenges of using social media (e.g. Twitter) for decision-making in major incidents (e.g. emergencies). In order to reduce uncertainty, one of the goals of this research was to create a descriptive model to illustrate the Evaluation of Twitter Information Quality in Incidents (ETIQI) for decision-making followed by experts.

In emergencies, a model is understood as a chart that shows theoretical links between different variables or relationships in or among groups (McEntire, 2004). By providing a descriptive model that includes the perception of information in major incidents such as emergencies, the study enhances our theoretical understanding of decision-making using social media and user-generated content. Therefore the objective of this researcher was:

> ***'To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents.'***

A review of the literature in Information Quality (IQ), Emergency Management (EM) and social media (especially Twitter) helped to operationalise the objective through three phases. These were coined into three Research Questions (RQ):

RQ1 - Research scope: How is Twitter used for decision-making in major incidents?

The use of Twitter for Emergency Management (EM) is still in its infancy. Research in the real impact of the information obtained using this channel for decision-making is a novelty. Emergency management organisations use Twitter as part of their risk communication strategies; however, there is limited evidence of its use as an information source for decision-making. Therefore, this research proposed to investigate further how emergency stakeholders use Twitter for decision-making in major incidents. The first Research Question (RQ) was:

> *'RQ1. How is Twitter used for decision-making in major incidents?'*

The findings obtained from this research question helped define the context for building an Evaluation for Twitter Information Quality in Emergencies (ETIQI) model.

RQ2 - IQ dimensions: What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?

Twitter enables sharing timely information in major incidents and emergencies but also presents challenges associated with its usage. After reviewing previous research, five fundamental problems were identified. Three of them are related to system characteristics (velocity, volume and variety) and the other two to the user interaction with the platform (malicious use and information inaccuracy).

A gap was identified in Emergency Management (EM) as limited research has been published in information quality (IQ) for Twitter. The researcher aimed to lessen this gap by aligning the emergency management Information Quality (IQ) requirements with IQ dimensions identified in Information Systems (IS) and social media. Little was known about the IQ dimensions available on Twitter for emergency management; therefore, the following question was proposed:

> *'RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?'*

The identification of information requirements in emergency management and how this aligns with IQ dimensions provided the second step to develop the model and defined the scope to analyse IQ dimensions' relationship with quality and uncertainty reduction.

RQ3 – Decision-making steps: What steps are followed by experts to use Twitter in their decision-making process in major incidents?

Lastly, several existing IQ framework models have been published in the area of Information Systems (IS). A more limited number exist in Emergency Management (EM). While efforts have been made to evaluate Emergency Management Information Systems (EMIS) and data integration, to the best knowledge of the researcher, there is not an existing model to illustrate the evaluation of Twitter IQ for decision-making in emergencies followed by experts. Furthermore, decision-making is a mechanism that

includes multiple steps to support the decision process. Hence, any proposed model that does not define the steps of this process fail to support decision-making.

After evaluating the IQ dimensions in RQ2, the researcher analysed their relationship to develop a must-have IQ model to help stakeholders reduce emergency decision-making uncertainty using Twitter's information. Hence, the following Research Question (RQ) was outlined:

> *'RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?'*

The following section defines the research process strategy used to answer these RQs and describes this research's organisation.

1.3. Research strategy and organisation of research

This research investigated experts' decision-making processes in naturalistic environments (e.g. major incidents) using online social media platforms such as Twitter to develop an Information Quality (IQ) model. Figure 1-1 provides a visual illustration of this research strategy and its organisation.

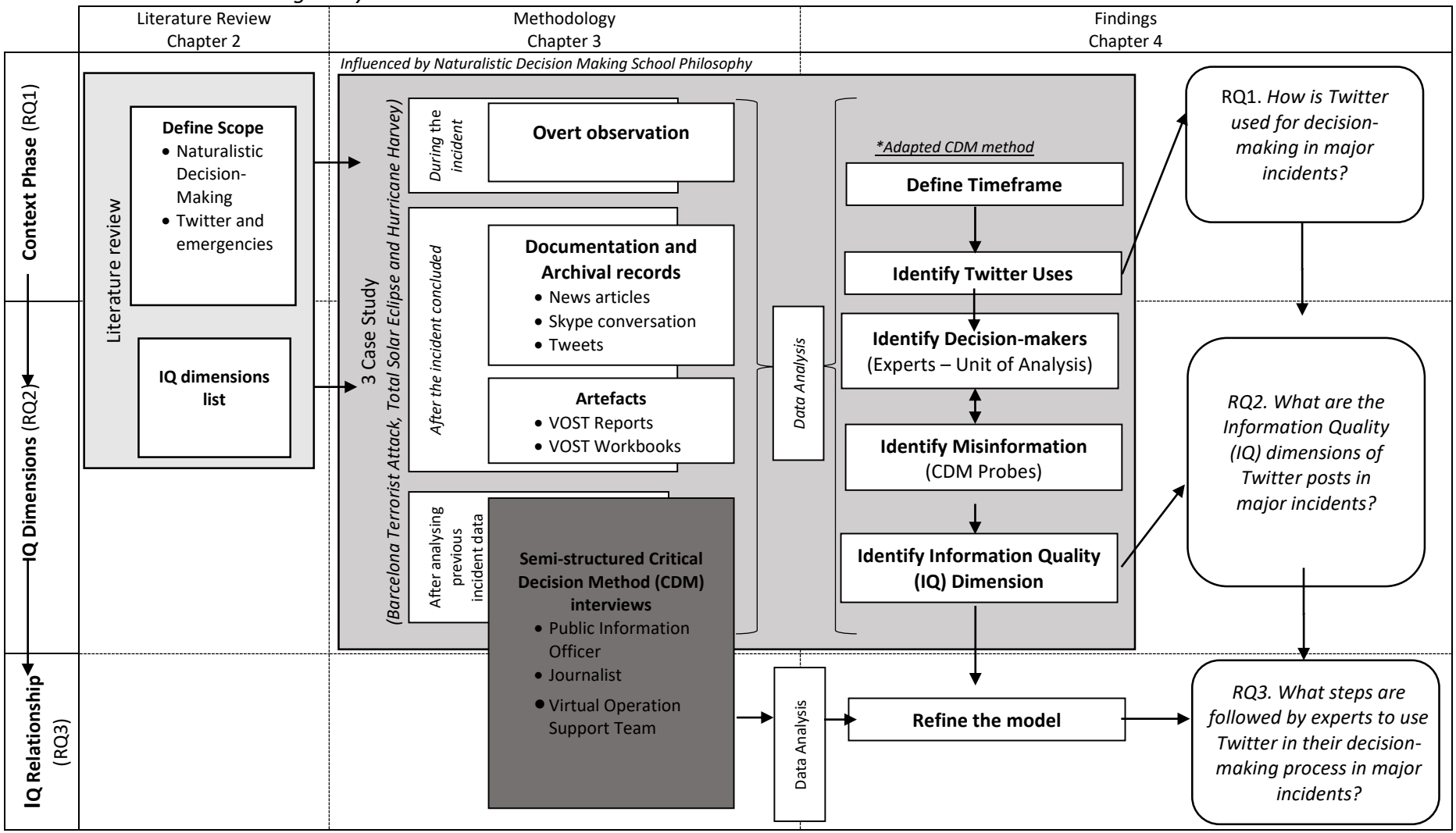


Figure 1-1 Research structure overview

The literature review (Chapter 2), summarised in section 1.2., identified a gap in understanding decision-making processes using Twitter in emergencies which could be addressed by evaluating Twitter Information Quality (IQ) to reduce uncertainty. The analysis of decision-making in major incidents (e.g. emergencies) aligns itself within the Naturalistic Decision Making School (Chapter 3) and its philosophy.

As described in section 1.1., decision-making in emergencies has different characteristics of decision-making in other situations (e.g. ill-structured problems, uncertain dynamic environments, shifting, ill-defined or competing goals, time stress). The Naturalistic Decision Making School (NDMS) of thought addresses these differences by proposing research methods that encourage experts' eliciting knowledge using real case scenarios (Klein, Orasanu, Calderwood, & Zsambok, 1993). They are based on an interpretivism (relativism) approach, which defends that reality is subjective and different from person to person. This research advocated that reality is a social construction somewhat impacted by the projection of human interpretation and imagination. The researcher believes that social media provides us with an excellent example of this. The same event can be defined, explained and justified using a large variety of subjective premises, all depending on users' interpretation. In addition, the NDMS argue that the perception of reality and the decision-making process varies according to the decision-maker's expertise. Therefore, the world's existence and its interpretation depend on our knowledge of it (Grix, 2004).

As the NDMS focuses on real-world incidents, there are ethical challenges to overcome while selecting the appropriate methodology. This research addressed these difficulties using three case studies with experts' Critical Decision Method (CDM) interviews. The cases studied took place in August 2017: Barcelona Terrorist Attack, Total Solar Eclipse, and Hurricane Harvey.

Rich data from multiple sources of evidence (overt observation, documentation and archival records, artefacts and semi-structured CDM interviews) were utilised to support the following research protocol: 1) define the timeframe of each case study, 2) identify decisions to use Twitter, 3) identify decision-makers, 4) identify misinformation /rumours (probes), and 5) identify Information Quality (IQ) dimensions. All these data

informed the CDM interviews to Public Information Officers (PIOs), journalists and Virtual Operation Support Team (VOST) members. They are experts in the use of Twitter in major incidents (unit of analysis). In turn, this protocol (as illustrated in Figure 1-1) supported the documentation of 75 decision-making processes. Experts' mental processes were used to fulfil step 6, establishing the model's IQ dimensions conceptual relationship. This research's findings are presented in Chapter 4, and they answer the three research questions outlined in section 0. Furthermore, they enabled the researcher to develop the Evaluation of Twitter Information Quality in Incidents model (ETIQI), which could aid decision-making in naturalistic environments (Figure 1-2 page 11).

To conclude, the researcher summarises the research's findings and their implication in Chapter 5, closing with the proposed ETIQI model fulfilling this research's objective and outlining the benefits of this descriptive model to practice and theory. For the reader's assistance, conclusions and key contributions are summarised in section 1.4 of this introductory chapter.

1.4. Conclusions and key contributions

Information Quality (IQ) is relevant to any decision-making process. Its importance increases when decision-makers employ Twitter data in naturalistic environments such as major incidents (e.g. terrorist attack, hurricanes, fires, pandemics). This social media platform, a popular tool in risk communication and emergency research, provides decision-makers with a large volume of data presented in a high-velocity context and variety of formats. These characteristics can enhance decision-making before, during and after an incident. However, at the same time, they impact negatively on the uncertainty level of any decision. In addition, user-generated content can include misinformation and rumours, which influences the quality of the information and endangers decision-makers.

This research contributes to the theory and practice of Emergency Management (EM), Information Quality (IQ) and User-Generated Content (UGC), especially Twitter. It enables academia and practitioners alike to understand better (RQ1) the use of Twitter

in emergencies for decision-making, (RQ2) the Information Quality (IQ) dimensions of Twitter posts in this context and (RQ3) the steps required for Twitter posts to be used for decisions in emergencies.

The researcher also suggests that Information Systems (IS) research can benefit from the Naturalistic Decision Making School (NDMS) of thought while designing task-specific systems for emergency managers, where data uncertainty is inherent. Key contributions are further described as part of the conclusions' summary in Chapter 5.

This research highlights how emergency stakeholders use Twitter data from a production and consumption perspective in order to reduce uncertainty and facilitate decision-making processes. Evidence gathered through the three case studies (Barcelona Terrorist Attack, Solar Eclipse and Hurricane Harvey) illustrated the use of Twitter posts in the outcome of four key decisions: 1) the creation of tweets, 2) the engagement with tweets, 3) the development of news articles, and 4) the escalation of information to emergency management organisations. While these uses are not exhaustive, they showcased best practices in the three case studies and provided examples of efforts to evaluate information utility and reduce uncertainty.

The identified examples became the probes for the interviews designed using the Critical Decision Method (CDM). Through data triangulation and including Subject-Matter Experts (unit of analysis) in the use of Twitter in major incidents, the researcher evaluated existing Information Quality (IQ) dimensions proposed in previous research in the area of Information Systems (IS) and Emergency Management (EM). After a comprehensive analysis, it was concluded that not all Twitter Information Quality (IQ) dimensions have the same relevance in major incidents. Subject-Matter Experts (SMEs) agreed on the importance of information utility, timeliness, source reputation and comparability as critical dimensions for decision-making in major incidents using Twitter. In addition, it was stated that citizens play a crucial role in creating tweets in major incidents (e.g. emergencies) which can help but also difficult decision-making in these situations. Therefore, dimensions that supported comparability (e.g. amount of information, completeness, and concise representation) were suggested to increase IQ

perception and enabled decision-makers to confirm their internal model with contextual data.

While efforts were made to describe these dimensions as discrete variables, SMEs referred to their decision-making processes as a combination of dimensions. The researcher contributes to the emergency management research area by proposing an Information Quality (IQ) descriptive model based on the proposed dimensions' conceptual relationship (Figure 1-2).

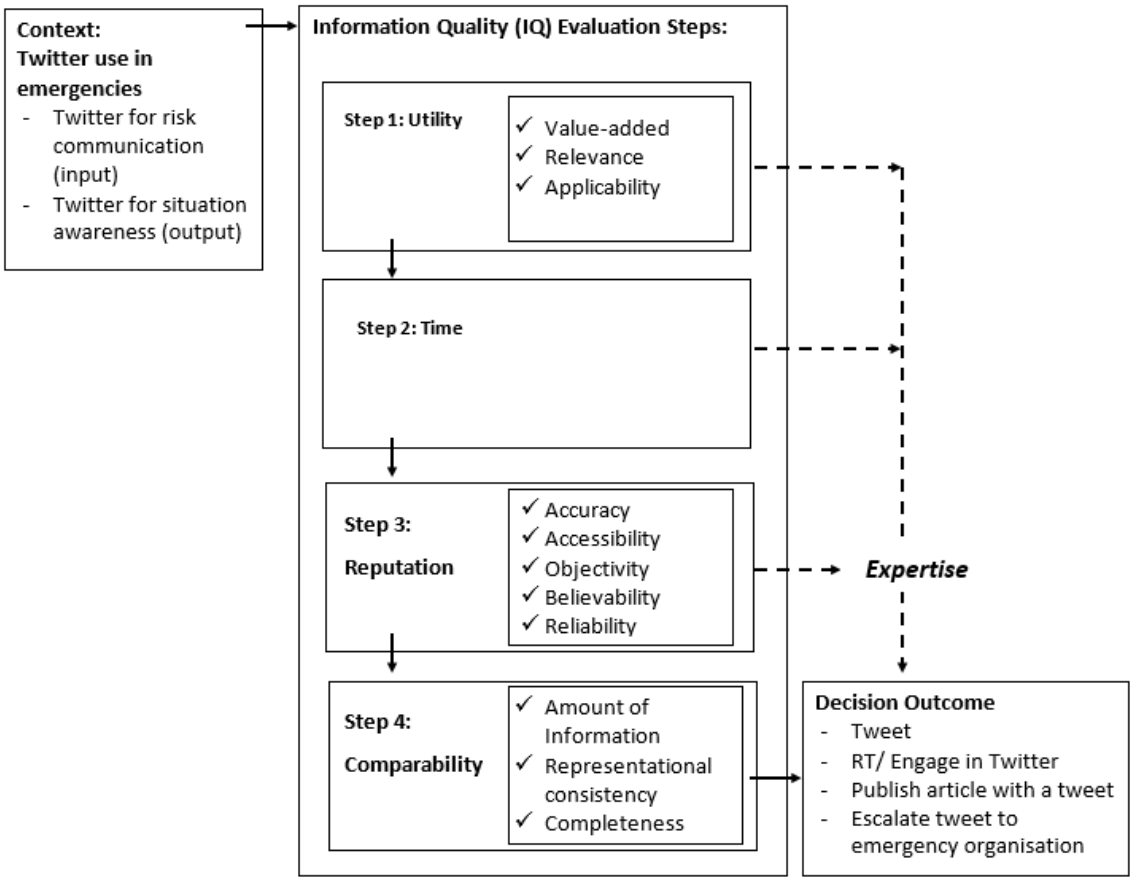


Figure 1-2 Evaluation of Twitter Information Quality in Incidents model (ETIQI model)

As described in Figure 1-2, the proposed model (ETIQI) was built centred on the steps outlined by experts in the area and based on four key dimensions: utility, timeliness, reputation and comparability. This descriptive model proposes decision-makers to evaluate tweets' utility in emergencies and major incidents concerning tweets applicability, relevancy and value-added. When utility is deemed appropriate, timeliness of the information is deliberated as in major incidents, Twitter's data can become quickly outdated. Then, the information source reputation should be taken into account. All

interviewees agreed on the relationship between IQ and official sources. Key dimensions associated include source accessibility and accuracy of information provided. Additionally, subjective dimensions such as reliability, objectivity and believability were mentioned as relevant while assessing IQ.

To conclude, when official sources are not available, it is encouraged to assess tweets based on a comparability approach. Therefore, decision-makers must consider the amount of information, its representational consistency and its completeness as part of the decision-making process. Through information triangulation between sources and messages shared by each Twitter user, decision-making uncertainty can be reduced. This descriptive model can be applied to Twitter IQ from a production and consumption perspective. In turn, the Twitter IQ challenge in Naturalistic Decision Making (NDM) described in the literature review (Chapter 2) can be minimised.

While the researcher encourages applying the model process from beginning to end, evidence in this and previous research demonstrated that experts use cues, their own expertise and mental models to reach decisions without comparing all options. Hence, they may exit the proposed model at any step when they are satisfied. This finding provided evidence of how the Prime Recognition Model (PRM) and Situational Awareness (SA) theory apply to Twitter User-Generated Content (UGC) in emergencies. Hence, it contributes to the development of the theory in the NDMS and, at the same time, to Information Quality (IQ) research.

Overall, the ETIQI model can be utilised while developing risk communication strategies, performing information search in Twitter in major incidents (e.g. emergencies), and training novice and citizens in the use of Twitter for decision-making in naturalistic environments. It can also help in the design of expert systems in the area of emergency management, including Twitter information. As described by Elliot (2005, p. 46), *"successful research in this area [naturalistic decision-making] could allow people to be trained to think like experts, possibly without the large time commitment generally associated with becoming an expert."* In turn, this can contribute to improving problem-solving processes. Good decision-making can prevent tragedy and help emergency stakeholders to recover more quickly (FEMA Independent Study Program, 2005).

Chapter 2. Twitter Information Quality (IQ) challenges in emergencies

Chapter 2 provides the reader with a theoretical background of the use of Twitter in naturalistic environments for decision-making, its challenges associated, and existing solutions to reduce uncertainty. Through the literature review, the researcher identified a gap in the solutions available to reduce Twitter uncertainty in major incidents for decision-making and found a suitable school of thought within the Naturalistic Decision Making School (NDMS) to investigate and address this gap. Lessons learned from the literature review allowed the researcher to detect future contributions of this research to academia and practice.

Figure 2-1 (page 14) provides a conceptual model of the literature review described in Chapter 2 and the research questions proposed. Chapter 2 is divided into four sections.

In the first section (2.1), the researcher describes the decision-making process in emergencies. Decision-making is a complex research area that comprises multiple schools and disciplines (section 2.1.1). The researcher focused on explaining the singularities of decision-making in emergencies and the role of the NDMS in analysing decisions in uncertain events (section 2.1.2). Section 2.1.3 describes how decisions are made in emergencies. In specific, it describes two Naturalistic Decision Making (NDM) contributions: Recognition-Primed Decisions (RPD) and Theory of Situational Awareness (SA) theory. Both are based on the concepts of expertise and information available to the decision-maker. It is noted that different emergency stakeholders have access to different information sources. Section 2.1.4 describes the most relevant Information and Communication Technologies (ICT) available during major incidents, while section 2.1.5 focuses on the role of risk communication as an information source. There are multiple channels available to emergency stakeholders, with social media being one of the newest additions. The literature review illustrates an extended research body around the social media platform: Twitter.

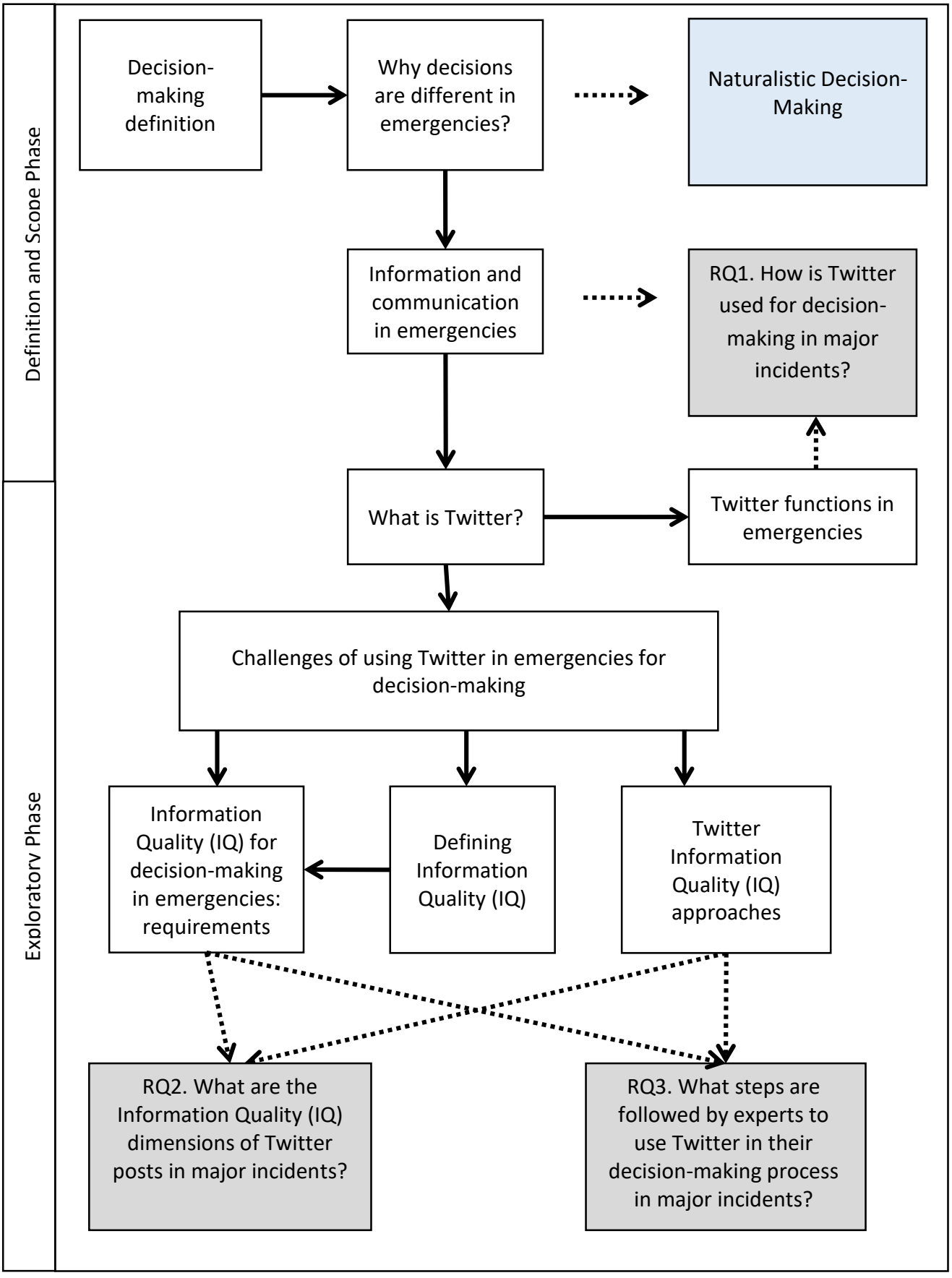


Figure 2-1 Literature review conceptual model

In the second section (2.2), the researcher evaluates Twitter for decision-making during emergencies. The reader is provided with an operational definition of Twitter (2.2.1) and its functions during emergencies (2.2.2). The researcher proposes to analyse the use of Twitter in major incidents using two research lens: risk communication (tweets creation and bidirectional capability described in section 2.2.3), and information source (tweets consumption for SA in section 2.2.4). While it is within this latter approach that Twitter becomes an asset for decision-making: an efficient decision-making process in the production of tweets will also benefit the consumption of this information. Section 2.2.6 focuses on the challenges of using Twitter in emergencies for decision-making. It is analysed from two perspectives. First, from a macro big data consumption approach reviewing challenges associated with volume, velocity, and variety of the information. Secondly, from a message level with a focus on the role of information creation: malicious use, inaccurate information and rumours. All these challenges pose an Information Quality (IQ) problem to use Twitter in uncertain Naturalistic Decision Making (NDM) environments.

Therefore, section 2.3 describes previous efforts performed to address Twitter Information Quality (IQ) challenges in major incidents. First, in section 2.3.1, the concept of IQ is introduced from a production and consumption perspective. Then, IQ dimensions and framework models in the Information Systems research area are introduced (2.3.2). As the research focuses on Emergency Management (EM), using the literature review, the researcher documented IQ requirements for decision-making in this area (section 2.3.3). To conclude, existing studies addressing Twitter information challenges are described in section 2.3.4.

The literature review concludes in section 2.4. It summarises all literature findings, and the reader is provided with an overview of the research questions and methodology chosen to address the research objective. It closes by evaluating the implications of the literature reviewed for the development of this research. The researcher uses the knowledge extracted from existing research to justify 1) the approach to the study topic, 2) the selection of the research methodology, and 3) demonstrate contribution. By reviewing the existing body of knowledge, the researcher identified a gap in the

literature and theoretical background to answer the research objective and its associated research questions.

2.1. Decision-making in major incidents

People make many decisions every day; however, decision-making in major incidents (e.g. emergencies) is different. While the key parameters of a decision - such as a decision-maker, alternatives, decision criteria and uncertainty- remain the same (section 2.1.1), the approach to decision-making varies. Therefore, in section 2.1.2, the researcher describes '*why decision-making is different during major incidents?*' by defining emergencies and disasters and describing the singularities of decision-making in uncertain environments. Published work (e.g. Doyle, McClure, Paton, & Johnston, 2014; Gore & Ward, 2017; Lipshitz & Strauss, 1997) shows that differences are such that a new school of thought, the Naturalistic Decision Making School (NDMS), was created. This school investigates the decision-making process (section 2.1.3) in complex environments, for instance, major incidents (emergencies and disasters alike), where information access and Information Quality (IQ) are uncertain. NDMS researchers capture and analyse differences with the traditional decision-making model. For instance, the NDMS advocates that it is challenging to evaluate decision-making in a laboratory as it is impossible to recreate an emergency setting and the characteristics faced by a decision-maker. Additionally, it would be unethical. This premise impacts the development of any research strategy in Emergency Management (EM) and conditions the selection of a suitable methodology. Therefore, the NDMS advocates the need to investigate decision-making in naturalistic environments (Klein, 2008).

NDM researchers had contributed to Emergency Management (EM) practice and theory development. Two key theoretical contributions include (Hoffman & Militello, 2008): Recognition-Primed Decisions (RPD) and Theory of Situational Awareness (SA). Both highlight the importance of expertise and information access. NDMS argue that experts in an emergency do not make decision comparing alternative options, but they use their previous experience and decision-makers' situation awareness to make a decision. However, not all emergency stakeholders are experts. Furthermore, it is noted that experts tend to have access to more reliable information sources (section 2.1.4) than

citizens which must rely on Mass Communication Media (MCM) for updates. Therefore, the importance of risk communication for decision-making must be considered (section 2.1.5).

A relatively new MCM used for major incidents is social media, especially Twitter. Its features are empowering citizens to share information with their peers but also with emergency organisations. Further research is required to understand better how Twitter can meet emergency management requirements and what IQ limitations have Twitter as an information source.

2.1.1. Decision-making definition

Decision-making has been analysed by multiple scholars in diverse areas, including finance, economics, and emergency management, to name a few (H. A. Simon, 1959). Overall, decision-making is defined as *"a mechanism for making choices at each step of the problem-solving process"* (FEMA Independent Study Program, 2005, p. 2.1). Therefore, it is a process with different steps.

Any decision has a set of basic elements that include (Table 2-1): decision-maker, candidate alternatives, control variables, states of nature, outcome, decision criteria, utility and uncertainty. In a nutshell, a decision is taken by a decision-maker after considering candidate alternatives. Any of these alternatives has characteristics associated (control variable) with a different state of nature, a level of uncertainty and a level of utility for the decision-maker. The evaluation of the decision criteria, established by the decision-maker in conjunction with utility and uncertainty considerations, will motivate a decision and, therefore, an outcome.

Table 2-1 (page 18) provides definitions of the basic elements of a decision.

Element	Definition
Decision-maker	Individual or set of people who has to select an alternative.
Candidate alternatives	An alternative course of action, a candidate solution to a problem. They are mutually exclusive.
Control variables	Characteristics that describe a candidate alternative. A change in one control variable constitute a different alternative.
States of nature	A set of pertinent attributes describes nature. A *'state of nature'* is identified by specifying a level or magnitude for the measure of each member of this set of attributes. There is a probability associated with each state of nature where the addition of all of them is equal to 1.
Decision criteria	Each dimension of an outcome which is significantly affected by choice of alternatives, and which decision-maker considers being critical in making his decision.
Outcome	Consequences associated with implementing a candidate alternative given a state of nature.
Utility	Used to identify the scalar measure of relative contribution to success. It may be done subjectively, intuitively or implicitly
Uncertainty	The magnitude of a decision criterion depends on the state of nature and the decision alternative. The magnitude of given decision criteria cannot be known with certainty when an alternative must be selected.

Table 2-1 Decision elements (Lifson, 1972)

In any given emergency, a decision-maker can be any emergency stakeholder, including citizens and organisations alike. The decision-maker will consider candidate alternatives as a possible solution. For example, in a flood event, decision-making may have two candidate alternatives: to stay (alternative 1) or to evacuate (alternative 2). Many control variables will describe each alternative, and a change in one of these variables will prompt a different candidate alternative. The selection of one or another alternative is given a state of nature that will inspire an outcome. In the flooding example, the outcome could be a high probability of drowning if the decision-maker chooses the alternative of staying and rainfall is over 100ml per hour (example of a state of nature). The decision will be made in relation to a set of decision criteria, for instance, the rain level prediction (example of decision criteria 1) or the number of days projected before being allowed to come back (decision criteria 2), amongst others.

Any decision will have a level of uncertainty. The scale is related to the information known by the decision-maker and its degree of certainty. In the flooding example, the magnitude of the decision criterion *'rain level prediction (decision criteria 1)'* depends on the state of nature, *'e.g. rainfall is over 100ml per hour (state of nature)'* and on the alternative *'stay'*. The magnitude of a given *'rain level prediction (decision criteria 1)'*

cannot be known with certainty when a different alternative, *'e.g. leave',* must be selected.

While in principle, most decisions could include all the concepts defined in Table 2-1, decision-making research had focused more on one or another key element. Existing decision-making models are generally classified in two continuums: analytic-heuristic continuum and heuristic judgment continuum (Kapucu & Garayev, 2011). Traditional theories (analytic-heuristic continuum) include normative, prescriptive and descriptive models of analytical decision-making, which are based on the evaluation of candidates alternatives in the decision-making process (Bell, Tversky, & Raiffa, 1988; Elliott, 2005; Flin, 2001; McFall, 2015; Smith & Dowell, 2000). However, in dynamic, complex and uncertain incidents where group decisions may be required, the analytical approach may not be suitable. Decision-making models based on heuristic judgments have been then considered. In this setting, most decisions are the products of complex interactions (Patterson, Weil, & Patel, 2010) with sometimes faulty or incomplete information (Kowalski-Trakofler et al., 2003; Tapia & Moore, 2014).

Within the two continuums, analytic-heuristic continuum and heuristic judgment continuum, there are four main decision-making sub-disciplines:

i. **Classical Decision-making (CDM*):** Focuses on the development and study of operational decision-making methods.
ii. **Organisational Decision-making (ODM):** Focuses on decision-making as an element of organisational behaviour, specifically individuals' decision-making behaviours as part of an organisation.
iii. **Judgment and Decision-making (JDM):** Emphasises normative, descriptive, and prescriptive theories of human judgments and decisions.
iv. **Naturalistic Decision Making (NDM):** Emphasises psychological approaches and methods in decision processes. It is based on careful descriptions of how experts make choices in complex, real-world situations.

Of these four, NDM has been previously used in the area of emergency management. Its theories focus on the decision-making process in naturalistic environments, including situations with high pressure, unclear goals and high uncertainty levels (Elliott, 2005).

Researchers within this school argue that the decision-making process is different in emergencies. Section 2.1.2 describes the singularities of decision-making during emergencies and further explains the NDM School.

2.1.2. Why are decisions different?

Decision-making is a critical skill in emergencies when it is paramount to make timely sound decisions to reduce human and material losses (Kowalski-Trakofler et al., 2003). Emergencies are dynamic, urgent, complex and uncertain environments (Aldunate et al., 2005; Comfort, 1999; Danielsson & Ohlsson, 1999; Kapucu & Garayev, 2011; Moynihan, 2008) where a large number of decisions must be taken (Helsloot & Ruitenberg, 2004).

Decision-making in Emergency Management (EM) has been addressed by scholars of the field from different perspectives, including individual (Allison & Zelikov, 1999; Bigley & Roberts, 2001; Flin, Slaven, & Stewart, 1996; Flüeler, 2006), group (Driskell & Salas, 1991; Salas, Burke, & Samman, 2001; Takada, 2004), organisational (Quarantelli, 1997; Rosenthal & Kouzmin, 1997) and collaborative/more than one organisation level (Kapucu & Garayev, 2011). The consensus is that major incident, emergencies and disasters require a non-traditional approach to decision-making.

To better understand the importance of decision-making in these situations, this section describes its singularities from a decision-making perspective. The provision of a definition for *'emergency'* is challenging. On the one hand, *'emergency'* and *'disaster'* terminology is usually misused by citizens, journalists and even emergency services. On the other hand, various *'emergency'* and *'disaster'* definitions exist (Oliver-Smith, 1999; R. W. Perry, 2007). In addition, major incidents that involve a large congregation of people (e.g. concerts, political manifestation) are sometimes prepared and managed as emergencies by Emergency Management organisations in order to minimise potential risks, and they do not become an emergency or a disaster.

In this research, the terms of emergency, disaster and major incident are used based on their similarities:

> *'An extraordinary non-routine situation in which emergency stakeholders could or are unable to meet basic survival needs, or there are severe and immediate*

> *threats to human life and well-being, and calls for urgent action (Blanchard, 2008; Emergency Management Australia, 1998; Reliefweb, 2008).'*

Porfiriev (1995) states that disaster and emergencies may involve communities; however, disaster focuses on the community and not individual needs. The Australian Emergency Management Glossary defines a disaster as *"a serious disruption to community life which threatens or causes death or injury in that community and/or damage to property which is beyond the day-to-day capacity of the prescribed statutory authorities and which requires special mobilisation and organisation of resources other than those normally available to those authorities"* (1998, p. 33).

All disasters are emergencies, but not all emergencies are disasters. In fact, an *"effective emergency action can avoid the escalation of an incident into a disaster"* (Beneito-Montagut, Shaw, & Brewster, 2013, p. 23). An emergency may involve citizens or individuals who are unable to meet their basic survival needs, are in danger and require immediate action from emergency managers. This research looks into the commonalities of non-routine major incidents, including emergencies and disasters; moreover, it focuses on the individual perception of Information Quality (IQ) within the decision-making process in this naturalistic environments.

Scholars (e.g. Waugh Jr & Streib, 2006) propose using a four-phased approach to defining emergency management. These four phases (mitigation, preparedness, response, and recovery) have been widely used in emergency management organisations such as the Federal Emergency Management Agency (FEMA) in the United States of America (S. Yang et al., 2013). One phase leads to the next one, and they are timely related depending on their closeness to the emergency incident. However, due to the difficulty of establishing when a phase ends and the next one begins (Neal, 1997), some researchers (e.g. Kaplan, Jacobs, & Tuohy, 2012; Kryvasheyeu, Chen, Moro, & Hentenryck, 2014) prefer to use a three-phase model: before, during and after the incident for their research. For example, in a terrorist attack for the police force, the response phase can last until the perpetrators have been detained, while for first responders, the response phase would end when the injured are attended to at the scene. It creates two different timelines depending on stakeholder perception.

Additionally, the type of incident has an impact on the length of emergency phases. For instance, natural emergencies such as hurricanes may have cycles (e.g. El Niño) and those impact the duration of the mitigation, preparedness, response and recovery phase. Notwithstanding, Yang et al. (2013) succeeded in using Twitter data to visualise the four-phase model; the use of the mitigation, preparedness, response and recovery phases remains a complex issue. Therefore, to better identify the decision-making process, the researcher used the three-phase model (Figure 2-2) while evaluating decision-making in this research.

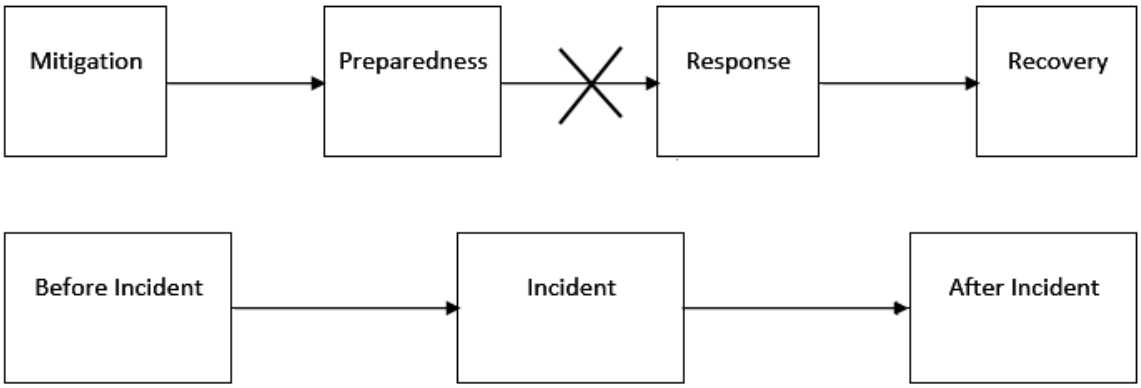


Figure 2-2 Emergency management 4 phases versus 3 phases' model

Decisions in incidents may be affected by several factors. Researchers (Chaudet, Pellegrin, & Bonnardel, 2015; Doyle, Paton, & Johnston, 2015; Klein & Klinger, 1991; Moon, 2002; Orasanu & Connolly, 1993; Osman, 2010) have identified eight essential factors that characterised decision-making in an emergency:

i. Ill-structured problem
ii. Uncertain dynamic environments
iii. Shifting, ill-defined or competing goals
iv. Action/feedback loops
v. Time stress
vi. High stakes
vii. Multiple players
viii. Organisational goals and norms

All these factors present challenges for decision-making. Research had been performed to minimise them analysing the different characteristics such as complexity of the situation and response organisation (Bigley & Roberts, 2001; Carley & Lin, 1997; Sellnow, Seeger, & Ulmer, 2002); the urgency of response (e.g. Buchananan & O'Connell, 2006; Danielsson & Ohlsson, 1999; Flüeler, 2006; Lin & Su, 1998); information uncertainty (e.g. Cosgrave, 1996; Johnston, Driskell, & Salas, 1997; Therrien, 1995); risk perception and cost associated with the decision (e.g. Buchananan & O'Connell, 2006; Lim, Lim, Piantanakulchai, & Uy, 2015); decision-makers stress levels (e.g. Driskell & Salas, 1991; Kowalski-Trakofler et al., 2003; Paton, 2003; Wallace & De Balogh, 1985); and decision-makers' previous experience (e.g. Carley & Lin, 1997; Flin, 2001; Flin et al., 1996; Moynihan, 2008) to name a few. These factors can affect the decision-making process in emergencies.

The Naturalistic Decision Making School (NDMS) focuses on better understand decision-making in naturalistic environments (e.g. major incidents and emergencies) and how decisions are different in this context. Three key differences are noted if compared with other decision-making schools: situation analysed, the expertise of the decision-makers and the research in a real-world setting (Hoffman & Militello, 2008).

- **Situation:** Naturalistic decisions, also referred to as dynamic decision-making (Busemeyer, 2002; Hotaling, Fakhari, & Busemeyer, 2015) or complex dynamic control task (Osman, 2010), investigate ill-structured problems and domains (Hoffman & Militello, 2008). They focus on uncertain and dynamic environments with situations that involve goal conflict or incidents involving high stress due to time pressure and high risk. Decision-making can be analysed individually or as part of a team.
- **Expertise:** NDMS aims to investigate best practices from experts and develop training and decision aids based on research findings (Keller, Cokely, Katsikopoulos, & Wegwarth, 2010). NDM scholars found that experienced decision-makers rely on their tacit knowledge and mental models for decision-making. They defend that decision-makers can identify patterns, and sometimes they do not compare options. Some researchers postulate that decision-makers'

performance can suffer from information overload, which can increment the uncertainty levels (Chengalur-smith, Ballou, & Pazer, 1999; Schulz & Probst, 2012). Therefore, their decisions are not only based on rules and procedures. This approach to decision-making has led to new descriptive decision-making models, which included the concept of *'experience'* as a decision-making variable such as the recognition-primed decision-making. Their interest not only lies in decision-making but also analyses and seeks ways to improve the performance of other cognitive processes, including situation awareness, problem detection and anticipatory thinking.

The challenge of expertise is that not all emergency stakeholders are expert in major incidents. Research shows that communities previously hit by certain types of disasters often respond to the same type more appropriately. They often develop a *'disaster subculture'* in which preparation and exercises are of central importance; however, they cannot always cope with another kind of emergency (Helsloot & Ruitenberg, 2004). Each type of disaster has its unique characteristics; therefore, communication and information technologies can play a vital role in emergencies as part of the intelligence phase of any decision-making process.

- **Real-world situations:** NDMS focus on evaluating real-world situations in dynamic environments. The evaluation of decision-making in a controlled setting is pruned to bias. The characteristics of a crisis, disaster or emergency are challenging to replicate in a laboratory setting. Additionally, experimenters' problem is that it is dangerous and unethical to conduct their studies in truly hazardous or harmful circumstances. Therefore, naturalistic environments are explored as a macro-cognitive phenomenon as opposed to phenomena studies in controlled laboratory conditions (micro-cognitive).

These key characteristics have implications on selecting a suitable methodology and the interpretations of research findings while examining decision-making in major incidents. Researchers must use different techniques to observe and capture data during naturalistic investigations and still obtain reliable results. To explore real-world incidents and collect suitable feedback from experts, the NDMS proposes a set of methodological

techniques aligned with their school of thought. It includes the Critical Decision Method (CDM), Knowledge Audit Method (KAM) and Goal-Directed Task (GDT) analysis. These techniques emphasise evaluating decision-making in a real incident focusing on the interviewee situation awareness of the event evaluated (see Chapter 3 for further information about these methods).

Intending to describe the decision-making process in major incidents (e.g. emergencies), the next section describes how the NDM School has contributed to developing two key theories: the Recognised-Prime Decision (RPD) Model and the Situation Awareness (SA) Theory. Both of them consider the approach to decision-making followed by experts with the available sometimes uncertain information.

2.1.3. The process of decision-making in emergencies

As previously described, the decision-making approach in naturalistic environments (e.g. major incidents) is different. Studies of fire-fighters and nurses in the 1980s demonstrated that the Decision-Analytic Model has significant limitations, and therefore, a new approach was required (Hoffman & Militello, 2008). The Naturalistic Decision Making School (NDMS) was born as a reaction to the analytic heuristic continuum and its normative and prescriptive models.

According to Elliot (2005, p. 8), Naturalistic Decision Making (NDM) theories focus on *"how people use experience to make decisions in naturalistic environments (e.g. under time pressure, shifting conditions, with unclear goals, degraded information and within team interactions)"* where a naturalistic environment is defined as taking place in a real-world context.

Over the years, the NDM community has made multiple practical and theoretical contributions to the emergency management field. Two key theoretical contributions include (Hoffman & Militello, 2008): Recognition-Primed Decisions (RPD) and Theory of Situational Awareness (SA).

The first model, RPD, was developed in 1989 using the information collated from experienced fire-fighter's commanders working under time pressure and uncertainty but has also been explored in other areas such as the military (Klein, 1989). RPD defends

that experienced decision-makers rarely had time to consider alternative options. Instead of generating a range of options, comparing them and selecting the best one at a specific decision point, they depend on their own experience and mix situation awareness and mental simulation (Klein, 1993b; Sellnow et al., 2002). Decision-makers focus on the situation as opposed to analytically comparing all available options.

Figure 2-3 illustrates that the RPD model has three variations (page 27). All include four crucial aspects of situational assessment (goals, cues, expectancies and actions) but with different level of complexity (Kaempf, Klein, Thordsen, & Wolf, 1996; Klein, 1993b; Klein & Crandall, 1995; Pennington & Hastie, 1993):

- **Simple Match:** A decision-maker experiences a situation and responds with the first option identified according to relevant cues, expectancies, goals, and a typical course of action for that incident. Previous experience provides them with prototypes and functional categories for typical cases with typical suitable responses.
- **Developing a Course of Action**: Decision-maker experiences a situation that is not as clear as previously described. Through a story-building strategy, decisions are made using evaluation via mental simulation. Decisions are made according to their likelihood to work.
- **Complex RPD Strategy or progressive deepening:** A more complex, unfamiliar situation is presented, requiring reassessing the situation and seeking more information. Several potential actions are not compared but serially considered concerning their adherence to expectancies and their likelihood to work. It is based on the notion of satisficing described by Simon (1959), where the first workable option is implemented instead of trying to find the best possible option (Klein, 2008).

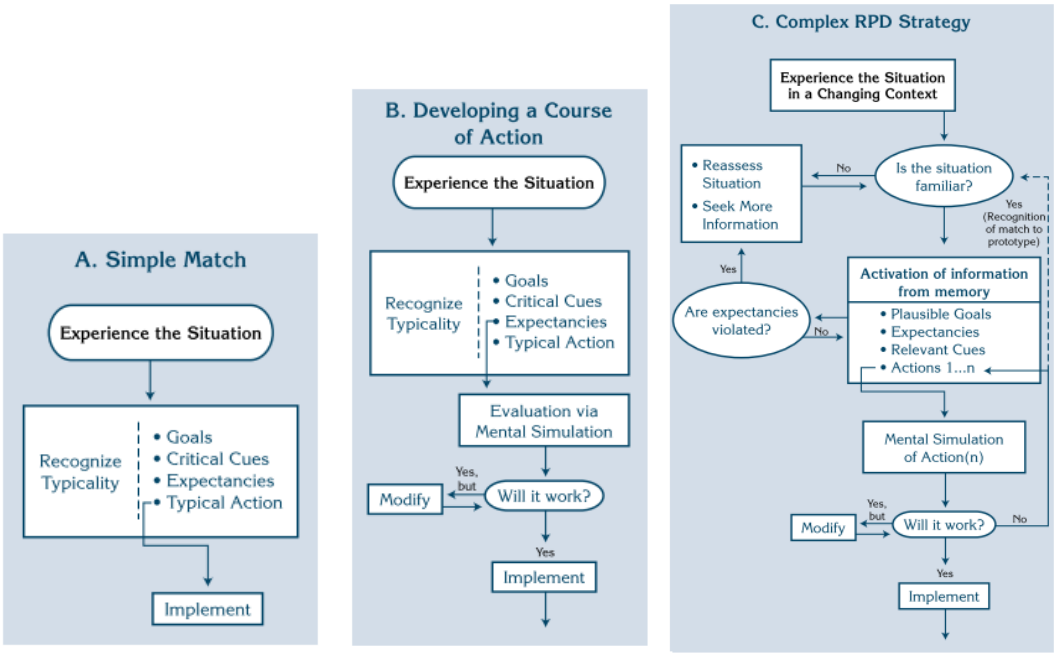


Figure 2-3 Recognition-Primed Decision (RPD) model (Klein, 1993a; Klein & Klinger, 1991)

The second contribution described is the Theory of Situation Awareness (SA). The term situational awareness was first used in aviation, but it has been researched in different contexts, groups/responders such as firefighters, and industry sectors such as nuclear power plants (Endsley, 1995b). SA is relevant for decision-making in complex and dynamic environments (Harrald & Jefferson, 2007). The SA theory emphasises that there is an ongoing awareness of one's environment and not only the detection of isolated signals, stimuli, or cues, or even the perception of static objects. There is an inverse relationship between SA and complex and dynamic environments. Situational awareness decreases during uncertain events. Endsley (1995) proposes a model for the design of dynamic systems. As illustrated in Figure 2-4 (page 28), situation awareness could be achieved through three levels for its successful implementation during the decision-making process (Endsley, 1988):

- **Information Processing:** meaningful interpretation of data as a whole, resultant in information;
- **Model development:** comprehension of information, developing into a mental model or higher level of understanding prioritised according to information related to achieving defined goals; and

- **Projection:** the mental or imaginable forecast of these events into a possible future.

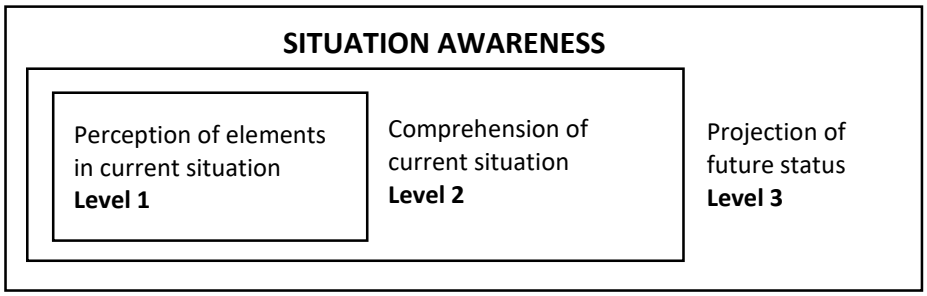


Figure 2-4 Situation awareness model (Batorski, 2012)

The literature also describes eight significant factors that can impact the SA process. These are *"attentional tunnelling, memory limitation, human stress, data overload, incorrect projections inserted, system complexity, incorrect mental models and automation"* (Souza, Botega, Eduardo, Segundo, & Berti, 2015, p. 4408).

Findings related to the RDP model and SA theory can be observed during any major incidents where uncertainty is inherent. While these theories have led to approaches to modify the operational response to emergencies (Gore, Flin, Stanton, & Wong, 2015; Klein, 1989), they can also impact other areas. For example, both of these theories have been used to design information technologies (Hoffman & Militello, 2008). In this area, Emergency Management Systems (EMS) should provide decision-makers with a *'common operating picture'* and *'shared situational awareness'* to support the decision-making process. Harrald and Jefferson (2007) outlined the importance of the information component of situational awareness and its dependency on the particular domain and the users' dynamic information needs. Building on this concept, media dependency theory predicts that individuals rely on mediated information to meet their needs, but individuals have specific preferences related to where they will turn for information concerning a particular topic (Ball-Rokeach & de Fleur, 1976). Therefore, task complexity, decision aid familiarity and cognitive fit can play a vital role in decision-making. Researchers have revealed that media dependency increases during crisis situations (e.g. Hindman & Coyle, 1999; Lachlan, Spence, & Seeger, 2009; Loges, 1994; Lowrey, 2004; Tai & Sun, 2007). According to this theory, individuals retrieve

information from mediated sources during a crisis and complement it with additional data from other sources (Mazer et al., 2015).

Access to information sources depends on the type of stakeholder that seeks information. While expertise could reduce the need for information, emergency managers responding to major incidents usually have more accurate information as they have access to a more significant number of more reliable data sources (section 2.1.4). They may make decisions with uncertain information as they use their previous experience and take actions based on internal prototypes or mental models. However, this approach is not suitable for all emergency stakeholders with limited information access and unfamiliar with the unfolding situation. Thus, the importance of access to high Information Quality (IQ) sources is paramount for them to decide the best course of action. The majority of stakeholders access information through Mass Communication Media (MCM) channels which are part of emergency management's risk communication strategies (section 2.1.5).

2.1.4. Information and communication technologies (ICT) in decision-making

Decision-makers can access and interrogate information using multiple media, including print, communication exchanges (group and interpersonal), and computer-based tools, such as Decision Support Systems (Power, 2001). During a significant incident, emergency managers have access to different information and communication technology (ICT) than other emergency stakeholders. The emergency response coordination team congregates in a control room and communicates with other entities such as police, fire departments and hospitals. Information is obtained from a combination of sensors and human reports. Emergency organisations (e.g. police, fire departments, and hospitals) provide information to the control room using mainly the phone. While the information source will be highly reliable, this channel is potentially error-prone and inefficient (Scherp, Franz, Saathoff, & Staab, 2012). Several emergency management systems have been developed in recent years to overcome this challenge. They support multi-organisation communications during major incidents and

standardise data entry (e.g. VectorCommand Command Support System[2], Atlas Incident Management System[3], S-HELP[4], WeKnowit[5]).

Technology advances, including dedicated sensor networks and multi-purpose sensor networks (T. Sullivan et al., 2013), allow collecting a large volume of both structured and unstructured data that can be integrated into emergencies systems (e.g. Decision Support Systems). Emergency data sources now include seismometers, wireless networks, unmanned systems and embedded sensors (IBM Corporation Software Group, 2013; JST-NSF, 2013). Examples of Decision Support Systems (DSS) using this technology include WaveLet[6] designed to support decision-making during Earthquakes (Yong et al., 2001), EMDSS[7] created for hurricanes (Lindell & Prater, 2007), or BCIN[8] developed to support recovery processes (Saleem et al., 2008).

In addition to sensors and official sources, mass media organisations and citizens' input have proven valuable as emergency managers' information source. Citizens can become

[2] VectorCommand is UK operational command support software for the emergency services and the oil and gas industry. Aids operational control of major single and multi-agency incidents, providing commanders at all levels and locations with a common operational picture, a clear, timely, integrated view of all relevant information and resources. Sketch maps and organisational charts / asset allocation. Website: https://www.thebigredguide.com/vectorcommand-command-support-system-technical-details.html#more-info

[3] Atlas is a software application that helps public and private organisations manage their incidents. It gives instant access to emergency procedures, site maps, incident support documents, communication plans, emergency equipment and post incident procedures. Website: https://atlasleadingtheway.com/

[4] The S-HELP Decision Support System (DSS) is an emergency management software application to reduce the impact of major emergency incidents on public health by providing a faster, more efficient approach to decision-making through coordination, collaboration and interoperation between agencies, in line with current best practice. Website: http://crbc.ucc.ie/wp-content/uploads/sites/95/2018/07/S-HelpBook.pdf

[5] WeKnowit is a FP7 European project (2009-2011) that designed, implemented and delivered technologies and methodologies enabling both Emergency Response organisation personnel and community citizens to participate in the monitoring of an emergency incident. Website: http://www.weknowit.eu/

[6] WaveLet is a Decision Support System (DSS) designed to assess the expected damage and loss assessment in earthquakes. This tool is supported by the World Agency on Planetary Monitoring and Earthquake Risk Reduction. Website: http://ioc-unesco.org/index.php?option=com_oe&task=viewInstitutionRecord&institutionID=9621

[7] EMDSS (Evacuation Management Decision Support System) displays information about evacuation time estimates, estimated times of arrival for storm conditions and calculates the cost of false positive (the economic cost of an evacuation) and false negative (lives lost in a late evacuation) decision errors.

[8] BCIN (Business Continuity Information Network) system designed to support the collaboration between USA local, state, federal agencies and the business community for rapid disaster recovery.

'information nodes' for their ability to capture and share information through multiple devices, including social media sites. For example, social media platforms (e.g. Twitter) provide real-time data for monitoring and analysing the impact of emergencies (e.g. Q. Huang, Xiao, & Huang, Q. and Xiao, 2015; Imran & Castillo, 2014; Imran, Castillo, Diaz, & Vieweg, 2015).

In order to manage all this information, an information officer is appointed to support decision-making. According to the *'Emergency Field Handbook'* (UNICEF, 2005), Information Managers need to gather information about 1) type of disasters that occurred, including time and location; 2) the number of people affected/ death/ injured; 3) what agencies are working in the region and what are they doing; 4) the most urgent needs and gaps to save the most significant number of lives. Therefore, the information manager role includes the responsibility of "*seek information, question it and, where appropriate, validate acquired information; sort it, group it, prioritise it and then display it, ensuring that what is being presented on the information management boards are both facts and safe deductions, and not suppositions*." (National Working Group, 2008, p. 6)

While all these data sources are available to emergency management organisations, traditionally, citizens must rely on risk communication and access to Mass Communication Media (MCM) channels for updates. Therefore, the role of Public Information Officers (PIOs) and Journalists is vital in risk communication. The next section reviews MCM as an information source.

2.1.5. Risk communication in decision-making

Multiple researchers have analysed the role of Mass Communication Media (MCM) in emergencies. It is the primary information source for most emergency management stakeholders (Höppner, Whittle, Bründl, & Buchecker, 2012).

Despite Af Wåhlberg & Sjöberg (2000) reported a lack of clarity about the role of traditional media in risk communication and Binder (2012) added that social media also share a lack of transparency in this context, it is believed that risk communication impacts on decision-making. Houston et al. (2014) state that mass-mediated disaster

communication influences personal disaster knowledge, attitudes, and actions. Indeed, Rodriguez et al. (2007, p. 482) defend that mass media *"significantly influences or shapes how the population and the government views, perceives, and responds to hazards and disasters"*. Efficient communication is paramount for citizens to take practical action to look after themselves when natural disasters occur (Wenham, 1994). Risk communication is the collaborative exchange of information related to a real or perceived risk (Committee on Risk Perception and Communication, 1989). In the traditional disaster management model, social agents such as government, agencies or journalists were in charge of communicating risk and crisis updates; in turn, information flowed from emergency organisations to the public (Low et al., 2010). In this model, authorities operated as senders and citizens as the audience. Traditional MCM channels included radio, newspapers and television. Despite the differences between these channels (i.e. media involved, time to provide an update); their commonalities have grouped them as offline communication channels. With the advent of the internet, many channels appeared online: weblogs, social media and forums/wikis. Table 2-2 shows a comparison of mass media communication channels according to information direction, the model of communication, gatekeeper figure and type of data.

Group	Mass Media Channel	Direction	Model of communication	Gatekeeper Figure	Type of data
Offline	Newspapers	Asymmetric	One-to-many	Yes	Text and images
Offline	Radio	Asymmetric	One-to-many	Yes	Audio
Offline	Television	Asymmetric	One-to-many	Yes	Video
Online	Websites (include online MCM)	Asymmetric	One-to-many	Yes	Multimedia
Online	Forums /Wikis	Symmetric	Many-to-many	Sometimes	Text
Online	Social media	Symmetric	Many-to-many	No	Multimedia

Table 2-2 Mass media channel characteristics

Common traits of the offline group include the asymmetric information direction and the role of *'gatekeeper figure'*. The gatekeeper person has been broadly analysed in communication science (e.g. Shepherd & Vuuren, 2014; Sung & Hwang, 2014; Utz, Schultz, & Glocka, 2013). The gatekeeper figure is the person that decides what messages reach the *'mass'* (citizens) according to the approved agenda (Sung & Hwang,

2014). Furthermore, the agenda-setting theory implies that traditional media not only choose the topics to consider, it also influenced in *"how to think about it''* and *''what to think''* (McCombs & Shaw, 1993, p. 65). This role has disappeared in the online environment (excluding moderated platforms). Citizens are no longer passive recipients of information (Sung & Hwang, 2014), but they actively contribute to creating conversations. Social media communication symmetry allows this two-way interactive experience (Merrill, Latham, Santalesa, & Navetta, 2011). Citizens can create, modify and consume information and, additionally, they can distribute it to a broad audience. The *'one to many'* model of communication is replaced by a *'many to many'* model (Freberg, 2012; Gonzalez-Herrero & Smith, 2010), where the inexistence of a gatekeeper and the low entry barriers have a positive and negative impact on Information Quality (IQ). Traditionally, journalists had the moral obligation to verify the information before sharing it. But nowadays, citizens input is impacting the news disseminated in traditional media, and they have become, on occasions, the first source to report breaking news (Wigley & Fontenot, 2010, 2011). Social media allows communicating and reaching the mass public quickly and effectively (S. Kim & Liu, 2012). Information can be disseminated anywhere and anytime by minimising geographical distance problems (Evans, Kairam, & Pirolli, 2010; Irfan et al., 2015; J. Li, Li, Khan, & Ghani, 2011). Appropriate network connections can help to address information flow shortcomings during major incidents. In fact, in the absence of enough and credible news, social media users can fill the gap (Howell et al., 2014), and influential actors can quickly broadcast to relevant personnel in their networks (Abbasi, 2014).

Organisations are starting to use social media as part of mass communication during crisis and major incidents. Certain factors condition adoption of social media as mass communication by government and organisations, for example, the size of the community served by the department (M. W. Graham, Avery, & Park, 2015), the number of staff members (M. Graham & Avery, 2013) or stakeholders' motivations (Ruehl & Ingenhoff, 2015). Nevertheless, organisations are every day more present in social media. For example, the U.S. National Weather Service relies on Twitter as an environmental information service for weather alerts (Holthaus, 2014). Social media has been used as a risk communication tool during numerous events, including hurricanes,

such as Sandy, Isaac, Katrina, Hugo and Rita (Belardo & Harrald, 1992; Q. Huang et al., 2015; Kapucu & Garayev, 2011; Tinker, 2013) and flooding, like in Queensland and Saxony in 2013 (Ehnis & Bunker, 2012; Peters & Paulo, 2015).

In the last decade, the number of studies analysing social media and emergency management has increased (e.g. Alexander, 2014; Buzzelli, Morgan, Muschek, & Macgregor-Skinner, 2014; Harrison & Johnson, 2019; Horita, Degrossi, Assis, Zipf, & De Albuquerque, 2013; Houston et al., 2014; Veil, Buehner, & Palenchar, 2011), but it is still in its infancy. Research on social media as mass communication has been mostly performed from an organisational perspective using case studies (Freberg & Palenchar, 2013; Veil et al., 2011). Its main aim has been to highlight best practices such as: communicate quickly, be credible, accurate, complete and straightforward, and communicate broadly (Freberg, Saling, Vidoloff, & Eosco, 2013). Using lessons learned, emergency organisations have also developed guidelines for social media use (DST, 2012; NSW Rural Fire Service, 2015; Reynolds & Seeger, 2014; Sheppard, Janoske, & Liu, 2012).

Social media is mainly used as a communication tool by citizens. However, a study commissioned by The American Red Cross (2010) stated that social media is the fourth most popular source to access emergency information. The selection of one or another social media may have intrinsic and extrinsic motivations. For example, after the Japanese tsunami in 2011, people chose Twitter as it used less battery energy than alternative communication devices (Howell et al., 2014). The most popular social media platforms by the number of users are Facebook and Twitter. Therefore, efforts to further understand social media usage during major incidents, emergencies, disasters and crisis have focused on these.

Twitter is the preferred method to spread information, confirm data and engage in brief discussions, while Facebook provides greater engagement and more in-depth conversations (Howell et al., 2014). Its characteristics make Twitter a suitable channel for input and output activities, including risk communication, bi-directional communication, and data analysis. The utility of Twitter during extreme events is also supported by general reliance on the medium for news. A survey from the Pew Research

Center indicated that 52% of Twitter users obtain intelligence from the site and that 8% of all adults in the United States turned to Twitter for news in 2013 (Holcomb, Gottfried, & Mitchell, 2013). The next section further analyses the role of Twitter in emergencies and tentatively evaluate it for decision-making.

2.2. Evaluating Twitter for decision-making in emergencies

In section 2.2, the researcher evaluates Twitter capabilities to support the decision process in major incidents addressed as emergencies. Sadovykh, Sundaram, & Piramuthu (2015) research demonstrated that properly governed and designed online social networks can support decision-making -in the intelligence, design and choice phases- by providing stakeholders with different support forms, including instrumental, emotional and informational.

The use of social media and social networks in the area of Emergency Management (EM) is relatively new. Social media is a set of internet-based applications that have been continuously evolving since its origins. Social media is based on the Web 2.0 concept, which describes a new way of using the web where users continually modify content and platforms in a participatory and collaborative approach. A growing research body analyses this Information and Communication Technology (ICT), particularly Twitter, in emergency management.

In section 2.2.1, Twitter is defined. It is paramount to understand social media's capabilities wholeheartedly to comprehend and evaluate the fitness of Twitter use in major incidents. First, the researcher provides a short history of social media and describes how Twitter is part of it. Many social media platforms exist, but all of them share two main principles: social networking and user-generated content. Social media types include blogs, social networking sites, virtual social networks, content communities, virtual game worlds, news and activities feeds, location-based services and social couponing. As can be appreciated, many platforms are available for an emergency manager to choose from; and while this research focuses on Twitter, findings can be applied to other online social media networks. This platform's selection is motivated by its number of users and previous research findings in its use by citizens

and organisations in emergencies (e.g. de Albuquerque, Herfort, Brenning, & Zipf, 2015). However, these research findings could be applied to other platforms based on User Generated Content (UGC).

Twitter is a micro-blog platform that allows users to create profiles, generate content, network and search information. Content is limited to 280 characters – 160 characters until November 2017. The platform also allows users to share images, short videos, URL links, polls, audio and much more. Any user can navigate Twitter without creating a profile; however, after signing up as a user, access to further functionalities is granted: post tweets and create a network. Twitter also allows searching for the information posted by other users. Twitter information is considered big data and includes structured, semi-structured or unstructured data. Researchers and practitioners can access a percentage of this information using Twitter Application Program Interface (API) and third-party software. This access permits to explore the dataset more in detail, including user ID, timestamp and Global Positioning System (GPS) location (if enabled).

Section 2.2.2 summarises Twitter use in emergencies through a collated list of examples published in research articles and emergency management organisation reports. The importance of including practitioners' reports documents the infancy of social media usage as part of the emergency management toolset. Identified uses are classified according to the user interaction with the system. Access to Twitter and its data can be valuable during major incidents from two perspectives supporting the decision-making process: risk communication channel (section 2.2.3), and information source (2.2.4). Compared with other classifications proposed by other researchers, the suggested approach is based on users' interaction (action) with Twitter, and it serves better the purpose of this research. It enables the researcher to identify potential uses of Twitter for decision–making (decision-making outcomes).

Any emergency stakeholder can post content and share it with a large population. However, not all Twitter's users are experts in major incidents (section 2.2.5). It has been noted that citizens are sometimes the first to report incidents using social media, but they still depend on updates from journalists and Public Information Officers (PIOs). In addition, virtual volunteers (such as Virtual Operation Support Teams) have

demonstrated their usefulness to find online information and provide situational awareness to emergency teams and ground volunteers.

Expertise and accessibility enhance situation awareness for citizens and other emergency stakeholders, and Twitter becomes a relevant information source. However, its usage presents several Information Quality (IQ) challenges to overcome. Section 2.2.6 describes the problems associated with the use of Twitter as an information source in major incidents. The first challenge is associated with *'big data'* properties. Volume, velocity and variety of data characteristics become a large quantity of information gathered at high speed in multiple formats. Difficulties encountered by decision-makers include the challenge of finding relevant information (2.2.6.1), information shift (2.2.6.2) and completeness of the information (2.2.6.3). The second challenge is associated with the information production/consumption relation. The users' intention while creating or sharing inaccurate information: intentional or unintentional. These challenges are translated to the malicious use of Twitter (2.2.6.4) and the inaccuracy of the information shared (2.2.6.5). All these challenges have an element in common: the difficulty of accessing high-quality information; therefore, IQ is identified as the biggest challenge to overcome for the use of Twitter in Naturalistic Decision Making (NDM) environments (section 2.3).

2.2.1. What is Twitter?

Twitter is one of the most used and researched social media platforms in emergency management. The interest in the use of social media for emergency management has increased over the years. This section focuses on providing the reader with background information about Twitter. First, Twitter is described as part of the social media ecosystem, which is rich in relation to the typology of existing platforms. This section explains social media by providing the reader with a background overview of its evolution, including main characteristics and building blocks.

Social media is a set of internet-based applications that have been continuously evolving since its origins. The concept of social media took form when Bruce and Susan Abelson created *'Open Diary'*, a social networking site that grouped online diary writers into one community (A. M. Kaplan & Haenlein, 2010).

In 1979, Tom Truscott and Jim Ellis (Duke University) created the Usenet, a discussion forum that allowed users to create and post public messages. The concept of *'blogs'*, which focuses mainly on creating content, was developed simultaneously. In 1997 Six Degrees was born, a site that allowed users to upload a profile and make friends, and it existed until 2001. Six Degrees focused on the development of an online network.

Web 2.0 brought the concept of social media to a new level. The *'Web 2.0'* is a term first used in 2004 and describes a new way of using the web in which all users continuously modify content and platforms in a participatory and collaborative approach. Building on the Six Degrees concept, Friendster (2002-2015), Facebook (2004), Google+ (2011), ello (2014) and, in the business niche market, LinkedIn (2003) focuses on the creation and development of online networks. Additionally, to connect people, chat services have existed for many years, including AOL Instant Messenger (1997-2010). Recent services have appeared with new features, including WhatsApp (2009), which allow creating 1 to 1 and group chats. The platforms previously listed allow distinct entities—individuals, groups, and/or organisations— to interconnect, preserving a determined structure and supporting characteristics of the relationships that connect them (Borgatti, Mehra, Brass, & Labianca, 2009; Knoke & Yang, 2008). Social media success is due to the ability to link users to create an online social network and, therefore, enable communication.

Other platforms have based their business model on a specific sharing media content type such as photos, videos, location-based services, news aggregation, blog post and gaming platforms. Therefore, their model is based on the ability to support end-users to generate content. User-Generated Content (UGC) is considered as such when a relative effort is allocated to its creation, and an organisation does not directly create it.

The majority of platforms have incorporated a mix of features that enable users to perform more than one type of user-generated content. For example, Twitter is known for its microblogging functionality (the characters count was increased in November 2017 from 140 to 280 characters). However, it also allows users to have a network of followers, send private and public message service, take and upload photos and videos, stream live video through Periscope, and create a list to aggregate content. In a related

concept, news aggregators such as Digg (2004) or Reddit (2005) help users filter relevant information from the Internet.

Image and video sharing features gained more significant popularity with the ability to take images from mobile phone devices. In 2003 Photobucket was born to allow users to share, host and link online photo albums. Similarly, image sharing is the primary feature of Flickr (2004), Instagram (2010), and Pinterest (2010). Snapchat (2011) is one of the latest additions by allowing users to send images that are deleted after being seen by the receiver.

Within the video hosting environment, YouTube (2005) has the most significant market share. Other video-hosting social media platforms include YouNow (2011) and Vine (2013). A new interest in live stream videos has emerged with new services, including Periscope (2015) and Meerkat (2015-2016) reconverted in Houseparty (2016) for group video chat.

Mobile phone devices also have impacted the development of social media. New platforms have been built on location-based services (powered by GPS signal and IP address), allowing users to filter information by their proximity. Foursquare, launched in 2009, is a location-based check-ins application that allows finding places to go with friends. Yik Yak also uses location as their main feature enabling notifications to be received by people within a 1.5-mile radius.

Additionally, several online games exist that can be considered social media by their ability to create an online network of multiplayers. Gaming related social media platforms rely highly upon simulated environments. A precursor of this type of social gaming is Linden Lab's Second Life (2003) which allowed users to create avatars.

As can be appreciated, a large number of social media platforms exist. The provision of a social media definition is not exempt from challenges. To define Twitter, it is necessary to understand their commonalities and differences and outline critical parameters. The researcher proposes to use the following definition for this research:

> *'Social media is a set of applications built on the collaborative concept of Web 2.0 technologies which support the creation and dissemination of user-generated content, and online social networking.*
>
> *Each platform presents a different level of social presence/media richness and self-presentation/self-disclosure, enabling communication and information revelation. Social media support social interaction and personal disclosure through the creation, posting, sharing and diffusion of rich user-generated content (UGC) in the form of comments, documents, video, photos or audio files. Social media technology is based on seven functional building blocks: identity, conversations, sharing, presence, relationships, reputation and groups. Social media types include blogs, social networking sites, virtual social networks, content communities, virtual game worlds, news and activities feeds, location-based services and social couponing.'*

Kaplan & Haenlein (2010) suggested six social media categories: blogs, social networking sites, virtual social networks, content communities, and virtual game worlds. They classified these according to each platform's degree of social presence/media richness and self-presentation/self-disclosure. Using social presence theory (Short, Williams, & Christie, 1976) and media richness theory (Daft & Lengel, 1986), the first parameter refers to the degree of contact (acoustic, visual, and /or physical) that can be achieved, the medium level of intimacy (inter-personal vs mediated) and immediacy (asynchronous vs synchronous), and its ability to resolve ambiguity and the reducing uncertainty. The second classifying parameter, self-presentation/self-disclosure, denotes users' ability to create and control an image of themselves within the social media platform. It refers to the user's ability to consciously or unconsciously reveal personal information to their network. Kaplan & Haenlein (2010) classification matrix suggests that communication and information are the two key drivers of any social media platform.

Building on this concept, Kietzmann et al. (2011) presented a framework with seven functional building blocks to describe social media: identity, conversations, sharing, presence, relationships, reputation and groups. In their paper, they explore each block

examining (1) a specific facet of social media user experience, and (2) its implications for organisations. From an advertisement perspective, Ewards (2011) proposed a similar classification. However, he also included other media and tools such as platforms to keep updated about news and activities (e.g. tagging, RSS, and Twitter); location-based services (e.g., Foursquare, Gowalla, hotpot); social gaming (Zynga, words with friends, Farmville); and social couponing (e.g. Groupon, LivingSocial, deals.com). All of them comprise information as user-generated content and rely on communication as a structure. The researcher uses this classification to define Twitter (Table 2-3):

Criteria	Twitter
Social media category	Micro-blogging limited to 280 characters – 160 characters until November 2017
Presence /Degree of contact	Mostly visual, but also acoustic through recordings
Relationships /Medium level of intimacy	Inter-personal. Followers and followees. Option for direct messages.
Conversations /Immediacy	Synchronous
Identity: Self-presentation/self-disclosure	Small biography. Identity is built through information posted and interaction with the network.
Sharing capabilities	Information publicly accessible
Reputation	Existence of verified accounts
Groups	Ability to create a list of users
Purpose	Keep updated about news and activities

Table 2-3 Twitter overview using Kaplan & Haenlein (2010), Kietzmann et al. (2011) and Ewards (2011) adapted classification

Twitter functionalities allow the development of almost real-time/synchronous conversations, which enables a bidirectional discourse. To access all its features, users must create a profile and disclose basic information to the community. A user's identity is built on the combination of information shared by the user and their activity in the network (through likes, retweets and relationships). While posting is restricted to registered users, any person can search Twitter as its privacy setting default allow the search of its database from any search engine. The creation of a profile is relatively easy. Aware of this, Twitter provides the ability to official accounts to claim ownership and verify their accounts. Claimed accounts can be recognised by a blue badge.

To conclude, the primary purpose of Twitter is to access news and activities shared by other users. The following Twitter definition is used through this research:

> *'Twitter is a micro-blogging social media platform limited to 280 characters which are mostly visual (text, photos, polls) but can include acoustic content (i.e. through recordings). Twitter enables inter-personal relationship allowing users to share information with their followers and followees in a public or private space (direct messages).'*

2.2.2. Twitter in emergencies: classification approach for Twitter uses

The use of social media during emergencies and major incidents is still relatively new; however, a growing body of knowledge with examples exists. Guan & Chen (2014) argues that existing research studies can be classified in two main areas: 1) analyse disaster-related behaviours such as user intentions, information generation and dissemination and user interactions on social media (e.g. Hughes & Palen, 2009; Sakaki, Okazaki, & Matsuo, 2010; Spiro, Dubois, & Butts, 2013; Starbird & Palen, 2010; Starbird, Palen, Hughes, & Vieweg, 2010; Vieweg, Hughes, Starbird, & Palen, 2010) and 2) investigate the network properties of social media (e.g. Holguín-Veras, Jaller, & Wachtendorf, 2012; Sutton et al., 2013; Wachtendorf & Kendra, 2005).

Usually, emergency managers and researchers are optimists in the potential use of social media to improve disaster communication and operations (Houston et al., 2014). Original creative content generated by non-professional users is published publicly accessible on Internet (input) and provides real-time access to a selected group of people (output). The use of this content posted on social media can have a high impact on the decision-making process.

Several researchers have published literature review papers that aim to create a classification of the use of Twitter. They use different approaches related to the use of social media, including best practices, successes in the use, and ethic of social media usage (Alexander, 2014; Houston et al., 2014; Veil et al., 2011).

After a careful review of the literature, the researcher proposes to simplify the classification of the use of social media to three generic categories that are related to the user interaction with the system and based on the concept of information consumption and information creation:

i. User can **input information** (push) to disseminate facts, request, opinions and ask questions (e.g. Provide and receive disaster preparedness information; Raise and develop an awareness of an event; Express emotions, concerns, well-wishes, memorialise victims).
ii. Users can **output information** (pull) from social media information by reading it or extracting it (e.g. Enhancing research; Listening to public debate; Signal and detect disasters; Monitoring situations).
iii. Additionally, this input/output capability allows the user to create a **bi-directional conversation**. (e.g. Partner with the public; Provide and receive disaster warnings; Discuss socio-political and scientific causes and implications of and responsibility for events).

A similar classification was proposed by Kaminska & Rutten (2014), who, after validation from experts, classified the social media in emergency management within three pillars of emergency management: (1) public information, (2) situational awareness, and (3) monitoring, evaluation and planning.

Table 2-4 (page 44) provides a sample of Twitter uses classified using the mentioned strategy. Using this, the researcher shows how uses defined by previous research can be classified. For example, Houston et al. (2015) provided a list of fifteen functions of disaster social media, including *'provide and receive disaster preparedness information'; 'send and receive a request for help or assistance'; and 'implement traditional crisis communication activities'*. Another example is the classification proposed by Alexander (2014). He listed seven uses of social media (1) listening to public debate; (2) monitoring situations; (3) extending emergency response and management; (4) crowd-sourcing and collaborative development; (5) creating social cohesion and promoting therapeutic initiatives; (6) furthering causes (including charitable donation); (7) enhancing research.

Researcher	Risk Communication	Bidirectional Conversation Space	Information Source
Houston et al. (2015)	- Inform others about one's condition and location and learn about a disaster-affected individual condition and location; - Express emotions, concerns, well-wishes, memorialise victims; - Implement traditional crisis communication activities.	- (Re)connect community members; - Provide and receive disaster preparedness information; - Provide and receive disaster warnings; - Signal and detect disasters; - send and receive a request for help or assistance; - Provide and receive disaster response information, identify and list ways to assist in the disaster response; - Raise and develop an awareness of an event, donate and receive donations, identify/list ways to help - Provide and receive disaster mental/behavioural health support; - Provide and receive information about (and discuss) disaster response, recovery, and rebuilding, tell and hear stories about the disaster; - Discuss socio-political and scientific causes and implications of and responsibility for events;	- Document and learn what is happening in the disaster, deliver and consume news coverage of the disaster
Alexander (2014)	- Creating social cohesion and promoting therapeutic initiatives; - Furthering causes	- Extending emergency response and management; - Crowd-sourcing and collaborative development;	- Listening to public debate; - Monitoring situations; - Enhancing research.
Sellnow & Littlefield (2005)	- Communicate with honesty, candour and openness; - Communicate with compassion, concern and empathy; - Provide messages of self-efficacy;	- Partner with the public; - Collaborate and coordinate with credible sources; - Meet the needs of the media and remain calm; - Acknowledge and account for cultural differences.	- Establish risk and crisis management policies and process approaches; - Plan pre-event logistics; - Listen to the public; - Accept the uncertainty and ambiguity;

Table 2-4 Twitter uses in the Emergency Management (EM) literature described by researchers (researcher classification)

Social media and Twitter are suitable risks communication and analytical tools in emergencies (Radisch & Jacobzone, 2010; Sheppard et al., 2012; Veil et al., 2011). The next two sections review previous research in the use of Twitter from a risk communication perspective (2.2.3) and as an information source (2.2.4).

2.2.3. Twitter as a risk communication tool

Social media is used as a mass and peer-to-peer communication channel before, during and after disasters and emergencies (Xiao, Huang, & Wu, 2015). It provides the opportunity to share and capture real-time messages/data in multiple formats (text, video, images, sound, GPS) and the ability to communicate with online communities (Crowley, Dabrowski, & Breslin, 2013). However, social media adoption varies from country to country, and its usage is related to age, education and income (Alexander, 2014; Veil et al., 2011); nonetheless, the acceptance of this technology by the population cannot be denied.

It is challenging to estimate the exact number of users for each social media platforms as they can become outdated quickly. Additionally, even though internet access is globally extended, there are different access and usage levels within the population. Some researchers have used the concept of *'digital divide'* to refer to the difficulty of technology access by low-education and low-income groups (e.g. Veil et al., 2011). Furthermore, even within people with access to social media, there is a percentage of users, namely *'lurkers'*, which read/observe but do not contribute. According to Nielsen (2006), 90% of social media users are lurkers. Despite its limitations, social media's importance in communicating with a large portion of emergency stakeholders is indisputable.

The use of social media by different stakeholders changes depending on the phase of the disaster. Government and emergency organisations use social media for dissemination purposes during the preparation, recovery and mitigation phases. However, their interaction level decreases in the response phase. The uncertainty levels are higher during this phase; therefore, government and emergency agencies may not share information until official sources have adequately verified it. This approach decreases the number of messages shared and their speed (e.g. Kaewkitipong, Chen, &

Ractham, 2015). As a reaction, citizens and volunteer groups become more active in social media by organising themselves and sharing information. For example, in the 2011 Thailand floods, more than 50 Facebook groups were created to support the victims (Kaewkitipong et al., 2015). Engagement level can also differ concerning the social media type used. For example, Snoeijers, Poels, & Nicolay (2014) compared the number of reactions obtained by a message on Facebook and Twitter within a university's crisis communication context. They found that students (average age 22 years old) were more inclined to leave a Twitter message than on Facebook.

Emergency stakeholders can be impacted by misinformation and rumours shared through social media during major incidents. To overcome the information and experience challenge, the researcher highlights communication channels' importance during emergencies for decision-making. Veil et al. (2011) convey that communication should be involved in decisions during all emergency management stages (i.e. mitigation, preparedness, response and recovery). Emergencies and crises create a need for not only information but also for human conversation and compassion (Shklovski, Palen, & Sutton, 2008).

Twitter® enables this through its platform. This micro-blog application allows users to create profiles, generate content and search information. Any user can navigate Twitter without registering; however, to post tweets and create a network, users need to create a profile. This process is relatively easy as it just requires selecting a unique username (@) and the provision of an e-mail account or a phone number. Each Twitter account must be associated with one unique e-mail address/phone number. Therefore, it is not possible to create multiple accounts using one e-mail address. While creating the account, users can identify their interests and follow suggested users. Profiles should also include a description, a profile image and a background image. It is possible to include a website's URL, date of birth and the account holder location (Twitter, 2016a). Twitter provides users with the option to apply for a verified account. If an account is deemed as public interest, then a blue verified badge appears next to their username in the profile and search results.

Twitter defines itself as an information network where user interchange information using Tweets or 140-character messages (Twitter, 2016a). In November 2018, the number of characters increased to 280 (Rosen, 2017; Rosen & Ihara, 2017). Twitter's definition implies using text to communicate; however, as summarised in Table 2-5, this platform allows users to share images, short videos, URL links, polls, and audio. Twitter rules include the exclusivity of features. For example, if a user chooses to upload an image, they are not allowed to add a GIF or a Poll.

Feature	Definition	Twitter
Text	Words and phrases	Yes
Keywords (#hashtags)	Any word or phrase immediately preceded by the # symbol. Convert content in a clickable link.	Yes
URL	Link to external content *'http: //www.'*	Yes
Photos	Pictures	Yes
GIFS	Lossless format for image files that supports both animated and static images	Yes (GIFS samples)
Video	Audio and moving visual images	Yes
Audio	Sounds recorded	Yes
People (user tags /user mentions)	Mention another user and create a link to their profile	Yes (@username)
Location /Geotags /Geolocation	User can input their location or use GIS service	Yes (GIS)
Polls	assessment of public opinion by questioning users	Yes
Feeling /activities	User can select their feeling or a description of their activity from a list	No
Post Audience	Select who can access the post	No
Add new post	Allows to publish multiple posts interlinked	Yes

Table 2-5 Twitter composing features (Adapted from Twitter, 2016b)

The use of social media as a bidirectional space can allow a user to answer questions through targeted asking and network asking strategies (Evans et al., 2010). Social media enables users to send messages directly to specific individuals and groups, including emergency management organisations (targeted asking). Privacy settings play a vital role in this functionality. Social media can compete against other communication channels such as telephone, live chat, or e-mail. It provides multiple features such as sending text, audio, images, videos and emoticons. Additionally, it is linked to personal information, such as users' profiles.

On the other hand, questions can be posted on the social media feed (network asking). Privacy settings of the network and the user play a key role by limiting the number of people who can see the information and reply. Strategies to maximise the number of

viewers include the use of hashtags which facilitate the retrieval of information related to a topic.

It has been noted that the use of social media may be related to different emergency phases (Horita et al., 2013; Houston et al., 2014). Information needs and access is different in each emergency phase; therefore, it requires a system that allows changes in the information flow.

During the mitigation and preparedness phases, information usually flows from government and organisations to citizens; however, this information flow changes during the response. Official information can become quickly outdated, and citizens can provide first-hand updates (e.g. Kaewkitipong et al., 2015). In fact, the number of online social communities increases during this phase. For example, during the Thailand flood in 2011, social media became the de facto source of information when government agencies were no longer considered a trustworthy source of information (Kaewkitipong et al., 2015).

After the emergency, the use of social media is directed to help the victims return to normal life. The information shared by different stakeholders includes processes to claim for damage, call for volunteers, and ask for donations (e.g. Turner & Robinson, 2014). For example, 700,000 people made donations using their phones after the 2010 Haiti earthquake (Turner & Robinson, 2014). Additionally, social media is also used to increase victims' morale. For example, after the Thailand flood in 2011, parodies and funny videos were created and hosted on YouTube to reduce stress levels (Kaewkitipong et al., 2015).

2.2.4. Twitter as an information source

The insight provided by social media data can be really beneficial for disaster and emergency management (Guan & Chen, 2014). User-generated content (UGC) provides broader coverage and more up-to-date information of crisis events than traditional media (Bruns, Burgess, Crawford, & Shaw, 2012; Conklin & Dietrich, 2010; Earle, Bowden, & Guy, 2011). Furthermore, it can support emergency stakeholders to achieve and maintain situation awareness in real-time, enhancing their evaluations, need

assessments (Foresti, Farinosi, & Vernier, 2015; Vieweg et al., 2010), and overall their decision-making processes (U.S. Department of Homeland Security, 2014). Twitter is a social awareness stream (Naaman, Becker, & Gravano, 2011).

Twitter can be considered as a source of information to use for decision-making. This platform provides users with the functionality to search for queries in their database. For example, Virtual Operations Support Teams (VOSTs), a group of social media and emergency experts, support the development of situation awareness in relevant major incidents by searching Twitter and other social media platforms (Fathi, Thom, Koch, Ertl, & Fiedrich, 2019).

Simple and complex searches can be performed on Twitter (see appendix 1). A basic search box is located at the top right of Twitter's interface and allow searches of up to 84 characters. Text can be sentences, hashtags, words, usernames or profile names. Further search parameters are accessible through the advanced search webpage (https://Twitter.com/search-advanced) where the definition of additional parameters, including language definition, specific locations, dates or user accounts, is available.

Search features are further enabled through the Twitter back-end. Twitter provides an Application Program Interface (API) that facilitates the extraction of relevant information from its database. Using Twitter API, researchers and practitioners can access additional metadata from messages such as user ID, timestamp and GPS location (if enabled). It provides social media data with temporal and spatial characteristics (Tin, Zin, Toriu, & Hama, 2013). However, access to historical data is regulated by the platform's terms and conditions (Twitter, 2018). Tweets use JavaScript Object Notation (JSON) encoded objects and attributes, which can be classified in four data dictionaries: Users, Entities, Extended Entities and Places all *'child'* objects of the *'parent'* object Tweet.

Tweets are the basic atomic building block of all things Twitter (Twitter, n.d.) and have a long list of *'root level'* attributes (e.g. ID, creation date, text). The reader is presented with an overview of fields that can be extracted from Twitter in Appendix 2.

This platform's importance for situational awareness is such that multiple decision-making systems include Twitter within their modules. For example, S-HELP[9] an Emergency Management (EM) Decision Support System (DSS) part of an FP7 project included a Twitter board where to search by hashtags, display them in a map and export the messages. Social media can help emergency stakeholders to achieve and maintain situation awareness in real-time enhancing the decision-making processes (U.S. Department of Homeland Security, 2014). Social media can facilitate information search, communication and support experts' decision-making processes. However, it is essential also to understand Twitter limitations for its use in research and create an operational picture. Twitter algorithms shape and influence how users interact with the platform (create tweets, share them and see them), and therefore, it creates its own bias (Crawford & Finn, 2014).

Nevertheless, as a data source, Twitter provides a variety of information types that can support decision-making within different contexts. However, data quality becomes a great challenge while using user-generated content, especially from social media (Lukyanenko & Parsons, 2015). Social media adoption has accelerated information flows and empowered communities, even if the content created and shared is sometimes incorrect and inaccurate (Foresti et al., 2015). Rumours, misinformation and malicious information disseminated through social media can endanger citizens and first responders. Practitioners and researchers have discussed the reliability of the quality of social media information (L. Li & Goodchild, 2010), and further research is required to address the challenges associated with Twitter as an information source for decision-making.

2.2.5. Experts in the use of Twitter in emergencies

Social media users in major incidents (e.g. emergencies) include individuals /citizens, communities, volunteers (including online/digital volunteers), first responders, medical personnel, professional responders, emergency managers, emergency agencies and

[9] S-HELP FP7 European project (2014-2017) - DSS manual: http://www.fp7-shelp.eu/sites/fp7-shelp.eu/files/downloads/factsheet_shelp_neu_2.pdf

organisations, government, media and researchers (Alexander, 2014; Buzzelli et al., 2014; Horita et al., 2013; Houston et al., 2014; Veil et al., 2011).

A broader classification was proposed by Reuter et al., (2014) and divided stakeholders into two groups: (1) Citizen and (2) Authority. They emphasise that stakeholders have transposable roles in risk communication as the sender *('push data')* and the receiver *('pull data').* Houston et al. (2015) argue that all users are producers and consumers of information *"illustrating the two-way communication nature of social media"* (p.7). While it is evident that anyone can be a social media user, no all emergency stakeholders are experts in major incidents.

In any given emergency, a decision-maker can be any emergency stakeholder. An emergency management stakeholder is defined as *"an individual who is affected by the decisions made (or not made) by emergency managers and policymakers in his or her community"* (Lindell, Prater, & Perry, 2007, p. 33).

The challenge of expertise is that not all emergency stakeholders are expert in emergencies. Furthermore, research shows that communities previously hit by certain types of disasters often respond to the same type more appropriately. They often develop a *'disaster subculture'* in which preparation and exercises are of central importance; however, they cannot always cope with another kind of emergency (Helsloot & Ruitenberg, 2004).

Blum et al. (2014) identified relevant groups of experts in the area of information management during emergency and disaster response: decision-makers in the command or dispatch centres (e.g., emergency operations centre), Public Information Officer (PIO), virtual volunteers, such as virtual operations support teams (VOSTs), first responders or emergency response team (ERT) and citizens.

The Naturalistic Decision Making School (NDMS) promotes the selection of experts while researching decision-making in naturalistic environments. The literature review surveyed indicates that two of these key stakeholders must be considered while evaluating experts in social media use in major incidents. Those are Public Information

Officers (PIOs) and Virtual Operation Support Teams (VOST). In addition, journalists play a vital role in risk communication and shaping citizens' perception of the world.

While other stakeholders use Twitter actively, their role or background is harder to identify and cannot be assessed initially in matters of expertise. For example, citizens who participate in crowdsourcing initiatives to support major incidents can have an unrelated background to emergency management but an excellent willingness to support emergency teams' response. Or first responders may or may not use social media as part of their routine job.

Emergency organisations: Public Information Officers

In the last decade, the number of studies analysing social media and emergency management has increased (Alexander, 2014; Buzzelli et al., 2014; Horita et al., 2013; Houston et al., 2014; Veil et al., 2011), but it is still in its infancy. Public Information Officers (PIOs) recognise the importance of social media use in major incidents at least since 2010. According to PIO for Los Angeles, California Fire Department, Brian Humphrey (E. Tobias, 2011, p. 221): *"We believe that there can and should be a social media layer of data and we're eager to incorporate those data for our own fact checking. Every citizen is a communicator or contributor and we will benefit greatly from those initiatives."* (interview 1st August, 2010 – Red Cross report).

Research on social media as mass communication has been mostly performed from an organisational perspective using case studies (Freberg & Palenchar, 2013; Veil et al., 2011). Its main aim has been to highlight best practices such as: communicate quickly, be credible, accurate, complete and straightforward, and communicate broadly (Freberg et al., 2013). Using lessons learned, emergency organisations have also developed guidelines for social media use (e.g. DST, 2012; NSW Rural Fire Service, 2015; Reynolds & Seeger, 2014; Sheppard et al., 2012). The key challenges are to create effective social media messages. As Freberg, Saling, Vidoloff, & Eosco (2013) researched, *'Do emergency messages benefit from having a hashtag? What return do communicators receive from photos or hyperlinks? How does having a more conversational tone or a personal touch (e.g., use of text, voice, or video) contribute to the effectiveness of an emergency message?'* (p.186).

On the other side of the spectrum, information manager, instead of sharing content search and combine data to improve situational awareness. PIO must work closely with them to ensure that information can be shared with the public. In some emergencies and organisations, there is a need for multi-tasking and information managers are at the same time PIOs (Harvard Humanitarian Initiative, 2011). Graham et al. (2015) analysed the differences in the use of social media in government and found that larger communication departments had a more substantial social media presence. When social media is less deploy, PIOs must rely on the role of journalism for risk communication.

Journalists

As described in section 2.1.15, Mass Communication Media (MCM) is the primary information source for most emergency management stakeholders. Hence, journalism's role combined with Public Information Officers (PIOs) is paramount in supporting citizens' decision-making process. Studies of social media as a mass communication tool have been mostly researched by communication scholars, including public relations, journalism and media studies (Freberg et al., 2013; Wigley & Fontenot, 2011). As a marketing and a research tool, the utility of Twitter in journalism has been demonstrated as early as 2009 (Ahmad, 2010).

Journalists have the ethical obligation to provide context and verify the information before publishing it (Wardle, 2015). The importance of information inquiry has increased while these professionals use social media information to identify breaking news. Different solutions had been proposed to aid journalists in their verification purposes. These solutions range from manual techniques to the use of different technologies such as semantic data or natural language processing. Heravi & Mcginnis (2013) proposed a social semantic journalism framework composed of four steps: content discovery, filtering & contextualization, trust verification, and publication. Multiple tools are required for each step. In the case of the trust verification step, they recommended the use of provenance analysis, eyewitness detection, point of view analysis, community analysis and veracity. From a technological perspective, different systems have been developed, including SRSR standing for Seriously Rapid Source Review (Diakopoulos, De Choudhury, & Naaman, 2012), "*SocialMention, Storyful, Politifact, Fastfact, Topsy, Sulia,*

TinEye, FotoForensics, and Trackur" (Brandtzaeg, Lüders, Spangenberg, Rath-Wiggins, & Følstad, 2015, p. 3), or the H2020 Provenance tool[10].

Social media platforms are also supporting the use of user-generated content by journalists. For example, the First Draft News[11] Initiative, created to fight misinformation and disinformation online in 2015 by Google News Labs[12] and other nine organisations including Twitter, provides guides, tools (i.e. CrossCheck) and training to journalists.

Furthermore, journalism schools and universities (e.g. the city university of New York[13]) include courses to teach new journalists to use social media effectively.

Citizens: Volunteers, crowdsourcing and VOST

Citizens can also share risk updates. Oftentimes, individuals are on the disaster scene and can provide updates using social media (Horita et al., 2013). Citizens' updates can be complemented by geographical and locational data using mobile devices (Vieweg et al., 2010). This kind of information is defined as volunteered geographic information (Goodchild, 2007), and it is an effective way to gather information for humanitarian purposes (Coleman, Georgiadou, Labonte, Observation, & Canada, 2009). Volunteers' work improves the amount of information available about events. It also benefits of the local knowledge of community members who can provide situational awareness information using tools like the grassroots maps of the Humanitarian OpenStreetMap Team (HOT), Wikimapia, and crisis maps of Ushahidi (Okolloh, 2009; Ziemke, 2012). The people involved creates a new group of players in disaster management known as Volunteer and Technical Communities (VTC) or digital humanitarians.

The importance of digital volunteers in previous major incidents is undeniable. Some of them have a very structured approach with internal policies to ensure consistent and

[10] H2020 Provenance, European project (2018-2020), developed a verification-based warning system for disinformation. Website: https://www.provenanceh2020.eu/
[11] First Draft News is an international non-profit coalition formed in 2015 that provides practical and ethical guidance in how to find, verify and publish content on Internet. Website: https://firstdraftnews.org/
[12] Google initiative that whose mission is to work with journalists and entrepreneurs to drive innovation in news. Website: https://newsinitiative.withgoogle.com/google-news-lab
[13] Fact Checking, Verification & Fake News: Social Media Verification in Craig Newmark Graduate School of Journalism. Website: https://researchguides.journalism.cuny.edu/c.php?g=547454&p=4256116

reliable operations (e.g.Map Action). However, members are considered volunteers. The literature and emergency world has pointed to a group considered experts in using social media in emergency management. It is a group of Virtual Operators formed by experts in active collaboration with emergency organisations: VOST.

VOST differs from other types of volunteer groups as it is integrated within a governmental or emergency response organisation. This team of professionalized digital volunteers is classified as an institutional organisation within the authorities and has high entry barriers for new memberships, as it is restricted to ensure better integration into available organisational structures (Fathi et al., 2019). Furthermore, there is an existing relationship based on trust between these two organisations team members (St. Denis, Hughes, & Palen, 2012). The inclusion of VOST into emergency management agencies' workflow creates new decision-making processes to consider in coordination centres, as demonstrated in the Düsseldorf Grand Départ of the Tour de France 2017 case study (Fathi et al., 2019).

VOST is considered a way to manage the Web 2.0 platforms stream of information, filter the noise, and fight rumours and unverified information (Beneito-Montagut et al., 2013). Two recurring tasks for VOST are the verification and Geolocation of information, identification of rumours and fake news, and sharing useful information to/with the public and disseminating key messages. It is suggested that VOST, digital volunteers and citizens can benefit from guidelines developed in the area of journalism to perform verification processes (C. Silverman, 2014).

2.2.6. Challenges of using Twitter in emergencies for decision-making

Social media has proven to be a useful Information and Communication Technology (ICT) before, during and after major incidents (e.g. emergencies). Many studies in disaster management have focused on the analysis of Twitter and its content (de Albuquerque et al., 2015).

Social media, including Twitter, poses at least five critical challenges for interpreting its data and its evaluation. This section classifies them by the properties inherited from the system and the user interaction with data production and consumption. Table 2-6 (page

57) summarises these five key challenges and groups them in a two-level macro environment (as it impacts all data) and microenvironment (it focuses on one message at a time).

The three macro challenges outlined are associated with *'big data'* properties. The amount of data being gathered and stored is growing at a phenomenal rate in volume, velocity, and variety (Sagiroglu & Sinanc, 2013; Tin et al., 2013). It is believed that the access and analysis of big data will provide big insights allowing researchers to understand better society and complex problems (Shen, 2018). Big data does not refer solely to the amount of data; it is also a qualitative shift in society's study (Boyd & Crawford, 2012). Multiple datasets might be cross-referenced and analysed to produce meaningful insights (Shelton, Poorthuis, Graham, & Zook, 2014). Big data provides significant opportunities for multiple disciplines, including business, military, bioinformatics, medicine and education (Kwon, Lee, & Shin, 2014; Shen, 2018). However, there are also general and discipline-related challenges to overcome.

In the area of disaster and emergency management, big data from dedicated and multipurpose sensors can help in the preparedness, response, mitigation and recovery phases. Data can be used to create models to predict events, support policymakers and response managers (e.g. Merchant et al. 2011). For example, big data helps mitigate disaster events by providing real-time situation awareness (Tin et al., 2013). Social media information, as part of big data, can give more insight. Guan & Chen (2014, p.838) stated: "*The insight provided by social media data goes far beyond*".

Level	Component	Definition	Challenge	Sample researchers
Macro	Volume	Quantity of data	Big Noise, Information Overload	(Bernstein et al., 2010)
	Velocity	Stream of data (speed)	Information shift	(Pohl, Bouchachia, & Hellwagner, 2013; Zhou & Chen, 2014)
	Variety	Types of data: structured, semi-structured and unstructured	Completeness	(Shelton et al., 2014)
Micro	Intentional misinformation	The user creates or shares content being aware of the inaccuracy of the information	Malicious Use	(Oh, Agrawal, & Rao, 2011; Wardle, 2017)
	Unintentional misinformation	The user creates or shares content being unaware of the inaccuracy of the information	Misinformation	(G. Chen et al., 2015; E. Kaplan et al., 2012; Takayasu, Sato, Sano, Yamada, & Miura, 2015)

Table 2-6 Challenges of using Twitter as an information sources

Volume, velocity and variety of data are translated to a large quantity of information gathered at high speed in multiple formats. Identified challenges are: (2.2.6.1) the difficulty of finding relevant information, (2.2.6.2) information shift and (2.2.6.3) completeness of the information. Even with these challenges, researchers have shown the power of analysing social media big data. Social media information can be extracted, transformed and loaded in an alternative system for analytical purposes. The manipulation of data can enable decisions that may affect policymaking since data is from a global community and not a unique individual. For example, social media platforms (e.g. Twitter) provide real-time data for monitoring and analysing the impact of emergencies (Q. Huang et al., 2015; Imran & Castillo, 2014; Imran et al., 2015). Social media use was a predictor of post-traumatic stress after Hurricane Sandy (Goodwin, Palgi, Hamama-Raz, & Ben-Ezra, 2013). While resolving the macro-level challenges can improve decision-making to a higher level (e.g. policy making), the resolution of problems associated with individual messages can impact a more significant number of stakeholders when most needed.

The next two challenges are associated with the information production/consumption relationship. The users' intention while creating or sharing inaccurate information: intentional (section 2.2.6.4) or unintentional (2.2.6.5). These challenges are translated to the malicious use of social media and sharing misinformation. The combination of all these challenges can contribute to the spread of rumours.

Mccreadie et al. (2015) proposed six types of social media post:

1) **Opinionated:** A post that expresses the author's opinion
2) **Reporting:** A post that details an event's occurrence and supplies a secondary source, e.g. a hyperlinked news article.
3) **Unsubstantiated Information/Speculation:** A social media post that discusses information that is uncertain or is unfounded.
4) **Disputed/ Controversial Information:** A post that challenges information provided in another post, article, image or video.

5) **Linked Dispute:** A post that attempts to deny a rumour, possibly in the form of a direct reply to a user. Like reports, corrections often supply a secondary supporting source of evidence.
6) **Misinformation/Disinformation:** A post that contains false information, misrepresented information or quotes out of context.

Social media are often perceived as more credible sources than traditional mass media (Procopio & Procopio, 2007). However, concerns have been raised concerning the accuracy of the information, malicious use of social media and bias in data generation (Xiao et al., 2015). Better understanding the type of tweets and the similarities of false information could help emergency stakeholders in their decision-making process.

2.2.6.1. Big Noise: the volume challenge for Information Quality (IQ)

Massive quantities of data are created and captured by and about people, machines, and their interactions (Boyd & Crawford, 2012). Alexander (2014) stated that "*perhaps the greatest challenge in using social media is the sheer volume of information involved*" (p.725). The volume challenge for data veracity is explained through the concept of Big Noise. It refers to the quantity of data within social media that are irrelevant to the topic researched.

Open source big data such as Twitter poses the amount of noise within the data as one of the key challenges (JST-NSF, 2013). The Data Science Association defines noise in their website as *"a competing interpretation of data not grounded in science that may not be considered scientific evidence. Yet noise may be manipulated into a form of knowledge (what does not work)"* (Data Science Association, 2016).

Big Noise can be interpreted as all data not related to the topic researched (intention). The intentional analysis of social media content can be during and after major incidents.

During emergencies, the need for specific information varies according to event circumstances, and the type of stakeholder involved such as fire brigade, health manager and citizens (Imran et al., 2015). For example, relevant information for an affected citizen can be related to shelter facilities or news from loved ones. Simultaneously, a first responder team could benefit from information related to

blocked roads and traffic jams. Therefore, access to the right information is paramount for emergency stakeholders. Access to this information has technological and social challenges. First, social media search Application Program Interface (API) allow the limited collection of data in terms of the number of queries per unit of time. For example, a 1% limitation exists in the extraction of messages collected from Twitter by the Internet Archive and in the display of random sample of messages through their public streaming API (Imran et al., 2015). Secondly, not all social media platforms provide the same functionalities or data access facilities. Thirdly, not everyone uses social media, and privacy settings can limit access to the information posted. Terms and conditions restrict data extraction, and users can set their privacy levels limiting access to public real-time data. Finally, terminology, grammar, and spelling can bias the sample collected.

Despite all the limitations, overcoming the big noise challenge has its benefits to detect trends and patterns. The number of users is so large that the volume of data gathered excess the potential responses of questionnaires, surveys or focus groups providing greater insight into future emergency management plans.

2.2.6.2. Information Shift: the velocity challenge for Information Quality

Using Twitter, researchers and practitioners can collect the data that social media users have quickly generated. The speed of the stream of data, velocity, is impacted by the number of events reported by users.

The temporal aspect of social media, referred to as *'freshness of information'* by Agarwal & Yiliyasi (2010), is considered in many studies, especially for event detection. Social media in general and Twitter specifically provide the ability to detect events using a space-temporal approach in the data analysis (Cheng & Wicks, 2014). Events and sub-events can be identified by reviewing social media streams (Pohl et al., 2013; Zhou & Chen, 2014). Multiple studies combine the temporal and geographical aspect to gather better insight into the information collated (Fontugne, Cho, Won, & Fukuda, 2011; Petkos, Papadopoulos, & Kompatsiaris, 2012; Rattenbury, Good, & Naaman, 2007). However, emergencies are usually quick events where information/knowledge may be changed continuously, outdated, and incomplete (Tin et al., 2013). Therefore, access

systems that can answer the information requirements at every stage can further enhance decision-making.

Twitter can be an excellent asset to identify trends; for example, by merely observing tweets, an earthquake can be detected (Sakaki et al., 2010). However, social media poses challenges associated with the velocity at which the information is shared and accessed. Citizens must receive time-sensitive details before the information expires (Spiro et al., 2013). However, this is not always the case. For example, in March 2011, after the Japanese earthquake and tsunami, tweets for assistance were retweeted after the victims were rescued (Acar & Muraki, 2011).

This challenge can severely impact the allocation of resources by first responders and citizens' decisions before, during and after major incidents.

2.2.6.3. Completeness: the 'variety' challenge for Information Quality (IQ)

The third challenge presented by the system is the variety of data available to the user and its typology. Big data can be obtained from a variety of sources and usually has three data types: structured, semi-structured and unstructured (Sagiroglu & Sinanc, 2013). Structured data can be incorporated in a data warehouse and queried, while unstructured data is random and difficult to analyse. Semi-structured data sits between both. Social media usually host these three data types. Twitter allows users to post text, image, video, gifs, or polls while also providing system information.

Richthammer et al. (2014) proposed a taxonomy of social network data types after analysing related classifications from Schneier (2010), Årnes et al. (2011) and Beye et al. (2012). It included the following data type: login, mandatory, extended profile, network, ratings/interest, private communication, disclosed, entrusted, incidental, disseminated, contextual, application and connection. Each social media platform has its capabilities and business model. For example, YouTube, Flickr and Slideshare -considered content communities (A. M. Kaplan & Haenlein, 2010)- have specialised in specific content: videos, photos or presentations. However, they all share to a major or minor degree the taxonomy provided by Richthammer et al. (2014).

The variety of data hosted in social media can help users better understand users and their behaviour. Furthermore, data disclosed, entrusted incidental, disseminated, contextual, and application data merged from different users can increase situation awareness.

2.2.6.4. Malicious use of Social media

The low entry requirements and content moderators' inexistence make social media, including Twitter, a fertile ground for misinformation.

The old concept of *'Fake News'* has acquired a new dimension in the online environment and its supposed implications for sharing people behaviour. Sharing unverified information can have a considerable impact during any major incident as malicious use of social media can put people in danger. For example, it can create additional instability during terrorist attacks by congregating people in a location and having a second attack at that location (Gao, Barbier, & Goolsby, 2011; Lindsay, 2011; Weaver, Boyle, & Besaleva, 2012). An example of this is the use of social media during the Mumbai attacks in 2008, with the following message was posted (Oh et al., 2011):

> *"RT @celebcorps remember when tweeting details that it is CONFIRMED terrorists have satphone (satellite phone—researchers added) access net sources (1:50 AM Nov 27th, 2008 from Ubiquity)"* (p.38)

While social media platforms have performed efforts to remove terrorist-related content and fake profiles, it is a difficult task to undertake if freedom of information has to be guaranteed.

In an attempt to better understand the misinformation challenge, the First Draft initiative (Wardle, 2017) has describes seven categories of disinformation:

1) **False connection:** News with headlines, visuals or captions that do not support the content.
2) **False context:** Genuine content but shared with incorrect contextual information.
3) **Manipulated content:** Content or images, but this is manipulated to deceive.

4) **Satire or Parody:** Content created with no intention to deceive but has the potential to fool people.
5) **Misleading content:** Uses news articles to frame an issue or an individual to mislead users.
6) **Imposter content:** Genuine sources are impersonated.
7) **Fabricated content**: Content 100% created to deceive and harm people.

Different techniques could be applied to resolve each of these potential misuses of social media content. Similarly, challenges are associated with posts published by genuine sources but with inaccurate information or propagating rumours.

2.2.6.5. Information inaccuracy and Rumours

Inaccurate information and rumours have been reported as a challenge by multiple researchers and emergency responders (Castillo, Mendoza, & Poblete, 2011; Mendoza, Poblete, & Castillo, 2010; Oh, Agrawal, & Rao, 2013; Procter, Vis, & Voss, 2013; Seo, Mohapatra, & Abdelzaher, 2012; Terpstra, Stronkman, Vries, & Paradies, 2012).

For example, during the Japanese earthquake, the tweet (Takayasu et al., 2015):

> *"Please spread: To those people who live close to the east shore of Tokyo Bay! Due to the explosion of oil tanks, harmful chemical materials may fall with rain soon. Bring your umbrella and rain coat with you to protect your skin from the dangerous rain!!"* (p.2)

However, this was a rumour without scientific basis (G. Chen et al., 2015; Takayasu et al., 2015). Other examples can be found after Hurricane Sandy in October 2012, where rumours circulated on social networks about paid volunteer opportunities and reimbursements for survivors (E. Kaplan et al., 2012).

Rumour theory has been used to analyse the reliability of community intelligence obtained through social reporting. In Twitter, Oh et al. (2013) identified three main rumour causing factors under social crises: (1) information with no evident source provided, (2) personal involvement and (3) anxiety. To further complicate this challenge, misinformation can spread fast on social media platforms (Lukasik, Cohn, & Bontcheva,

2015; Takayasu et al., 2015). As a response, Takayasu et al. (2015) evaluated rumour propagation speed and developed a model to estimate the rumour infection rate.

2.3. Information quality challenge: deciding to use Twitter in emergencies

The use of social media in general and Twitter in specific in major incidents, including emergencies, has proven beneficial for risk communication (section 2.2.3) and information awareness (2.2.4). However, its usage presents many challenges to overcome related to information production and information consumption (section 2.2.6). Aside from corporative content, Twitter mostly relies on User-Generated Content (UGC), which is created and shared without any control. This impacts Information Quality (IQ) and can endanger emergency stakeholders. IQ is a crucial challenge to solve for the use of Twitter's information for decision-making in Emergency Management (EM).

IQ was considered in relation to freedom of error until the 1990s. Then, as described in section 2.3.1, it was proposed to use a more customer-oriented definition, and information quality was measured according to its *'fitness of use'*. For the purpose of this research, Information Quality (IQ) and data quality are used as interchangeable concepts. IQ has been researched from two perspectives in Information Systems (IS) research (Bizer, 2007): the first focuses on improving IQ within the production process and the second approach investigates IQ from a consumption perspective. A limited number of practical actions can be done to enhance IQ from a production perspective for all Twitter users (i.e. training all Twitter users, remove fake accounts). However, emergency stakeholders can be supported to reduce the uncertainty during the information consumption process for decision-making. It is posited that IQ perception depends on the relationships of different information attributes. By reviewing 71 existing IQ framework models, the researcher identified fifteen IQ dimensions in IS that could support uncertainty reduction in decision-making. The most commonly cited are accuracy, timeliness, relevancy, concise representation, completeness, objectivity, accessibility, reliability, appropriate amount of information, security /access security, interactivity, interpretability, value-added, usability, reputation, believability, and

understandability. Further analysis of these in the area of social media for decision-making in major incidents is required.

Therefore, the researcher interrogated existing literature in the area of IQ in emergency management. Different researchers had documented the IQ requirements from an emergency organisations perspective. In section 2.3.3, the researcher describes the importance of Information Quality (IQ) in major incidents and existing Emergency Management IQ models and frameworks proposed in the literature.

After this review, the researcher concluded that further analysis is required to understand Twitter emergency information requirements and solve its associated challenges. Over the last few years, researchers have provided suggestions to support data validation in social media, especially using two approaches (section 2.3.4). The first one analyses properties of Twitter to evaluate one or multiple entities providing insight to user-generated content (2.3.4.1), users' information (2.3.4.2) and network behaviour (2.3.4.3). The second approach relies on additional resources outside the capabilities provided by social media platforms to verify the information. Three main strategies were identified as experts (2.3.4.4), crowds (2.3.4.5), and machines (2.3.4.6). While all previous efforts focused on better understanding and using the data, the researcher advocates for using a more holistic approach based on IQ while creating and implementing all these solutions. With this aim, existing research is surveyed to identify a suitable IQ model in the area of social media (2.3.4.7). But first, the researcher defines Information Quality (IQ).

2.3.1. Defining Information Quality (IQ)

Information Quality (IQ) was considered in relation to freedom of error until the 1990s. Over the years, researchers tried to differentiate between information quality and data quality. There is a tendency to refer to data quality concerning technical issues, and information quality is used concerning non-technical issues (Madnick, Wang, Lee, & Zhu, 2009). Nevertheless, both terms have been used alternately in this literature review. This section defines IQ from two perspectives: the production process and the consumption perspective.

Information Quality (IQ) in the production process

Information can be created by and obtained from multiple sources. From a business perspective, data is divided into internal data and external data, where internal refers to data produced directly or indirectly within the organisation, and external refers to data from sources outside the firms' control, for example, social media (Lukyanenko & Parsons, 2015). The relevance of external data within the business context has increased with the advent of big data analytics. It is understood that big data may provide fascinating insight for businesses helping during the decision-making process (H. Chen, Storey, & Chiang, 2012).

As previously discussed in section 2.2.6, data from social media presents multiple challenges for its consumption. Indeed, IQ is impacted by its provenience. For instance, data from a firms' machine has specific parameters predefined in advance with a limited margin of error. On the other hand, human input data is prone to error. In the business setting, several initiatives can be performed to improve information and data quality input. For example, as Iversen & Mathiassen (2003) described in their case study the use of business incentives to improve data quality in a software organisation, internally firms can train employees and develop regulations to encourage adherence to data quality protocols. The evaluation of its adherence can be performed using internal and external data processes. However, training can sometimes introduce biases (Galloway, Tudor, & Haegen, 2006) and may not be realistic for casual contributors (Lukyanenko, Parsons, & Wiersma, 2014).

Measures to regulate the IQ from a business perspective become more challenging to implement within external data sources. Data obtained from citizens can be subjective and, therefore, affected by internal (e.g. attention to detail, mood, stress levels) and external conditions (e.g. weather, noise). Also, the level of engagement can impact the quality of the User-Generated Content (UGC) contributions (Coleman et al., 2009; Nov, Arazy, & Anderson, 2011; Yates & Paquette, 2011).

Information Quality (IQ) from a consumption perspective

The analysis of IQ from a consumption perspective refers to its usage for decision-making. IQ is defined by most researchers in relation to *'fitness for use'* which relies on

the concept of meeting end-users' requirements and expectations (Kahn, Strong, & Wang, 2002; Y. W. Lee, 2003; Y. W. Lee, Pipino, Strong, & Wang, 2004; R. Y. Wang & Strong, 1996; Zhu & Wu, 2011).

In a computer-mediated environment, users' decisions can be determined by their Perceived Quality of Information (PQI). IQ studies evaluate the usefulness of the information on the basis of four attributes (Jeong & Lambert, 2001): (1) perceived usefulness; (2) perceived ease of use; (3) perceived accessibility; and (4) attitude. When users perceive that the information meets their needs and requirements, they can make decisions based on their own decision criteria (e.g. useful, accessible, level of difficulty, attitude). Experience and knowledge play a vital role during the information processing phase. Knowledge can be classified in *'past personal,' 'past formal,'* and *'contextual knowledge'* (Diniz, Borges, Gomes, & Canos, 2005). Past personal knowledge impacts the decision-maker own experience, while past formal knowledge refers to prescribed rules and procedures. Contextual knowledge is *"the most dynamic and should be updated quite often"* (Kapucu & Garayev, 2011, p. 369). Additionally, PQI is correlated to source trust and risk perception (Nicolaou & McKnight, 2006). Determining receivers' PQI on social media is a primary stage to assess potential decision behaviour.

2.3.2. Information Quality (IQ) in Information Systems

While searching for a definition, the researcher noticed a tendency to define Information Quality (IQ) based on different attributes or dimensions, all depending on the context analysed. In fact, multiple IQ models exist depending on the area of research. For example, Garvin (1988) proposed eight attributes in the manufacturing-firm context, including performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality.

IQ is an area of interest in the Information Systems (IS) literature. It has been analysed as a stand-alone element but also as a part of systems evaluations. For example, DeLone and McLean (2003) included IQ as one of their six dimensions framework model to evaluate information systems in addition to system quality, individual impact, organisational impact, user satisfaction and system usage.

Many IQ studies employ models that posit or depend on theorised relationships between information attributes and overall information quality. The measurement of quality dimensions or attributes can be relatively difficult as it depends on a specific user's perception and can be subjective.

IQ can be evaluated according to its content, format and the physical environment associated with the information (Culnan, 1985; Jeong & Lambert, 2001; Miller, 1996). Evaluation of information content assesses if the information is accurate, current, secure, relevant, valid and complete (Miller, 1996). Criteria for evaluating information format on the internet include analysing its design, format, and links (Miller, 1996). The physical environment assessment is related to easy access to the information and system (Culnan, 1985). IQ can influence various outcomes, including *"knowledge sharing behavior (Durcikova and Gray 2009), mobile device adoption (Kim and Han 2011), trust in the IT artifact (Vance et al. 2008), user loyalty (Zhou et al. 2010), and customer satisfaction (Kekre et al. 1995)"* (Setia, Venkatesh, & Joglekar, 2013, p. 570).

Various published literature review papers summarise existing IQ models and frameworks. Eppler & Wittig (2000) reviewed the literature to identify IQ frameworks from 1989 to 1999. Similarly, Knight & Burn (2005) evaluated IQ frameworks models from 1996 to 2002 to identify standard dimensions of IQ and data quality to develop through their research a framework for assessing Information Quality (IQ) on the Internet. Furthermore, as standard practice, published articles in the area provide a summary of the state of the art in IQ before suggesting any new framework model. Similarly, the researcher introduces in Table 2-7 commonly used IQ dimensions identified after reviewing 71 research framework models.

Dimension	Definition	Freq. Cited	Ref. Sample researchers
Accuracy	The extent to which data are correct, reliable and certified free of error.	38	(Chai, Potdar, & Dillon, 2009b; Delone & Mclean, 2003; Y. W. Lee, Strong, Kahn, & Wang, 2002; R. Y. Wang, Kon, & Reddy, 1992; R. Y. Wang & Strong, 1996)
Concise representation	The extent to which data are compactly represented without being overwhelming (i.e. brief in presentation, yet complete and to the point)	32	(Agarwal & Yiliyasi, 2010; Kandari, Jones, Nah, & Bishu, 2010; Y. W. Lee et al., 2002; R. Y. Wang & Strong, 1996)
Relevancy	The extent to which data are applicable and helpful for the task at hand	32	(Chai et al., 2009b; Klamma et al., 2007)
Timeliness	The extent to which data the age of the data is appropriate for the task at hand	32	(Agarwal & Yiliyasi, 2010; Seppänen & Virrantaus, 2015; Ulicny, Baclawski, & Magnus, 2007)
Completeness	The extent to which data are of sufficient breadth, depth, and scope for the task at hand.	31	(Chai et al., 2009b; Kahn et al., 2002; Reuter et al., 2014; R. Y. Wang & Strong, 1996)
Objectivity	The extent to which data are unbiased (unprejudiced) and impartial.	27	(Delone & Mclean, 2003; Kandari et al., 2010; Price & Shanks, 2004; Reuter et al., 2014)
Accessibility	The extent to which data are available or easily and quickly retrievable	23	(G. E. Jensen, 2012; Y. W. Lee et al., 2002; Seppänen & Virrantaus, 2015; R. Y. Wang & Strong, 1996)
Amount of Information	The extent to which the quantity or volume of available data is appropriate	20	(Chai et al., 2009b; Eppler, 2001; Naumann & Rolker, 2000; Reuter et al., 2014)

Dimension	Definition	Freq. Cited	Ref. Sample researchers
Reliability	The extent to which information is reliable or trustable.	20	(R. Y. Wang et al., 1992; R. Y. Wang & Strong, 1996)
Interactivity	The extent to which a user can interact with the data.	18	(Agarwal & Yiliyasi, 2010; Y. W. Lee et al., 2002)
Security	The extent to which data is secure	18	(Price & Shanks, 2004; R. Y. Wang et al., 1992)
Interpretability	The extent to which data are appropriate in language and units and the data definitions are clear	17	(Chai et al., 2009b; Kahn et al., 2002)
Believability	The extent to which data are accepted or regarded as true, real, and credible	16	(Bovee, 2004; Kahn et al., 2002)
Reputation	The extent to which data are trusted or highly regarded in terms of their source or content	16	(Y. W. Lee et al., 2002; Price & Shanks, 2004)
Usability	The extent to which data can be used for the task at hand	16	(Y. W. Lee et al., 2002; Price & Shanks, 2004)
Value-added	The extent to which data are beneficial and provide advantages from their use.	16	(Delone & Mclean, 2003; Katerattanakul & Siau, 1999)
Understandability	The extent to which data can be understood and processed	15	(Naumann & Rolker, 2000; Seppänen & Virrantaus, 2015)

Table 2-7 Information Quality dimensions in the IS and social media literature

The majority of the dimensions outlined above were proposed by Wang & Strong (1996), and multiple researchers use them. The Wang & Strong (1996) model was derived from the factor analysis of the importance of various Information Quality (IQ) dimensions rated by consumers (Bovee, 2004). Their research focused on consumers' perceptions of data quality. Wang & Strong used 15 dimensions of IQ, including believability, value-added and timeliness. These dimensions were used to build a framework based on four categories: intrinsic, accessible, contextual, and representational.

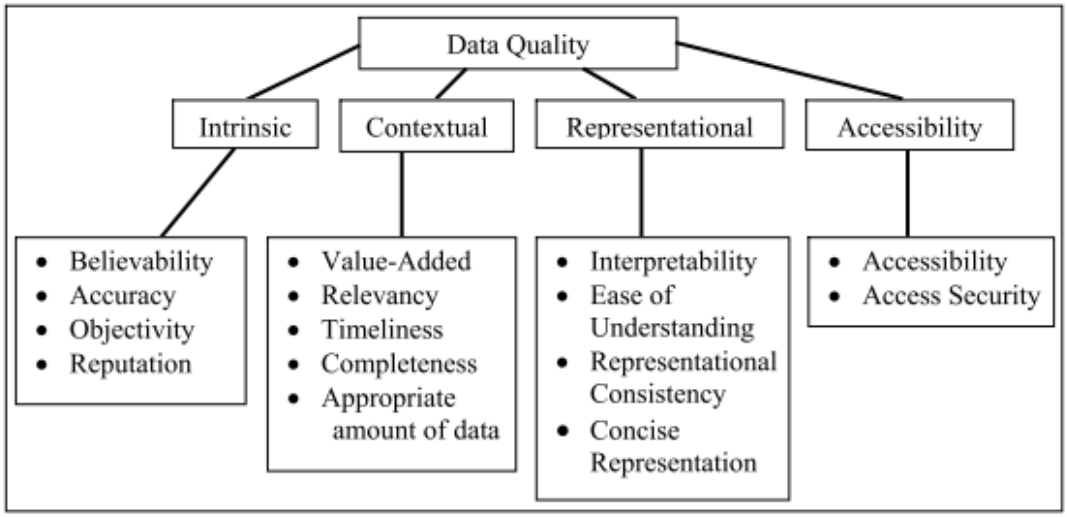


***Figure 2-5 Wang and Strong's model of data quality* (1996)**

Intrinsic IQ implies that information has quality in its own right. Contextual IQ highlights the requirement that IQ must be considered within the context of the task at hand; it must be relevant, timely, complete, and appropriate in terms of amount, to add value. Representational and accessibility IQ dimensions emphasize the importance of computer systems that store and provide access to information. Hence, the system must present information in such a way that it is interpretable, easy to understand, easy to manipulate, and is represented concisely and consistently. Besides, the system must be accessible but secure.

While Wang & Strong (1996) framework model has wide acceptance in the IS community, researchers have also used other frameworks and models as their baseline, including the Financial Accounting Standards Board (FASB, 1980) and the Y. R. Wang & Guarascio (1991) framework.

Researchers using the FASB framework focus on the definition *'fitness of use'*. Therefore, they evaluate the usefulness of the information provided as a critical element for IQ. The FASB models information usefulness as hierarchically dependent on attributes such as Relevance, Reliability, and Timeliness. Previous to Wang & Strong model (1996), Wang & Guarascio, (1991) identified a set of dimensions of data quality as defined by data consumers, including interpretability, representational consistency, ease of understanding, conciseness, believability, accuracy, objectivity, completeness, traceability, reputation, variety of data and data sources, access security, relevancy, the appropriate amount of data, timeliness, accessibility, ease of operation, and flexibility.

For example, Bovee, Srivastava and Mak (2003) developed an IQ model by adapting the Wang and Strong model (1996) in conjunction with the Financial Accounting Standards Board (1980) model. Alternatively, Bovee (2004) compared existing models and proposed a *'Modified Model of Information Quality (IQ)'* that can be summarized by its dimensions mnemonic AIRI – Accessibility, Interpretability, Relevance and Integrity.

Despite the notable contributions to IQ described above, the researcher concluded there is not a defined Information System IQ model to support decision-making in major incidents. Hence, quality requirements (section 2.3.3) in this context must be further analysed to assist the design and evaluation of information systems.

2.3.3. Information for decision-making in emergencies: quality requirements

As described in Section 2.1.2, decision-making is different in major incidents (e.g. emergencies). In all phases of any potential emergency, information is vital to reduce the incident's impact. Decisions made with the wrong information can endanger stakeholders' lives and create further damage.

Intelligence during major incidents can be gathered through information search and management. Information search is triggered by the violation of expectations after an initial situation assessment. Researchers and practitioners have highlighted the importance of information for emergency management. '*A Framework for Major Emergency Management*' (2008), a national framework used in Ireland to prepare and

co-ordinate the response to major emergencies between An Garda Síochána (Irish Police service), the Health Service Executive (HSE) and Local Authorities, states:

> *"The purpose of information management in a major emergency is to facilitate decision-making. The quality of the information that is presented to decision-makers is crucial to effective decision-making, and is recognised as a key determinant of outcome. Decision-makers in major emergency situations are likely to have to make critical decisions based upon incomplete information. Thus, great efforts should be made to generate information for decision-makers that is as timely, accurate and clear as possible"* (p. 64).

Additional information may not reduce uncertainty as it can create information overload (Reuter, Ludwig, Kaufhold, & Spielhofer, 2016). Hence, the quality of the information obtained must provide further insight. However, what are the information requirements for emergency management? Furthermore, what is considered Information Quality (IQ) by emergency stakeholders?

The importance of IQ increases while *"managing nonroutine, difficult and uncertain interdependencies in performing complex customer-oriented activities"* (Setia et al., 2013, p. 573). The emergency Information Quality (IQ) perception is described by analysing the fundamental elements required by emergency stakeholders to take decisions during major incidents. The US Department of Defence defines quality as *"doing the right thing from the first time, always aspiring for improvement and user satisfaction"* (Marcelo Zambrano, Esteve, & Palau, 2015, p. 307). However, quality assessment is a challenging issue, and quality itself is relatively ill-defined (Nelson, Todd, & Wixom, 2005). According to OCHA, the United Nations Office for the Coordination of Humanitarian Affairs (2014, p. 6), *"There is not a single model to assess all characteristics of the data with one single quality indicator. Quality is not absolute. Therefore, the assessment of data quality is always a trade-off between the various dimensions of the data, the importance of the data and the complex relationships between them"*. It is paramount to identify the required quality dimensions and their relationship to evaluate IQ. Table 2-8 summarises the Emergency Management Information Quality (IQ) requirements outlined in the literature review.

	UNICEF (2005)	Danielsson & Ohlsson (1999)	Humanitarian Data Exchange Framework (OCHA, 2014)	Bharosa, Zanten, & Zuurmond (2009)	Seppänen & Virrantaus (2015)
Accessibility & interpretability			X		X
Accuracy			X		X
Applicability					X
Availability		X			
Clarity					X
Comparability			X		
Completeness				X	
Comprehensiveness					X
Conciseness					X
Consistency					X
Context awareness				X	
Convenience					X
Correctness				X	
Currency					X
Interactivity					X
Location	X				
Quantity				X	
Relevance		X	X		
Reliability		X			
Reputation					X
Security					X
Speed					X
Timely	X		X	X	X
Traceability					X
Validation				X	
Value-added					X

Table 2-8 Emergency management: Information Quality (IQ) requirements

Based on the work of Danielsson and Ohlsson (1999), quality depends on the reliability, availability, and relevance of the information where reliability plays an important role, "*since information coming from incompetent sources is error-prone*" (Kapucu & Garayev, 2011, p. 369). Therefore, data integration plays a vital role. In the humanitarian context,

the Humanitarian Data Exchange[14] project (OCHA, 2014) presented an IQ framework to make humanitarian data easy to find and use for analysis. It bases its data quality definition in terms of fitness for purpose, where quality is identified as a five-dimensional entity that combines the relevance of the data for the users. In summary, accurate, timely and complete information about the current state and scientific predictions play a vital role in decision-making (Buzzelli et al., 2014; Horita et al., 2013).

The following phrase summarises the objective of information management: "*Getting the right information to the right person at the right place at the right time"* (National Working Group, 2008, p. 3). Therefore, these four constructs - the right information, the right person, the right place and the right time- can impact the decision-making process. These parameters are the underlying main elements in the existing information models evaluated by Information Systems (IS) research. A growing body of literature looks at the emergency management requirements to develop Emergency Management Information Systems (EMIS). In this area, researchers link IQ with system quality, where IQ describes the characteristics of the information produced or transferred by an information system while system quality focuses on the EMIS (Bharosa et al., 2009). For example, Wang & Strong (1996, p. 6) define data quality as "*data that are fit for use by data consumer*".

EMIS is a real-time system where efficiency is related to the communication and the synergy between its elements (Marcelo Zambrano et al., 2015). Bharosa et al. (2009) reviewed different case studies to identify IQ requirements in the area of disaster management. They discovered eight potential IQ requirements and interviewed emergency managers in relation to these. Requirements reported included Correctness (15 respondents), Timeliness (15), Completeness (14), Quantity/amount of information (15), Validation of information (9), and Context awareness (5). On the other hand, Prasanna & Huggins (2016) found in their EMS research that Information Quality (IQ) combined with performance expectancy, effort expectancy, social influence technology

[14] The Humanitarian Data Exchange (HDX) is an open platform that makes humanitarian data easy to find and use for analysis. Founded in 2014 by the United Nations Office of the Coordination of Humanitarian Affairs (OCHA), HDX enables to share data across crises and organisations. Website: https://data.humdata.org/

acceptance factors accounted for 65% variance in symbolic adoption. Information Quality (IQ) was added as a variable following the research performed by Moores (2012) and Wixom and Todd (Wixom & Todd, 2005). Some Emergency Management Systems (EMS) had been analysed using the Delone and McLean's IS success model (e.g. Y. Chen, 2012) and the Total Quality Management methodology (Marcelo Zambrano et al., 2015).

It is important to develop Information Systems that fit emergency managers' requirements as information access for this collective is usually integrated into one of these EMS.

2.3.4. Twitter Information Quality (IQ) approaches

The researcher has described Information Quality (IQ) in information systems and emergency research. This section focuses on Twitter IQ and approaches to solve the challenges associated with this social media platform.

While Twitter is considered an Information System, section 2.2.6 described five specific challenges for using Twitter and other social media platforms as an information source for decision-making. They were categorised into two groups depending on the origin of each challenge. The first group of difficulties is associated with big data properties and inherited by the system properties. The second group was related to the human interaction with Twitter (i.e. information production /consumption relation). Following a similar approach, two main lines to data verification discussed in the literature were identified. They are differentiated based on their relationship with Twitter: (1) Intrinsic properties and (2) Extrinsic properties. Table 2-9 (page 78) provides an overview of each approach with its description and a sample of researchers. Further information is provided in the following sections (2.3.4.1 to 2.3.4.6).

The intrinsic approach analyses properties of a specific social media platform, in this case, Twitter. As described in Section 2.2.1., an array of information can be extracted from Twitter about different database entities providing insight into user-generated content, users' information and network behaviour. For example, from a journalism and

enterprise perspective, SocialSensor[15] and REVEAL[16] FP7 projects explored the possibility of analysing tweets' validity based on a 3 C's framework: Content, Contributor and Context analysis (Corney et al., 2014; Middleton & Gottron, 2014). Previous research has showcased that ranking of tweets based on Twitter features can help assess the credibility of information, especially using a combination of both message and source (Gupta & Kumaraguru, 2011).

The first approach described is related to post information and content analysis (see Table 2-9 first section). It focuses on the analysis of the content posted by users to assess its veracity. The next section (2.3.4.1) provides a sample of the existing literature of emergency-related user-generated content. The concept extracted from the literature review is the existence of methods to classify a large quantity of user-generated content and, therefore, support emergency stakeholders to reduce the big data noise and facilitate the volume challenge. The second section of the analysis of the intrinsic elements for information verification (2.3.4.2), refers to the information related to the post's creator. As previously described, social media content can be originated from different motivations. Key elements reviewed in this section include the concept of fake profiles and source reliability. Section 2.3.4.3 evaluates the network behaviour in relation to the post and the user. Social media platforms have defended that the virtual space should be auto-regulated and democratic, relying on other users input to determine what is worthy. Therefore, this section provides an insight into research that has evaluated the data verification process through network recommendations and behaviour (e.g. likes, number of replies).

[15] SocialSensor, FP7 European Integrated Project (2011-2014), aimed to improve information management social media by developing tools to perform verification, filtering, sensing, analysis, visualisation tasks amongst others. Website: www.socialsensor.eu

[16] REVEAL, FP7 European Project (2013-2016), developed a tool to discover what is being said in social media and determine how trustworthy that information is, supporting verification processes. Website: http://www.revealproject.eu

Data Verification using Intrinsic Properties		
Approach	Description	Researchers Sample
Post information and Content analysis	Analysis of content posted on social media. Content features include: length of a tweet, num of words, emoticons, sentiment words, multimedia content, mentions, hashtags, URLs	Text Analysis (Canini, Suh, & Pirolli, 2011; Castillo et al., 2011; Gupta & Kumaraguru, 2011; Oh et al., 2013)
		Image (Boididou, Papadopoulos, Kompatsiaris, Schifferes, & Newman, 2014; Gupta, Lamba, Kumaraguru, & Joshi, 2013b)
User information analysis and behaviour	Analysis of information related to the user, including no. of followers, follower-friend ratio, num of times listed, the user is a verified user, profile image, num of tweets, num of URL in messages	(Boididou et al., 2014; Gupta & Kumaraguru, 2011; Stringhini, Kruegel, & Vigna, 2010)
Network behaviour	Analysis of reaction from other users: likes, shares, reported as spam…	(Mendoza et al., 2010)
Data Verification using Extrinsic Properties		
Approach	Description	Researchers Sample
Expertise	The user uses his/her expertise or authoritative sources to verify the message.	(Martin, 2014)
Crowdsourcing /human sensors	Verification is achieved by involving large groups of users to evaluate Information Quality (IQ)	(Chamales, 2013; Heravi, Morrison, Khare, & Marchand-Maillet, 2014; Imran, Castillo, Lucas, Meier, & Vieweg, 2014; Kamel Boulos et al., 2011; Ortmann, Limbu, Wang, & Kauppinen, 2011; Poblet, García-cuesta, & Casanovas, 2014; Popoola et al., 2013; Schulz & Probst, 2012; Weaver et al., 2012)
Linked data	Integration of other data sources and social media data in order to verify the information.	(Crowley et al., 2013; Daume, Albert, & von Gadow, 2014)

Table 2-9 Intrinsic and extrinsic social media information verification approaches

The extrinsic approach relies on using additional resources to verify the information and external input and, therefore, outside the capabilities provided by social media platforms (see Table 2-9 second section). Three main approaches are identified: experts, crowds, and machines (Kamel Boulos et al., 2011). Section 2.3.4.4 describes the role of

expertise in the verification process. As described in section 2.1.2., experience in emergency management plays a vital role in decision-making. However, experts' input is not always possible, and crowdsourcing has been proposed as a potential solution (section 2.3.4.5). Various researchers propose that the approach to data veracity is through data classification and the ability to filter irrelevant messages (big noise). One way proposed to achieve this is through the use of crowdsourcing techniques in concert with machine learning algorithms (Kamel Boulos et al., 2011; Ortmann et al., 2011; Poblet et al., 2014). Literature related to the use of collective knowledge, especially crowdsourcing during major incidents, is surveyed. Many research papers have been published concerning crowdsourcing initiatives for emergency management (e.g. Certomà, Corsini, & Rizzi, 2014; Laskey, 2013; D. Yang et al., 2014). In crowdsourcing, the input from a third person is paramount to identify the veracity of the information. This approach would benefit from a verification framework that targets challenges such as increased data sources (JST-NSF, 2013), message anonymity, and lack of context (Kamel Boulos et al., 2011). Lastly, the use of external data sources has also been considered to reduce the uncertainty of the data gathered through social media in major incidents (section 2.3.4.6). In comparison with crowdsourcing, a limited number of published papers have been published; however, it is expected that this body of literature will grow thanks to the development of more integrated Information Systems. For example, DESTRIERO[17] an FP7 project integrated geocoded Twitter messages with a demographic map and a medical resource map for the recovery phase.

2.3.4.1. Content analysis and post behaviour

Social media platforms such as Facebook and Twitter have enabled users to create and share content freely within their social networks. The Cambridge University dictionary (2006) defines content as *'the ideas that are contained in a price of writing, a speech or a film'*. From early 1990 until 2000, online content was created by a reduced number of publishers. However, information dynamics changed within the Web 2.0, citizens' access to the internet and social media platforms. The ability to produce and share content

[17] DESTRIERO, FP7 European project (2013-2016), developed a post-crisis needs assessment tool for reconstruction and recovery planning phase which included a Twitter dashboard. Website: http://www.destriero-fp7.eu/

freely has changed how people communicate and search for information (e.g. Meng et al. 2015). Social media features have impacted the volume, velocity, and variety of user-generated content and have a set of associated challenges (e.g. big noise, information shift).

Data from social media is semi-structured and unstructured. When users create messages, they must decide what features (if any) they want to include for each field. In Twitter, any post can include the following information: text (including Keywords/#hashtags, URLs and other users' references/@username), multimedia content (photos, GIFS, video, and audio), location /geotags /geolocation information and timestamps. Text and multimedia content is user-generated content, while location information (if enabled) and timestamps are created by the systems during the posting process. See appendix 1 for a list of tweets content allowed in the platform.

Content Analysis: text and multimedia

Text analysis using text mining techniques is the area most developed in the analysis of user-generated content. Text mining is a knowledge discovery process used to extract interesting and non-trivial patterns from natural language (Sørensen, 2009). The technique comprises multidisciplinary fields, such as information retrieval, text analysis, natural language processing, information classification, and database technology. Text mining techniques, in conjunction with social networks, can be used for finding a general opinion about any specific subject, human thinking patterns, and group identification (Aggarwal & Ang, 2011). However, it has an associated limitation. For example, information posted online can lead to lexical, syntactic and semantic ambiguities (Irfan et al., 2015; Sørensen, 2009). A survey performed in 2015 by Imran et al. (2015) mapped the challenges of processing social media messages to six information processing operations: filtering, classifying, ranking, aggregating, extracting, and summarizing.

Research that has used text analysis for emergency user-generated content have evaluated the content by using qualitative and quantitative techniques. Twitter features and variables included in their analysis are hashtags, sentiment words, length of tweets, the number of words, emoticons, mentions, and URLs.

Content classification plays a vital role to evaluate and act using tweets' information. For example, keyword search (including hashtags) has been used to identify specific infrastructure damage or human casualty (Ashktorab, Brown, Nandi, & Culotta, 2014).

One of the basic elements in tweets text analysis is the use of hashtags (#keyword). The post creator uses hashtags to mark up tweets with one or multiple thematic keywords (Starbird & Palen, 2011). This practice facilitates the ability to search and retrieve tweets. Hashtags used in major incidents vary in each event, and it is understood that local hashtag and localized information are more credible than the alternative (Lachlan, Spence, Lin, Najarian, & Greco, 2014).

Compared with text analysis, image and video analytics is somewhat in its infancy. The prompt identification of relevant images and videos can support users' situation awareness process and improve decision-making. Nevertheless, suspicious images or videos can endanger emergency stakeholders. In this line of work, the MediaEval-2015 Verifying Multimedia Use task works on classifying image /video fake content; and the FP7 REVEAL project has also focused on classifying real content, including image classification focusing on accuracy of tweets referring to these images initially for journalistic purposes (Middleton, 2015). Additionally, an image classification model based on visual features using Latent Semantic Analysis has been proposed by Han et al. (Han, Li, & Li, 2008). In this area, Gupta et al. (2013) researched fake images on Twitter during Hurricane Sandy. This showcase the potential opportunity of using tweets to gain situation awareness further while minimising the impact of false information.

Timestamp

In emergency management, having access to timely information can be the difference between life and death during the preparedness, response and recovery phases. The importance of user-generated content brings a new dimension when citizens are the first reporting breaking news. Citizens have also been considered human sensors. A timestamp is a key element to evaluate information shift and address the associated challenges to velocity. For example, people start tweeting about earthquakes within 10 seconds after feeling the shake (Earle et al., 2011).

The majority of research related to time has been performed in conjunction with location (e.g. Steiger, de Albuquerque, & Zipf, 2015). However, no Twitter users share their Global Positioning System (GPS) coordinates while sharing content on Twitter. Nevertheless, a stamp is predefined by the system, and users have limited opportunities to modify this information (e.g. schedule future tweets.)

Location

Several studies have focused on mapping text content with coordinates. For example, Lachlan et al. (2014) compared tweets associated with localization-based hashtags and discovered that actionable information is more familiar with localized hashtags.

In the area of journalism, it has been proposed a location-based event detection framework based on four Twitter location features: user profile information, geo-tagged content, entity extraction (e.g. natural language processing), and social network analysis (Heravi et al., 2014).

2.3.4.2. User information analysis

Social media platforms allow the creation of one or multiple accounts. Each account enables a user to disclose information about them. Social media have terms and conditions related to creating profiles and usage of their platforms; however, the control of it is somewhat limited (e.g. user age verification can be challenging). A user profile can contain a name, username, birthday, short biographical description, main photo, and background photo on Twitter. Additional user information can be accessed, including the account's creation date and user's network. Therefore, setting up fake profiles is relatively easy, and its identification is a crucial challenge. The importance of this identification is exceptionally high while managing malicious use of social media (section 2.2.6.4).

Twitter provides the ability to apply for verified profiles so users can easier identify official emergency organisations accounts. However, as citizens are sometimes the first information sources, this approach has a somewhat limited impact on the data verification process.

A reduced number of research papers were found concerning information verification during major incidents by means of user information. The use of trustable sources is paramount in emergencies. Trust is a relationship key variable that helps to reduce uncertainty (Gulati & Gargiulo, 1999; Gupta & Kumaraguru, 2011; Nicolaou & McKnight, 2006).

Analysing fourteen different events, of which seven are considered a crisis, Gupta & Kumaraguru (2011) developed an algorithm to evaluate tweets' credibility, including message and source-based features. Within the source-based features, they included: registration age of the user, number of statuses, number of followers, number of friends, is a verified account, length of description, length of screen name, has URL, and the ratio of followers to followees.

In theory, it is relatively easy to create fake profiles; however, users' information is not only created by data generated by them. Users' real identity and personality of others can be inferred by a combination of self-disclosure, information provided by their contacts (comments and photos posted), and the system (number and types of friends) (Utz, 2010).

2.3.4.3. Network behaviour

Social media platforms allow any user to share their opinion with a potentially broad audience. This ability has empowered users to create their own discourse independently of the main steam agenda. For many years, it has been widely defended that the virtual space should be auto-regulated. Lately, there is an increase in governments requesting a more significant involvement of social media platforms to monitor social media conversation and support false information identification. For example, in May 2018, Facebook opened an office in Barcelona (Spain) to fight against fake news (El Mundo, 2018).

As this is an epic task to undertake, currently, information flow and data verification rely on network recommendations and behaviour (e.g. likes, number of replies). Some features exist on Twitter to enable users to evaluate users and content. Relevant information can be liked and shared, increasing the visibility of the content. Additionally,

users can send messages to other users by replying to an existing post, creating news with a username mention (@username), or using the private chat functionality. If users are attracted by the theme and type of messages that another user creates or shares, then it may become a follower and share account content (retweet). On the other hand, content and users can be reported to Twitter in order to be evaluated by the social media platform team.

Trust can be expressed in social networks by associating strength with each tie (B. Huang, Kimmig, Getoor, & Golbeck, 2013). Trust is a transferable concept within a network. For example, if A trust B and B trust C, it is likely that A can trust C. Hence, Twitter's information propagated through credible users is considered reliable. Therefore, user-based features indicate users' reputation and hence credibility (Castillo et al., 2011).

Seo et al. (2012) created an algorithm to find rumour source and analyse the likelihood that a piece of information was indeed a rumour. The corpus of their research was obtained on Twitter using the keyword Kim, Geuntae (in Korean) - a Korean politician who died in Dec. 2011. The research showed that it is possible to recognise most rumours and their source with a sufficient number of monitor nodes (users). Their algorithm measures the *'reachability'* (p. 2) to all positive and negative monitors and the distance to positive and negative monitors. Positive monitors are the nodes that received the rumour and negative monitors those who did not. Additionally, the number of connections and the degree of centrality within a network can provide valuable information about fake profiles. The degree centrality of a user can be assessed by the number of user's connections (actors connected to the central node), and it reveals the user's activity and popularity in the network (Freeman 1979). When user information is not available, then rumours can be analysed according to the information flow. Therefore, this approach highly relies on the user's network.

2.3.4.4. Expertise

Experience in emergency management plays a vital role in decision-making (section 2.1). Fisher, Chengalur-Smith, & Ballou (2003) outlined that *"experience may improve performance because it increases alertness to errors (Klein et al. 1997), sensitivity to*

omissions (Sanbonmatsu et al. 1992), use of relevant information (Sanbonmatsu et al. 1992), adaptation to subtle contextual differences (Payne et al. 1993), ability to identify important features of a problem (Mackay and Elam 1992), ability to organize the information better (Mao and Benbasat 2000), ability to attend to greater amounts of knowledge (Mao and Benbasat 2000) and process it more extensively (Sanbonmatsu et al. 1992)" (p. 173).

The naturalistic school decisions made during the response phase depend on previous experience and differ from the analytical decision-making approach. The technology dominance theory also posits that one of the central constructs for decision-making is the experience with the decision and even the decision aid's familiarity. Therefore, stakeholders' expertise can play a vital role in evaluating and deciding the quality of emergency-related social media messages.

Risk communication and decision support systems can help to support decision-making. Both can also benefit from integrating social media for input and output purposes. One active group using social media, especially Twitter, to support communication and decision-making is VOST (Virtual Operational Support Team). They aim to monitor and share reliable information through social media helping to identify fake news and supporting emergency agencies. Several research papers had referred to the use of this group for the research of social media during the management of an emergency (Hughes, Palen, & Peterson, 2014; Ludwig, Reuter, & Pipek, 2015; T. Simon, Goldberg, & Adini, 2015; St. Denis et al., 2012; St. Denis, Palen, & Anderson, 2014).

2.3.4.5. Crowdsourcing /human sensors

Literature related to the use of collective knowledge, especially crowdsourcing in major incidents, was surveyed. During big emergencies and disasters, the volume of data can be overwhelming, and the power of the crowd can help reduce noise and find relevant information. Multiple research papers have been published concerning crowdsourcing initiatives for emergency management. For example, Vivacqua & Borges (2012) discussed the benefits of taking advantage of the collective knowledge during emergencies or Oh et al. (2013) evaluated the power of community intelligence in social media services to evaluate rumours during a social crisis. Additionally, several online

websites to help the coordination of emergency management crowdsourcing initiatives have emerged. For example, Ushahidi[18] allows creating reports from social, including different fields (i.e. message, a title, the date, the location name, coordinate, categories, flag for approval, and flag for verification). These reports can be visualized on a map and exported as a Comma-Separated Values (CSV) file and as a Really Simple Syndication (RSS[19]) feed.

A key challenge is the integration of crowdsourcing data with existing systems. Ortmann et al. (2011) described in their paper the difficulties of processing crowdsourcing data within existing systems and suggested a process to interlink this data with open linked data. This process includes *"an additional crowdsourcing layer for processing [which] adds some quality control"* (p.8). To improve data quality, some guidelines have been created. For instance, Sabou, Bontcheva, Derczynski, & Scharl, (2014) suggested best practice guidelines to support the annotation of social media post by crowdsourcers.

2.3.4.6. Semantic Web and Linked Data

The access to Twitter data through its Application Program Interface (API) facilitates integrating this information with external systems. Within the premise that big data has not only impacted the way that we analyse information but has also impacted the way that we approach the analysis, some researchers have considered linking social media data with existing datasets or existing Information Systems (e.g. Derczynski, Augenstein, & Bontcheva, 2015). The use of these external data sources has also been considered to reduce data's uncertainty gathered through social media in major incidents. A limited number of papers have been published in the area of emergency management; however, it is expected that this body of literature will increase thanks to the development of more integrated Emergency Management Information Systems (EMIS).

An avenue researched is the use of Linked Open Data (LOD) as a framework for loose integration. Using SemanticWeb technologies principles, LOD refers to use of web

[18] Ushahidi is a Kenyan not-for-profit civic tech company and a crowdsourcing platform initially designed to submit violence reports and map the events. It has been used other purposes including emergency mapping. Website: https://www.ushahidi.com/

[19] Really Simple Syndication (RSS) feed is an XML based format used for sharing and distributing Web Content

techniques to connect pieces of data by encoding data in the form of <subject, predicate, object> RDF-triples (Ortmann et al., 2011). This approach has been used as part of Social Semantic Journalism which proposes a semantic-based solution to formalise and link user-generated content to other data for the purpose of information verification and fact-checking (Heravi & Mcginnis, 2013). Another similar solution proposed for information classification is Word Clouds with Entity Grouping (Leginus, Derczynski, & Dolog, 2015).

Crowley et al. (2013) proposed a framework to allow the aggregation and connection of different data sources, primarily social and sensor data, and transform them into Linked Data. This framework is based on four levels where citizens' information become part of the data sources, including open data, Enterprise Information Systems, Social Data and Sensor Data. This is translated as Linked Data Wrappers and Linked Sensor Middleware which is integrated with the Linked Data Cloud. Using Semantic Web technology, the data can now be accessible by multiple enterprise and citizens applications (e.g. Crowdsourcing, Emergency Response Systems, Localization based Services). They argue that the integration of data sources in decision support tools can support decision-making.

In the area of emergency management, the U.S. Department of Homeland Security (2014) outlines that for the successful use of social media data in situation awareness, it is required its technical and contextual integration with a broader information environment. A call is made to *"evaluate the value of traditional data enhanced with social media for response teams in real-time operations"* (p.40).

2.3.4.7. IQ Framework Models in Social media

The number of papers proposing Information Quality (IQ) Model Frameworks in the field of social media is somewhat limited, despite a growing interest in the area. Furthermore, they usually focus on online content analysis. For instance, Chai, Potdar, & Dillon (2009b) reviewed a total of 19 frameworks and classified them according to sixteen IQ dimensions, including user feedback, amount of information and reputation. However, they focus on wikis, forums and weblogs. They outlined several aspects (e.g. User Feedback, Reputation, Objectivity) using as a starting point previous research in the area

of IQ in Information System (IS). Following their example and understanding the limitations outlined by previous researchers, it is deemed appropriate to review existing social media and IS framework models in conjunction with Emergency Management IQ requirements to develop a suitable model for Twitter IQ to support decision-making in major incidents.

Various researchers have noted the importance of analysing social media content from a quality perspective. It has been noted that traditional Information Quality (IQ) research view users as data consumers and not as content generators (Lukyanenko et al., 2014). In fact, it is stated that IQ research for traditional Information Systems fails to address IQ problems caused by information created in a context without a fitness for use predefined parameters (Chai, Potdar, & Dillon, 2009a). For example, the use of Twitter information for emergency management support.

Some researchers (e.g. Parsons, 2011) are advocating to adapt the Perception of Information Quality (PIQ), commonly researched as *'fitness for use'*, and approximated this challenge User-Generated Content (UGC) from a contributor-oriented perspective (Lukyanenko et al., 2014). In the area of social media, it must be considered that contributors can have different backgrounds related to their demographics, education, economic substrate and expertise level in the topic discussed. All these can impact the IQ (Chai et al., 2009a). Therefore, it is suggested that IQ can be improved by the way that UGC is collected and stored (Girres & Touya, 2010; Lukyanenko et al., 2014; Parsons, 2011). This approach modifies completely how IQ is defined and perceived, and therefore, impacts system modelling techniques. Lukyanenko et al. (2014, p. 671), who describe UGC Information Quality (IQ) as crowd IQ, proposes the following definition: *"the extent to which stored information represents the phenomena of interest to data consumers (and project sponsors), as perceived by information contributors."*

2.4. Research gaps, considerations and potential contributions

Literature reviews are an essential feature of any research project (Webster & Watson, 2002). Literature reviews are the first step to identify research gaps and contributions

to the field. Table 2-10 summarises this chapter key findings and describes how they shaped this research.

The literature reviewed (Chapter 2) impacted the topic's selection, outlined fundamental considerations for the research methodology and defined potential contributions to theory and practice.

As described in section 2.1, decision-making in major incidents (e.g. emergencies) is different. Experts rely on previous knowledge instead of comparing all available options. The problem with expertise is that not all emergency stakeholders are experts. Hence, Mass Communication Media (MCM) plays a vital role in informing citizens and risk communication. Twitter is a relatively new MCM used in major incidents. Researchers have proven the usefulness of this social media platform in these uncertain events. However, there are multiple challenges associated with its use for risk communication and as an information source. One of the main challenges is determining the Information Quality (IQ) of tweets for decision-making. Section 2.3 illustrated that IQ perception could be impacted by the decision-maker's production and consumption process. Despite the existence of multiple IQ models in Information Systems (IS) and Emergency Management (EM), there is a limited understanding of the IQ requirements for decision-making using Twitter in major incidents (e.g. emergencies). Hence, three Research Questions were proposed by the researcher:

'RQ1. How is Twitter used for decision-making in major incidents?'

'RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?'

'RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?'

Literature review impact	Rationale	Implications
Approach to the study topic	- Decision-making in naturalistic environments is different - Experts rely on previous knowledge - Not all emergency stakeholders are experts - MCM plays a vital role in risk communication - Twitter is a relative new MCM used for emergencies - Researchers have proven the use of Twitter useful in major incidents - There are multiple challenges associated with the use of Twitter as an information source - One of the key challenges is Information Quality (IQ) - Information Quality (IQ) is impacted by the production and consumption process followed - There are multiple IQ framework models in IS	- Limited understanding of the use of Twitter for decision-making - IQ requirements for decision-making using Twitter require a better definition - A better understanding of the relationship between IQ requirements and dimensions is required - Emergency Management IQ requirements for decision-making using Twitter are unknown
Selection of the research methodology	- It is unethical to create an emergency-related setting in a laboratory to explore decision-making - Existing Twitter uses classifications focus on the post content or in recommendations for risk communication - Journalist and Public Information Officers play a vital role in citizens decision-making through their updates - VOST have been identified as experts in the area of social media evaluation in major incidents	- The research strategy should be designed within the Naturalistic Decision Making parameters - Real-world incidents should be used - VOST, Journalist and Public Information officers as a unit of analysis - Existing IQ framework models can be used as a baseline to develop a suitable model for this research - Information production vs consumption as a research lens - Twitter challenges require a more holistic approach to reduce the uncertainty for decision-making during major incidents

Literature review impact	Rationale	Implications
Demonstrate contribution	- Limited knowledge of the IQ requirements for the use of Twitter information for decision-making - Limited knowledge of the global impact of Twitter information challenges for decision-making in major incidents - Limited knowledge of quality dimensions relationship and their impact on quality while using Twitter for decision-making in major incidents	- Expert knowledge can be used to develop training material to support decision-making - Propose an IQ framework model to be tested and implemented by different stakeholders - Establish a correlation between IQ dimensions to support decision-making during emergencies by reducing the uncertainty - EMS development can benefit from a better understanding of the IQ requirements while integrating Twitter data in DSS

Table 2-10 Literature review implications in the research: research gap, methodology implications and potential contribution

To address these research questions, the literature review pointed out several key elements to consider. These impacted the selection of the methodology and shaped data gathering and analysis processes. First, it is unethical to create an emergency-related setting in a laboratory to explore decision-making. Hence, the method selected needed to use real incidents. This approach aligns with the Naturalistic Decision Making School (NDMS) beliefs. Secondly, as decision-making in naturalistic environments is dependent on the decision-maker expertise, it was paramount to gather experts' knowledge in the use of Twitter for decision-making in emergencies to answer this research question. Three expert groups were identified in the literature reviewed, and they became the unit of analysis of this research: (1) Journalists, (2) Public Information Officers (PIOs), and (3) Virtual Operation Support Team (VOST) members. They play a vital role in processing information from and for Twitter through risk communication and gathering situation awareness. Lastly, the existing classification of Twitter uses focuses on analysing Twitter entities from a computer science perspective or in recommendations for the development of risk communication strategies. Therefore, a more IS-based approach was required where the focus is placed on the user interaction with Twitter (production and consumption of information). Existing Information System and Emergency Management IQ models were used as a base-line for the analysis of the findings.

The literature reviewed suggested several potential contributions to theory and practice. Research gaps identified included a limited body of knowledge on:

- IQ requirements for the use of Twitter information for decision-making in emergencies
- the global impact of Twitter information challenges for decision-making in emergencies
- Information Quality (IQ) dimensions conceptual relationship and their impact on quality while using Twitter for decision-making in incidents

Hence, potential contributions of this research include the use of expert knowledge to design a Twitter IQ model for decision-making in Emergencies, the identification of the conceptual relationship of the IQ dimensions, and the first step to developing training

material for non-experts decision-makers (novices). Further contribution, which was outside of this research's scope, could be achieved by testing and implementing the model by different stakeholders and evaluating its integration with Emergency Management Information Systems (EMIS) and Decision Support Systems (DSS).

All the information summarised in Table 2-10 was considered while defining the research process strategy and analysing these research findings. Chapter 3 defines the journey followed to address identified gaps and fulfil this research objective:

> **The development of a microblogging (Twitter) descriptive model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents.**

Chapter 3. Research methodology and its implementation

This chapter presents the research methodology and justifies its selection. Furthermore, it narrates the journey taken by the researcher to implement the research strategy, including the philosophical and ethical considerations of performing research in decision-making in major incidents, the selection of methods to meet this research objective, the process of identifying relevant data sources in a naturalistic environment, the steps took to capture suitable data, and the actions performed to manipulate, prepare and analyse the rich data gathered. Far from being a traditional methodology chapter, it showcases the uniqueness of aligning the Naturalistic Decision Making School (NDMS) with research in Information Systems (IS) by describing and justifying each step taken by the researcher.

The researcher acknowledges that research is about answering unanswered questions or creating that which does not currently exist, more than just a process of gathering information (Goddard & Melville, 2004). Hence, the methodology proposed and its implementation were guided by the literature review findings (described in Chapter 2) and informal conversations with emergency practitioners. The researcher identified a gap in the proposed solutions to evaluate Twitter Information Quality (IQ) in major incidents for decision-making. Therefore, the methodology selected aimed to fulfil the following objective and answer its associated Research Questions (RQs). Furthermore, this research outcome is a novel descriptive model developed using experts input and contextual data. It does not validate existing theory but contributes to developing it.

Objective: To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents.

- ***'RQ1. How is Twitter used for decision-making in major incidents?'****:* There is a growing body on the analysis of Twitter in emergencies from a computing and communication perspective. However, little is known about the impact of the

information obtained using this channel from Twitter for decision-making. Therefore, this research investigated, using three case studies, how emergency stakeholders use Twitter for decision-making. Information obtained from multiple sources of evidence (observation, artefacts, interviews and documents) defined the context to build a Twitter IQ model for decision-making in major incidents.

- ***'RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?':*** Despite its benefits, Twitter presents multiple challenges associated with its usage derived from the system's features (velocity, volume and variety) and the user interactions with the platform (malicious use, and information inaccuracy). Research has been performed to reduce the impact of these challenges; however, its majority is based on the development of mathematical models, which are inaccessible for multiple emergency stakeholders when uncertainty increases. The researcher proposed to align the emergency management Information Quality (IQ) requirements with IQ dimensions identified in the area of Information Systems (IS) and social media to address this shortcoming. There is limited knowledge about Twitter IQ dimensions required for decision-making in major incidents. Three case studies complemented with ten interviews with decision-making experts allowed identifying information requirements in emergency management and their alignment with Twitter IQ dimensions.
- ***'RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?':*** There are several existing IQ framework models in the area of IS and a more limited number in Emergency Management (EM) research; however, they do not describe the steps required to assess Twitter IQ for decision-making in major incidents. After evaluating the IQ dimensions in RQ2, the researcher analysed 75 decision-making processes performed by experts in the use of Twitter in major incidents in order to identify relevant decision-making steps and develop a must-have IQ Framework model. This descriptive model provides a tool that can help stakeholders reduce uncertainty in incidents decision-making using Twitter information.

Four research areas were evaluated through these research questions: social media (Twitter), decision-making, Emergency Management (EM) and Information Quality (IQ). Framing this research with decision-making in major incidents aligned itself within the Naturalistic Decision Making School (NDMS). The association with this school of thought had implications on this research's philosophical grounding definition. Section 3.1 describes ontology, epistemology, methodology, and ethical implications considered by the researcher.

The researcher describes, in section 3.2, key considerations while designing the research strategy. Section 3.2.1 provides the reader with an overview of the methods considered in the Information Systems discipline area (3.2.1.1) and the Naturalistic Decision Making School (3.2.1.2). Special attention is paid to the description of suitable methods in the area of Naturalistic Decision Making (NDM), including (1) Critical Decision Method (CDM), (2) Knowledge Audit Method (KAM), and (3) Goal-Directed Task Analysis (GDTA). The researcher integrates CDM within the case study methodology. Hence, the three case studies selected are introduced, and section 3.2.2 explains their suitability to identify the unit of analysis chosen. The unit of analysis is further discussed in section 3.2.3 where three key stakeholder types identified as part of the literature review (Chapter 2) are introduced: journalists, Public Information Officers (PIOs), and Virtual Operation Support Team (VOST) members.

Section 3.3 provides the reader with a detailed description of the research protocol which is divided into three phases: (1) defining the context for development; (2) building the model through three case studies, and (3) refining the descriptive model using expert input through an adapted Critical Decision Method (CDM). It includes the description of these phases and the steps followed to identify relevant data sources and answer associated questions.

Section 3.4 summarises the multiple sources of evidence used as part of each case study. The complexity of the defined research questions and the objective of this research required a mixed methodology approach to describe, explain and explore the phenomenon and its associated variables. Therefore, a combination of data collection methods was deemed as a suitable approach. Case study evidence can be collected from

many data sources, including documentation, archival records, interviews, overt observation, participant observation, and physical artefacts (Yin, 2009). In this research, the researcher used the following sources of evidence: overt computer-mediated observation (3.4.1), documentation and archival (3.4.2, 3.4.3 and 3.4.4), artefacts (3.4.5) and interviews (3.4.6). The combination of sources of evidence is encouraged in the case study methodology. It increases the validity and reliability of the findings. On the other hand, the researcher was aware of the importance of expertise in the decision-making process in major incidents and, at the same time, the complication of observing decisions made during these events. Therefore, the use of interviews within the Critical Decision Method (CDM) provided value to the case study approach.

Section 3.5 describes how the data gathered is analysed, and the data triangulation process used to provide evidence to answer RQ1, RQ2 and RQ3. The chapter ends with a summary of the research approach followed (section 3.6).

3.1. Philosophical grounding and the naturalistic decision-making school

This section outlines Information Systems (IS) research paradigms and evaluates Naturalistic Decision Making School (NDMS) of thought. It leads to an examination of the ontological, epistemological, methodological, axiological and ethical consideration of the NDMS.

Paradigms assumptions regarding ontology, epistemology and methodology and their weaknesses should be taken into account before selecting one of them for any research (E. G. Guba & Lincoln, 1994; Remenyi & Williams, 1995). Additionally, ethical considerations are relevant for any research efforts in particular within the NDMS. The researchers' own beliefs motivate the selection of one or another paradigm. The selection helps determine the researchers' position and justifies the research strategy selected (E. Guba, 1990), including research design, collection, and data analysis. Additionally, research paradigms guide researchers and readers in interpreting reality and provide the reader with the intended context chosen by the researcher to understand further research findings (Benbasat & Weber, 1996; Iivari, Hirschheim, & Klein, 2004; Patton, 1990).

In the last 50 years, a pluralism of philosophical perspectives has emerged (i.e. multiple paradigms) in IS (Iivari et al., 2004). Fundamental beliefs paradigms in IS include positivism, post-positivism, critical theory, constructivism (interpretivism), participatory, and design. Table 3-1 provides an overview of these paradigms concerning ontology, epistemology and methodology. The researcher describes the perception of the reality for each paradigm (i.e. positivism, post-positivism, critical theory, constructivism/interpretivism, participatory, and design), the approach to understand research's findings and the methods more aligned to each belief.

Amongst the listed paradigms in Table 3-1, interpretative is the closest to the researcher's belief and it is also aligned with the views of the NDMS. The researcher suggests that IS research can benefit from this school of thought while designing task-specific systems for emergency management where data uncertainty is inherent. In the case of epistemology, the researcher emphasises the importance of prescriptive knowledge to theoretical descriptive knowledge. It also expresses the need for using appropriate qualitative research methods with a strong focus on reliability and validity. Finally, the NDMS focuses on real-world incidents and, in the case of Emergency Management (EM), has associated ethical challenges. Researchers' problem is that it is dangerous and unethical to conduct experiments in truly hazardous or harmful circumstances to evaluate decision-making in these circumstances. However, as previously discussed in Chapter 2 (section 2.2), decisions made during major incidents are intrinsically different. All these challenges and implications were considered while evaluating and designing this research methodology.

Basic Belief	Positivist	Post-positivism	Critical Theory	Interpretive	Design
References	*(Aliyu, Singhry, Adamu, & Abubakar, 2015; E. G. Guba & Lincoln, 1994)*	*(E. G. Guba & Lincoln, 1994)*	(Aliyu et al., 2015; E. G. Guba & Lincoln, 1994)	(Aliyu et al., 2015; E. G. Guba & Lincoln, 1994)	*(Vaishnavi & Kuechler, 2008)*
Ontology	A single reality Knowable, probabilistic	A single reality but imperfectly and probabilistically apprehendible	Virtual reality shaped by social, political, cultural, economic, ethical, and gender values	Multiple realities, socially constructed	Multiple, contextually situated alternative world-stages. Socio-technologically enabled
Epistemology	Objective; dispassionate. Detached observation of truth	Modified dualist/objectivist. Findings considered probably true	Transactional /subjectivist; value mediated findings	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction	Knowing through making: objectively constrained construction within a context. Iterative circumscription reveals the meaning
Methodology	Observation; quantitative, statistical	Modified experimental /manipulative; critical multiplism; falsification of hypothesis; quantitative and qualitative.	Dialog /dialectical	Participation; qualitative. Hermeneutical, dialectical	Developmental. Measure artifactual impacts on the composite system
Axiology	Truth: universal and beautiful; prediction	Bias: undesired but inevitable.	Facts: never isolated from values.	Understanding: situated and description	Control, creation; problem-solving; progress (i.e. improvement understanding)

Table 3-1 Philosophical assumptions of research perspectives

The following subsections discuss the ontology, epistemology, methodology, axiology and ethical considerations related to Naturalistic Decision Making (NDM). Section 3.1.1 describes Ontology and epistemology, section 3.1.2 presents the Methodology aspects reviewed, and section 3.1.3 provides the ethical consideration assessed by the researcher.

3.1.1. Ontology and epistemology

Ontology is concerned with *'theories'* or *'views'* of how human-beings conceive the *'world'* and *'reality'*. It refers to the social constructions that exist independently of any individual perceptions of them. On the other hand, epistemology relates to the nature and forms of knowledge. It answers how knowledge can be created, acquired and communicated (W. Chen & Hirschheim, 2004; Scotland, 2012).

Patrick T. Hester (2017) classified the four decision analysis sub-discipline, Classical decision-Making (CDM*), Naturalistic Decision Making (NDM), Organisational Decision-Making (ODM), and Judgement and Decision-Making (JDM), concerning their ontological assumptions and epistemological instances. Figure 3-1 illustrates an adaptation of his classification. The four decision analysis sub-disciplines are visually positioned in relation to idealism and realism paradigms. CDM, which is related to operational decision-making methods, is positioned closer to the realism sub-discipline. This paradigm's ontological position is based on the view that everything exists independently of our awareness (Cohen, Manion, & Morrison, 2007; Pring, 2000). The positivist epistemology is one of objectivism. Positivists go forth into the world impartially, discovering absolute knowledge about an objective-reality. The researcher and the researched are independent entities. Meaning uniquely resides in objects, not in the researcher's conscience, and it is the researcher's aim to obtain this meaning.

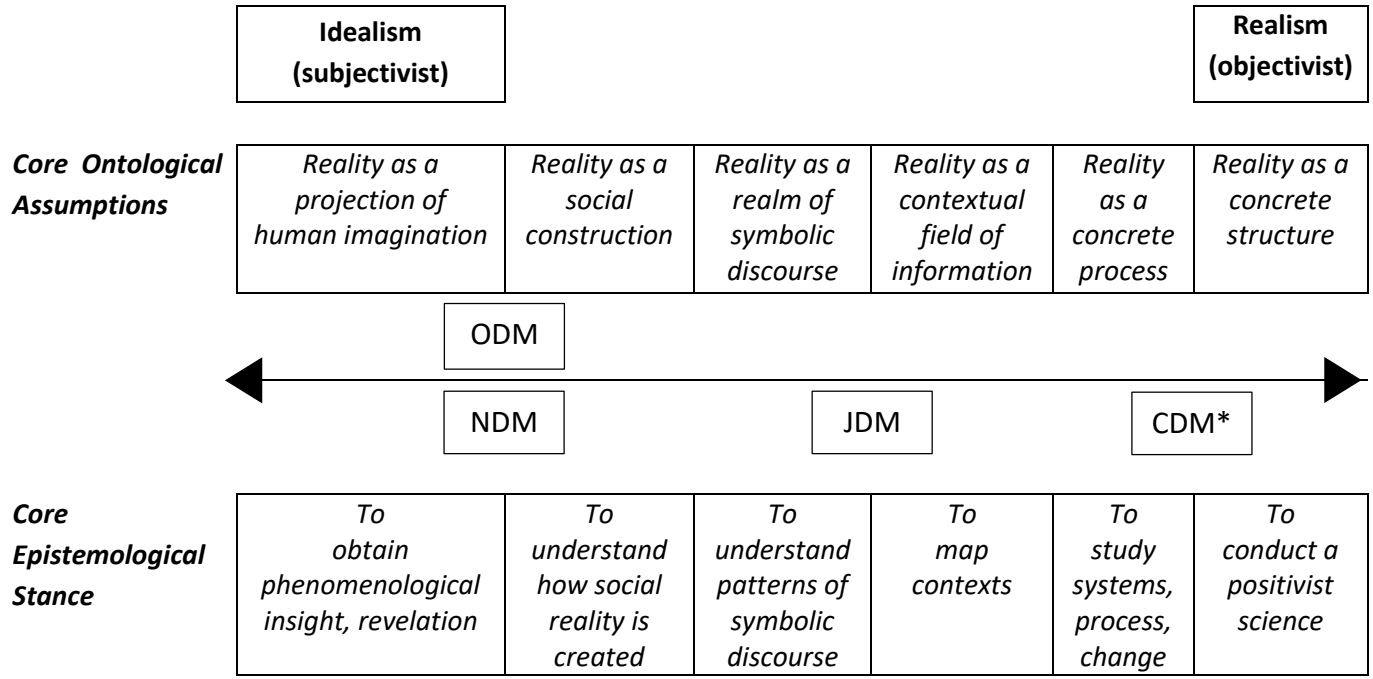


Figure 3-1 Decision-making sub-disciplines: Ontology and epistemology comparison (Adapted from Hester 2017)

On the other hand, the ontological position of interpretivism (relativism) defends that reality is subjective, and it is different from person to person (E. G. Guba & Lincoln, 1994). NDM, which emphasises psychological approaches and methods in decision processes, and ODM, which focuses on decision-making as an element of organisational behaviour, are nearest to this paradigm. The interpretive epistemology is one of subjectivism, which is constructed on real-world phenomena. It is based on the concept that the existence of the world depends on our knowledge of it (Grix, 2004).

Within these two extremes, several intermediate paradigms can be found, including post-positivism and critical paradigm. Post-positivism has similar beliefs to positivism, but they diverge into two key elements. First, their perception of how research knowledge acquired is only valid in the tested hypothesis (Popper, 1959); and secondly, their belief in the principle of falsification, which argues that scientific theories can never be proven true (Ernest, 1994). The critical paradigm ontological position is the historical realism that believes that demographics, economics and socio-cultural elements influence the view of the reality. Critical epistemology is one of subjectivism, which is based on real-world phenomena and linked with societal ideology. Knowledge is both socially constructed and influenced by power relations from within society. Cohen et al. (2007, p. 27) explain "*what counts as worthwhile knowledge is determined by the social and positional power of the advocates of that knowledge*." Regarding knowledge of trees, different organisations have differing beliefs. For example, the World Wildlife Fund[20] (WWF) and logging companies have differing agendas; therefore, they often dispute what constitutes an endangered tree.

This research is founded on the belief that reality is a social construction somewhat impacted by the projection of human interpretation and imagination. Social media provides us with an excellent example of this. One same event can be defined, explained and justified using a large variety of subjective premises all depending on users' interpretation. The Naturalistic Decision Making School (NDMS) focus on the concept of

[20] World Wildlife Fund (WWF): Their mission is to conserve nature and support diversity of life on Earth including wildlife, forest and oceans. Website: https://www.worldwildlife.org/

expertise. It argues that the perception of the reality and the decision-making process varies according to the decision-maker's knowledge.

3.1.2. Methodology

The methodology is the method/steps followed by the researcher to find what they believe can be known. There are three primary research methodologies (qualitative, quantitative and mixed); however, Information Systems (IS) discipline is also about doing and creating solutions. Therefore, within action research, the design methodology has been proposed by researchers and approved by practitioners.

Research aims to produce findings arrived at by mathematically based methods -mainly statistics (Muijs, 2004). Researchers using **quantitative research** methodology uses "*post-positivist claims for developing knowledge*"(Creswell, 2003, p. 18). It quantifies problems and states relationships between variables analysed. Using the quantitative methodology, researchers can collect facts, measure them and test their hypothesis. The ability to measure variables provides a sense of objectivity to the research findings (Berger & Berry, 1988); however, it limits the researcher understanding of the information collected. The design of quantitative research does not allow the integration of new information obtained during the data gathering process. For example, Goodwin et al. (2013) stated the positive relationship between the variables analysed but pointed out that there is not room for further comprehension.

Data collected using quantitative research methodology can be transformed into statistics (Muijs, 2004). For example, Verhoeven et al. (2014) provide the percentage of surveyed communication professionals that use social media during a crisis. The use of statistics allows for condensing large quantities of information (Gravetter & Wallnau, 2008). For this reason, samples are usually large in quantitative research (e.g. Brummette & Fussell Sisco, 2015; Freberg et al., 2013; Jain & Kumar, 2015; Kim, 2014). If the full population is not possible to survey, then quantitative research aims to select a sample that is representative of the universe. This representativeness can be achieved using probabilistic sample selection methods, which allows researchers to generalise their findings (Muijs, 2004).

Qualitative research is a non-mathematical process of interpretation of data gathered to discover concepts and relationships between them (A. L. Strauss & Corbin, 1998). **Qualitative researchers** often make knowledge claims based primarily on constructivist perspectives or/and participatory perspectives (Creswell, 2003). This type of research aims to understand the reasons, motivations and opinions of a problem (Newman, 2008). Knowledge is achieved by investigating people perspectives and behaviour in a specific situation or context (B. Kaplan & Maxwell, 2005). Usually, it has a smaller sample but with a more substantial understanding of the problem environment. This selection aligns with using samples by purpose (judgement sampling method). For example, Verhoeven et al., (2014) used a database provided by the European Association of Communication Directors (EACD) to enquiry how European professionals handle crises and risk/crisis communication (including the use of social media). Convenience sampling is one of the three broad approaches to select a sample for a qualitative research study (Marshall, 1996). This approach can bias researchers' findings, and representativeness may be jeopardised (Muijs, 2004). However, it can be mitigated by using the saturation principle: information is collected until no new knowledge is acquired. It can be argued that a qualitative approach to this research would provide a further understanding of *'how'* social media is used in major incidents.

The qualitative research methodology allows the researcher to modify questions according to subjects' knowledge and new findings. The complete analysis of the information (speech/narrative) collected is achieved when the topic researched is comprehended, and therefore, the research question answered. This approach is usually interpreted as subjective as it cannot be measured using statistics.

These two methodologies are compared in **Table 3-2** :

Orientation	Quantitative	Qualitative
Assumption of the world	A single reality and specified real-world phenomenon	Multiple realities and real-world phenomena
Purpose of the research	Trying to establish relationships between measured variables	Trying to understand the social situation from the participants' perspective.
Methods and processes	Research procedures and activities are established before research begins. Hypotheses are formulated before the study can begin. Deductive approach.	Research procedures and activities vary depending on data gathering and how the study is processing. The saturation point is essential for the data collection process. Inductive approach.
Researcher's role	Ideally an objective observatory	The researcher participates in the study activities, and it can have different roles during the research project.
Participant's role	No active role during the research project.	Participants' role is the active participant from start to the end of the project.
Research results and generalisations	Generalisations are context-free depending on sample size and population	Generalisations are based on context-detailed data and analysis.

Table 3-2 Comparison of quantitative and qualitative research approaches (Modified from Thormas, 2010)

Mixed methodology, also referred to as the data triangulation approach, combines quantitative and qualitative research methods to answer a single research question and test a unique hypothesis (Denzin, 1973; Jick, 1979; Zachariadis, Scott, & Barrett, 2013). A data triangulation approach aims to compensate for the weaknesses of qualitative and quantitative methods by combining their strengths (Jick, 1979). The researcher tends to base knowledge claims on pragmatic grounds. **Design methodology** research methodology aims to create an artefact to solve a problem observed (Fedorowicz et al., 2014; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). It can also combine quantitative and qualitative methods, but differs from mixed methodology in the requirement of having different iterations to complete the research and achieve its objective.

This research is centred on finding an information quality descriptive model that reduces the uncertainty from Twitter for decision-making in major incidents (e.g. emergencies). It is indeed a complex topic that requires a combination of multiple sources of evidence

to create and refine the model. The researcher aims to comprehend expert mental models and use the knowledge gathered as a basis to develop a descriptive IQ microblogging model to support decision-making in major incidents. While design methodology was initially considered as a suitable methodology for this research, the phenomenon complexity, including the definition of its challenges, requires more an exploratory analysis instead of a creative design process. Besides, decision-making in major incidents is intrinsically different from decision-making in other contexts. Therefore, the methodology selected must consider these differences while collecting data from real-life situations. Hence, ethical implications must be well-thought-out (section 3.1.3).

3.1.3. Ethical considerations

The ethics of research concerns the accountability of the investigators for the research findings and significances. This research presents some ethical issues that were considered and addressed mainly in the proposed methodology. The objective of the research is ***'To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents'.***

The first consideration is in relation to the social media platform used to analyse decision-making: Twitter. While emergency managers' use of social media is not limited to this platform, its fast environment makes it a suitable information source to quickly gather situation awareness. Additionally, its reduced privacy settings lessen the difficulty of accessing the data. From a research perspective, Bruns et al. (2012, p. 13) argue that while other social media platforms have complex privacy settings which need to be ethically considered, "*publicly visible Twitter messages are guaranteed to have been published to the internet at large, at least technically, and archiving them in the course of research activities is therefore substantially less problematic*".

The second consideration is related to the alignment with the Naturalistic Decision Making School (NDMS) of this research. The NDMS believes that decision-making in naturalistic environments (e.g. emergencies) is fundamentally different from other decision-making processes. Therefore, it can only be experimented with when an incident occurs and outside lab settings. The adherence to this research thought

presents the ethical consideration of endangering research participants in order to gather information. The same school proposes multiple methods that allow capturing information, a posteriori (section 3.2.1.2), to address this difficulty. Additionally, this research has used an opportunistic approach to detect and use specific major incidents creating three case studies.

Lastly, the researcher also considered data privacy as members interviewed take part in this research as volunteers and, their opinion does not necessarily represent the opinion of their employers or colleagues. All necessary steps were taken to protect their identity while availing of their expertise.

As described, a number of key considerations must be addressed to develop a suitable research protocol. The following section builds on the ethical considerations while selecting the method (3.2.1), the case studies (3.2.2), and the unit of analysis (3.2.3).

3.2. Considerations Twitter IQ model for naturalistic decisions

Section 3.2 describes the key considerations in designing this research strategy. In order to assess the best approach to develop an Information Quality (IQ) descriptive Model for this purpose, the researcher first (section 3.2.1) reviews exiting methodology in the area of Information Systems (IS) and within the Naturalistic Decision Making School (NDMS). To perform solid research, it is paramount to select research methods that address the research objective and questions outlined. It was deemed appropriate to use a combination of methods.

Two methods are considered in the area of IS: design science and case study. The NDMS has informed the selection of the research methodology. The importance of using real case incidents has impacted the evaluation of the methods proposed within the IS research area. Therefore, the use of case studies and the ability to use multiple information sources, including overt observation, have been paramount for the decision of utilising this method. Additionally, the importance of the experts' role and the ability to identify and use decision-making prompts have motivated the selection of the Critical Decision Method (CDM) as the best approach to perform interviews.

In section 3.2.2, the researcher describes the sampling strategy used to select the case studies, and section 3.2.3 describes the unit of analysis. The researcher wants to bring to the reader's attention the complexity and high interdependence between the selection of case studies and the unit of analysis. Decision-making in the area of Twitter information quality in major incidents is being analysed from an individual perspective in this research. Therefore, the unit of analysis are individuals who, adhering to the NDMS beliefs, are experts in the use of social media in major incidents. In Chapter 2 (section 2.2.5), three emergency stakeholders were identified as a suitable unit of analysis: Public Information Officers (PIOs), journalists and Virtual Operation Support Group (VOSG) members. Hence, while selecting case studies is essential to achieve this research objective, the researcher selected relevant case studies where VOSG were active as other units of analysis are present in any major emergency. Virtual Operation Support Team (VOST) is in principle only activated when an emergency organisation request it.

In turn, the selection of case studies was mostly opportunistic. However, the large number of recent emergency incidents allowed the researcher to select different types of major incidents (terrorist attack, eclipse-mass gathering event and hurricane) and locations (Spain, Texas and Oregon). The three incidents selected took place in August 2017 (C. Adams, 2017), and the VOS teams were activated according to their required involvement (Figure 3-2). These case studies played a vital role in identifying experts (unit of analysis) and collecting their input for the model's refinement process.

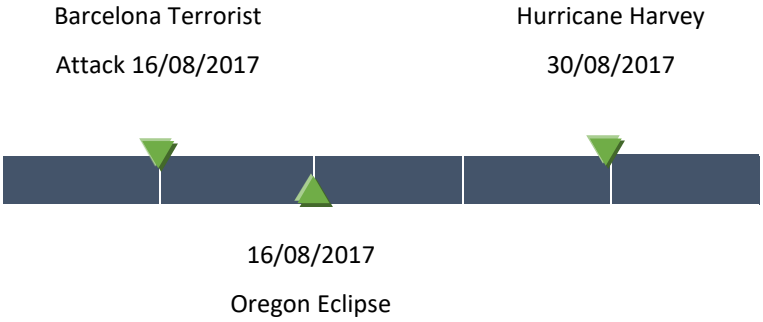


Figure 3-2 Case studies – Virtual Operation Support Team (VOST) activation dates

This section also discusses the importance of selecting the right unit of analysis (section 3.2.3). Building on the selection of the methods and understanding that the assessment of information quality obtained from microblogging platforms such as Twitter is an individual process, it has delimited the unit of analysis to individual emergency stakeholders who are experts on actively evaluating information (for production or consumption) from this source. As described in Chapter 2, there is evidence that decision-making in naturalistic environments (e.g. emergencies) is different from other decision-making processes, and decision-makers' expertise impacts it. However, not all emergency stakeholders are experts. Nevertheless, following the Naturalistic Decision Making school (NDMS) beliefs, lack of proficiency can be overcome through training materials. Therefore, experts in the area of social media Emergency Management (EM) were sought to achieve this research objective. As previously mentioned, three key expert groups were identified by their role in the use of social media in previous major incidents (risk communication and information seeking practice for situation awareness). They are journalists, Public Information Officers (PIOs), and VOST members.

3.2.1. Methods considered

Methods considered to fulfil this research's objective are grouped within Information systems methods (section 3.2.1.1) and the Naturalistic Decision Making School (section 3.2.1.2). The researcher considered two methods as part of the Information Systems section: design science and case study. Both methods are suitable to fulfil the objective of this research; however, after comparing and aligning those against the research questions and considerations, the researcher decided to use the case study as its primary method. Similarly, Naturalistic Decision Making (NDM) methods were reviewed, including the Critical Decision Method (CDM), the Knowledge Audit Method (KAM), and the Goal-directed Task Analysis (GDTA) method. These three methods were considered due to this research's nature and the researcher ontological and epistemological beliefs (section 3.1). After comparing them, the CDM provides better evidence to fulfil this research objective while benefiting from experts' input. CDM is a tested and validated method that provides further legitimacy to the research findings while framing them within the case studies proposed.

3.2.1.1. Information System Methods Considered: Design Science vs Case Study

Information System (IS) is widely accepted as an applied discipline (Iivari et al., 2004). There are two main paradigms in IS design. The goal of the first one, the behavioural science paradigm, is to find the truth. The second one, the design-science paradigm, focuses on utility as its primary goal.

This research aimed to create a descriptive microblogging model to be used by emergency managers and citizens alike supporting the reduction of the uncertainty during their decision-making process using Twitter information. Using the premise of *'creating a model'*, the researcher initially considered using a design science method to fulfil this research objective. Design science aims to devise artefacts to accomplish goals (H. A. Simon, 1996). Design science in the IS literature assumes that this method should be theory-based: a sort of hypothetic-deductive, theory-testing mode of design science. However, outside of IS, design science seems to be more theory-discovery: a pre-theoretical mode of design science (Baskerville, 2008). Nevertheless, it has been used to develop and implement solutions to society's problems (Gabel & Design Science /Global Solutions Lab, 2010). Examples of its use include designing strategies to solve real-world problems, including food and water shortage, clean energy, education, health and economy solutions.

To create a model based on its utility, the researcher approached several Irish and International emergency management experts to define the problem information. The researcher held informal conversations with relevant emergency managers in the events organised by the FP7 S-HELP[21] project in Ireland and Israel (2016), and by the H2020 Medi@4Sec[22] in Greece (2017). These events provided the researcher with access to

[21] The researcher worked as Research Officer in the S-HELP FP7 European project. She had access to practitioners and emergency managers through the different workshops organised to test the S-HELP Decision Support System. Informal conversations held on those events helped to define the scope of this research and select a suitable methodology. Website: http://crbc.ucc.ie/wp-content/uploads/sites/95/2018/07/S-HelpBook.pdf

[22] The researcher was invited by Medi@4Sec H2020 project to take part in the 'Social Media and Policing of Riots and Mass Gatherings' workshop hosted in Athens (Greece) on the 9th of May 2017 where the use of social media was discussed in the context of patrolling mass gathering to improve public security. Participants included: law enforcement representatives, researchers, software

emergency practitioners who had a genuine interest in using social media for decision-making in major incidents. Feedback was gathered during these events through informal conversation and complemented by the literature review (described in Chapter 2) concerning the infancy of verification of social media messages in major incidents, and the limited experience of using this tool by emergency stakeholders. Their input facilitated the understanding of the requirements for the development of the IQ model and informed the methodology selection. Overall, it was apparent that further context was required to propose a model to evaluate information quality. Furthermore, the nature of the decision-making process in major incidents and the difficulty of predicting when an emergency would occur posed challenges to test a model using iterations.

In addition, feedback collected and knowledge gathered from previous research evidenced the need for a more comprehensive approach using a combination of qualitative and quantitative methods to support exploratory analysis of the phenomenon, and at the same time to develop the *'microblogging information quality descriptive model for major incidents'*. Hence, case studies as methodology were considered.

A case study is one of the different approaches to do social science research, and the qualitative method most used by Information Systems researchers (Darke, Shanks, & Broadbent, 1998). This type of method is preferred when *"(a) 'how' and 'why' questions are being proposed, (b) the investigator has little control over events, and c) the focus is on a contemporary phenomenon within a real-life context*"(Yin, 2009, p. 2). The case study method is defined as "*an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*" (Yin, 2009, p. 14). Research using case study methodology may include one or multiple cases and it allows the use of qualitative approaches for data collection and analysis (Cavaye, 1996).

developers, and social activist from the UK, Greece, and Netherlands between others. Informal conversation and focus groups (were the researcher was a participant) helped to shape this research. Website: http://media4sec.eu/workshops/riots

Table 3-3 compares the advantages and disadvantages of both methods discussed above: design science and case study. Both enable the study of complex real-life problems. However, their approaches differ as the design science focuses on multiple interactions with end-users, while case studies benefit from the use of multiple sources of evidence. Difficulties in gathering and analysing information are highlighted as the main disadvantages for both methods.

	Design Science	Case Study
References	*(Gregor, 2002; Hevner & Chatterjee, 2004; Hevner, March, Park, & Ram, 2004; Iivari, 2015; Pries-heje, Baskerville, & Venable, 2008)*	*(Benbasat, Goldstein, & Mead, 1987; Gable, 1994; Miles & Huberman, 1994; Siggelkow, 2007; Yin, 2009)*
Advantages	- Focus on the creation of a new artefact to solve real-life problems - Use of multiple iterations to incorporate end-users' feedback - Involvement of stakeholders through the design, evaluation and testing of the artefact developed.	- Enables the study of complex processes - It supports the use of a variety of sources of evidence (e.g. documents and interviews).
Disadvantages	- Still in its infancy compared with other research methods. - Not a broad agreement on terminology, methodology, evaluation criteria, etc. - The difficulty of maintaining the involvement of all stakeholders during the research process	- Results cannot be generalised - Combination of multiple sources of evidence can prompt to the risk of information overload - The researcher has not the ability to control independent variables limiting the internal validity of the conclusions

Table 3-3 Design science and case studies: Advantages and disadvantages

Due to the complexity of the phenomenon studied and the need for contextualised emergency incidents to further understand the decision-making process, the selection of the case study method was more appropriate to fulfil this research objective. Within this and using an opportunistic approach, three case studies were selected and used for this research to provide context and address research question 1 and research question 2. Additionally, case studies were analysed following the Naturalistic Decision Making methodology (section 3.2.1.2) to include the philosophical principles highlighted in

section 3.1. The next section describes its methods and justifies its integration with case study methodology.

3.2.1.2. Naturalistic Decision Making Methods

The Naturalistic Decision Making School (NDMS) believes that humans are an acting organism that makes decisions considering their environment, themselves and their own experience. The world around them inseparably conditions decision-makers—living "*is always an inclusive affair involving connection, interaction of what is within the organic body and what lies outside in space and time and with higher organisms far outside*" (Dewey, 1965, p. 230).

The NDMS emphasises on the study of decision-making in domains characterised by *"time stress, high stakes, vague goals, the uncertainty, multiple players, organisational constraints, and dynamic settings"* (Hoffman & Militello, 2008, p. 205). NDM researchers had contributed to the decision science by focusing on field-work instead of theory-based laboratory evaluations. As part of this process, they have developed methodologies to explain cognitive processes and explain human actions. Methods commonly used by the NDM community include the Critical Decision Method (CDM), the Knowledge Audit Method (KAM), and the Goal-directed Task Analysis (GDTA) method.

- The **Critical Decision Method (CDM)** is an extension of the critical incident technique. It is a retrospective semi-structured interview method that through the use of cognitive probes to incidents, stimulates the recall of information about decision-making strategy from experts (Klein et al., 1989). This method provides valid results to develop training materials, identify requirements, develop expert systems, and assess this system's effect on task performance.
- The **Knowledge Audit Method (KAM)** is also based on the concept of expertise. However, it focuses on the psychological aspect (Militello & Hutton, 1998), which attempt to understand further the difference between novice and experts in a specific domain or task within a domain (e.g. Chi, Feltovich, & Glaser, 1981; Ericsson & Smith, 1991; Klein & Hoffman, 1993). Researchers can focus on the difference of diagnostic and prediction, situation awareness, improvisation,

recognition of anomalies and patterns, and compensation of resources limitations (e.g. technology available). The goal of this method is to demonstrate the importance of these factors but to identify the specific things that experts in a given domain need to know and skills they need to possess to progress from novice to expert. The purpose is to determine what distinguishes experts from non-experts in a particular domain or task within a domain. Its goal is to identify the specific things that experts in a given domain need to know and the skills they need to possess.

- The **Goal-directed task analysis (GDTA)** method aims "*to obtain detailed knowledge of the goals the decision-maker must achieve and the information requirements for working toward those goals*" (Hoffman & Militello, 2008, p. 184). GDTA focus on analysing the goals, and not the task to achieve the goals (the Hierarchical Task Analysis follows this approach). Therefore GDTA primarily analyses the individual participant's perceptions of whether different goal statuses are achieved. GDTA is a form of a structured interview that uses probe questions to conduct a top-down analysis of work (e.g. Endsley, 1993, 1995a, 1995b). GDTA can be used in combination with the Critical Decision Method (CDM), but it can be used with generic cases and not necessarily a particular experience or specific past incident. Therefore, researchers focus on the information that decision-makers would "*ideally like to know to meet each goal, even if that information is not available given current technology*" (Hoffman, 2005, p. 78).

Table 3-4 compares the advantages and disadvantages of using CDM (Flanagan, 1954; Hoffman & Militello, 2008; Taynor, Klein, & Thordsen, 1990), KAM (Biloslavo & Trnavc, 2007; Burnett, Illingworth, & Webster, 2004; Gourova, Antonova, & Todorova, 2009; Liebowitz, Rubenstein-montano, Mccaw, Buchwalter, & Browning, 2000; Mearns & du Toit, 2008; Ragsdell, Probets, Ahmed, & Murray, 2013) and the GDTA method (Bolstad, Riley, Jones, & Endsley, 2002; Gheisari & Irizarry, 2011; Hoffman, 2005; Hoffman & Militello, 2008; Kaber, Perry, Segall, Mcclernon, & Prinzel, 2006; Strater, Endsley, Pleban, & Matthews, 2001).

	Advantages	Disadvantages	Sources
Critical Decision Method	- Specific insight into decision-making strategies used by experienced participants within complex and dynamic systems. - The method usually is not time-consuming to apply. - Informants recall a memory with interviewer assistance rather than speak of their perceptions or assumptions, which increases the accuracy. - Enables researchers to analyse the change in informants' behaviour longitudinally over time by asking them to remember more than one incident of information seeking at different time points. - Enables researchers to collect more than one set of data from each interviewee to test the applicability of the model. - Data analysis can be partially performed during the interview - The decision process can be recalled well after the incident occurred	- Training, experience, and expertise are relevant to the successful application of the CDM technique. - The skill and experience of the analyst and the quality of the participant can influence the output data from the CDM interview. - Data are dependent on a verbal account of the incident. It is questionable how closely these accounts represent the cognitive process of the decision-maker.	(Flanagan, 1954; Hoffman & Militello, 2008; Taynor et al., 1990)
Knowledge Audit Method	- Focus on identifying the knowledge missing and how this omission restricts organisational activities. - It considers the organisation's environmental changes - It helps to determine and illustrates the knowledge possessed, where it resides, and how it flows through the organisation.	- Lack of specific methodologies in scientific literature and business practice. - It only involves a sample of the organisation, so it may not be represented accurately. - Analysis of the data is time-consuming. - Need to be performed regularly in order to check the progress and usefulness.	(Biloslavo & Trnavc, 2007; Burnett et al., 2004; Gourova et al., 2009; Liebowitz et al., 2000; Mearns & du Toit, 2008; Ragsdell et al., 2013)
Goal-directed task analysis	- It allows identifying the goals and how the data can be used to attain those. - This method focuses on perceptions. - It is not necessarily tied to particular experiences or the technology being used. - It is a method complementary to the CDM procedure.	- It requires a significant time investment. - Researchers need to have a general understanding of the field. - Results cannot be generalised. The priorities and goals can be different in individuals from the same organisation depending on their task or their backgrounds.	(Bolstad et al., 2002; Gheisari & Irizarry, 2011; Hoffman, 2005; Hoffman & Militello, 2008; Kaber et al., 2006; Strater et al., 2001)

Table 3-4 NDMS methods: Advantages and disadvantages of the Critical Decision Method, Knowledge Audit Method and Goal-directed task analysis

The researcher has considered these three NDM methods to include expert knowledge in developing the *'microblogging IQ descriptive model for major incidents'*. While the three methods can be integrated with the case study methodology (as part of the interview), their comparison (Table 3-4) showcased that the Critical Decision Method (CDM) was the most suitable for the objective of this research. As per Table 3-4, participants using CDM can recall the experience from memory and more than one incident can be analysed simultaneously. Knowledge Audit Method (KAM) and Goal-directed Task Analysis (GDTA) can be used as part of the CDM and provide further insight into the research; however, they would respond to other types of research questions. For example, KAM could be used to identify differences between novice and experts while analysing the credibility of content posted on Twitter, or using GDTA research can be developed in the evaluation of goal and sub-goals achieved while using Twitter information. While the research of these is interesting, the researcher aimed to understand better the process followed by experts to evaluate the Information Quality (IQ) of microblog messages posted on Twitter in major incidents. To address this objective and respond to the research questions associated, the CDM allowed creating interviews using probes obtained from the case studies where experts recall a critical incident and explained their own decision-making process using a storytelling approach.

3.2.1.3. Framing Critical Decision Method within Case Studies

Exploring the decision-making processes for the use of social media, Twitter, in major incidents, is a novel research area. Although research has been performed related to social media use for emergency management and the evaluation of this data source for different emergency task-related, little is known about the decision-making process followed to assess the quality of this information to reduce its uncertainty. Therefore, an exploratory research study was required in order to build a descriptive model to assess Information Quality (IQ) from this data source.

After comparing different methods in the area of Information Systems (IS) and decision-making, the researcher decided to profit from both approaches. By merging these two methods, the researcher benefited from more robust evidence of decision-making followed by experts.

Case studies allow triangulating data sources to answer research questions and objectives. One of this source of evidence can be interviews. Therefore, the researcher used the Critical Decision Method (CDM) approach to design the interviews developed as part of the three case studies. Table 3-5 summarises the alignment of research question with the methodology used by the researcher for the completion of this research.

Research Question	Strategy	Method	Outcome
RQ1. How is Twitter used for decision-making in major incidents?	Empirical & Archival	Case study (primary, secondary & tertiary data)	Evidence of use of social media for decision-making from two perspectives - risk communication (input) and social media monitoring (output)
RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?	Empirical & Archival	Case Study + Interviews – Critical Decision Method	Identification of Information Quality (IQ) dimension
RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?	Opinion	Interviews – Critical Decision Method	Development of the descriptive model

Table 3-5 Research methodological process

The first and second questions were answered using an empirical and archival strategy through the three case studies' findings. Research question two and three benefited from experts' input to better identify the IQ dimensions and the process followed during the decision-making process.

3.2.2. Selection of case studies: sampling strategy

The case studies' selection was opportunistic as emergency and disaster incidents are rarely *'predicted';* however, the large number of major incidents during 2017 enabled selecting case studies that satisfied multiple parameters. These included decision-makers from different geographical areas (the USA and Europe), type of incident (terrorist attack, eclipse, and hurricane), incident's phases (before, during and after) and social media uses (risk communication and situation awareness). All major incidents selected, one in Europe (Barcelona) and two in the USA (Oregon and Texas), took place

during the month of August 2017. The terrorist attack was completely unanticipated; however, the eclipse and the hurricane were predicted a priori. This knowledge allowed the researcher to better prepare for the data collection of these last two case studies and engage with relevant experts in the area before the emergency was declared.

For each case study, the researcher found suitable representatives for the unit of analysis, as decision-making is analysed from an individual perspective, based on their expertise and experience.

Expertise

Social media emergency management experts needed to be identified in order to understand their existing mental models while evaluating information obtained from Twitter. Three potential units of analysis were identified: journalists, Virtual Operation Support Team (VOST) members, and Public Information Officers (PIOs).

To ensure adherence to these criteria, the case selection has been conditioned by incidents where Virtual Operation Support Team (VOST) was activated. VOST are groups of social media experts activated during major incidents and directly collaborated with Public Information Officers (PIOs), which in turn inform journalists. See section 3.2.3 for further information about the unit of analysis.

Type of Incident

Three types of major incidents were selected as part of the research protocol. According to Houston et al. (2014), emergencies and disaster may have natural, technological or human causes. Therefore, an opportunistic case study for each was selected. The Barcelona terrorist attack pertains to the human-made disaster. It was an event planned to create as much disruption as possible. The eclipse has been considered a potential technological disaster as the main fear was fires starting due to the exhaust of cars touching the dry grass and other technology during Oregon's wildfire peak season. Thirdly, the Harvey hurricane pertains to the natural disaster type.

Previous research using terrorist attacks to evaluate the use of Twitter has been published in foregoing years (e.g. K. A. Lachlan et al., 2009; Oh et al., 2011; T. Simon, Goldberg, Aharonson-Daniel, Leykin, & Adini, 2014). Similarly, previous research has

been published in the area of Twitter use during hurricanes (e.g. Lachlan, Spence, Lin, & Del Greco, 2014; Stewart & Gail Wilson, 2015). Limited evidence (e.g. Tsytsarau, Palpanas, & Castellanos, 2014) was found of the use of social media in an eclipse as a case study. This literature informed the case study selection, and findings were used to define research parameters better.

Phases of incident

The researcher used a three-phased emergency model (before, during and after) instead of a four-phased model (mitigation, preparedness, response, recovery). This decision was taken after analysing Twitter information collated from previous emergencies and published research papers (e.g. Q. Huang et al., 2015; Sutton et al., 2014; Takahashi et al., 2015). It is noted that during the mitigation phase, the use of Twitter is limited to a reduced number of messages. Simultaneously, activity and uncertainty increase when the incident becomes a real probability, and the preparedness phase begins. Nevertheless, the start and end of a specific phase using the four-phase model become somewhat diffuse depending on the stakeholder situational perception analysed (e.g. fire-fighter versus police). Mitigation, preparedness, response and recovery phases often have tasks and roles that overlap on time (Heard, Thakur, Losego, & Galluppi, 2013; S. Yang et al., 2013). Therefore, it is more suitable to use a three-phased model where information could be analysed according to its temporal relationship with the incident: before, during and after. See section 2.1.2 for further information about the three-phased model.

Social media use

Data collected has focused on two primary use of social media (1) communication (pushing messages to social media) and (2) information source (pulling messages from social media).

As described in section 2.2.2, Twitter can be used for multiple purposes. However, using a more simplistic approach, the researcher decided to analyse the decision-making use of Twitter from the user interaction with the platform. Therefore, case studies were analysed according to the decision-maker action. First, the researcher investigated if the decision-maker evaluated the information presented. Second, it was analysed if the

decision-maker acted with it; hence, if it was worthy of being tweeted or retweeted (risk communication) or suitable to be reported or used outside Twitter (for example, in a news article).

The access to VOST activation for the Oregon Eclipse and Harvey hurricane allowed the researcher to observe better and evaluate the information source decision-making approach; while the limitations within the Barcelona terrorist attack implied the observation of this emergency from a risk communication perspective. Furthermore, the VOST activated for the Barcelona case study was more active posting on Twitter than the other two groups in comparison. These characteristics also impacted the data collection technique and source of evidence used for each case study.

3.2.3. Unit of analysis selection

The selection of suitable participants, Subject-Matter Experts (SMEs), was paramount for the successful implementation of the Critical Decision Method (CDM) as it relies on their expertise and their experience deciding how to proceed in major incidents. The researcher has made every effort possible to identify a suitable unit of analysis for this research that could be observed and interrogated following the paradigms outlined by the Naturalistic Decision Making School (NDMS) and at the same time includes different types of social media users. Experts in this research area are people who have professional-related experience in the use of Twitter in major incidents. Within these parameters, several emergency-social media information processers were identified through the case studies. It includes relevant representatives of emergency organisations, social media emergency management volunteers (Virtual Operation Support Team -VOST), and journalists specialised in this area. In order to select these participants, several key elements were analysed:

1. Evidence that they took part as decision-makers during the case studies analysed using Twitter information (see Table 3-6)
2. Experience in at least three different major incidents
3. Experience in using social media in major incidents: a minimum of two years' experience

While the selection of the case studies is paramount for the data collection's success, identifying the unit of analysis to analyse within the selected cases and for the CDM interviews impacted the overall dynamic of the research protocol. Table 3-6 summarises the three categories identified as the unit of analysis and what proof was seek for their inclusion.

Unit of Analysis	Proof for inclusion (Decision outcome)
Public Information Officer	Actively posted on Twitter during the case study analysed. Its role included debunking information. Collaborated with VOST to search for information.
Journalist	Published an article related to the emergency using Twitter as an information source during the case study analysed.
VOST member	Posted a tweet or reported a piece of misinformation captured on Twitter during the case study analysed.

Table 3-6 Unit of analysis criteria for inclusion

The following sections further describe their suitability to be considered as decision-makers using social media, particularly Twitter, in major incidents. They further develop the importance of identifying the proof for inclusion as part of their selection.

3.2.3.1. Public Information Officers

The first group identified are official representatives within emergency organisations in charge of social media platforms in major incidents. Their role involves interacting with the online community and supporting any risk communication efforts. Therefore, they are key players in deciding what messages are shared through the official social media profiles and how information is managed. Hence, any tweet posted must be approved by them and information obtained from Twitter falls within their responsibilities.

Public Information Officers (PIOs) were considered if they actively posted on Twitter during the case study analysed and their role, including debunking misinformation.

3.2.3.2. Journalists

The second group identified are journalists. Existing research has showcased that newspapers are using information from social media to detect newsworthy events and obtain evidence of the same (e.g. Khare & Heravi, 2014). In major incidents, journalists may use a combination of official sources and witnesses as information sources to build their stories and inform citizens. Nowadays, Twitter allows them to gather information,

and if it is deemed suitable, a news article is published citing that sources. Journalists who published an article debunking a piece of information obtained from Twitter during the case studies analysed were considered.

3.2.3.3. Virtual Operation Support Team: Social media Emergency Management Volunteers

The last group identified are social media emergency management volunteers. Several research papers have been published related to crowdsourcing initiatives for emergency management (e.g. Munro, 2012). However, this research aims to use experts in the area.

The Virtual Operation Support Team (VOST) was identified as the most suitable group for this research. The VOST initiative was born in 2011, and it responds to the need for monitoring, examining and sorting useful information from social media as well as the possibility that in a catastrophic disaster, it may be necessary the support of a trusted group to search, prioritise and forward crisis data from outside of the disaster location (e.g. the internet is not functioning, or bandwidth is limited). VOST seeks simply to use social media for emergency management to harness actionable information with predictable outcomes during all phases of disaster. VOST bridges the gap between social media and emergency management, using a surge support model; they act as a force multiplier for the official agency and use the public as a resource. VOST are charitable organisations registered in each country and formed by members with different backgrounds. Despite being a charitable organisation, the 'V' in *'VOST'* stands for *'Virtual'*, not *'Volunteer'*. Nevertheless, some teams rely heavily on unpaid emergency management staffing to operate effectively, including critical roles in the early stages of a team's development.

Decision-making from this group can be documented through two approaches (see the source of evidence in section 3.4). First, their use of social media channels (e.g. posting information to debunk rumours) and secondly, their reports to the activating organisation (e.g. information captured in their reports and workbooks). It is relevant to highlight that journalists and Public Information Officers (PIOs) can be part of VOST.

3.3. Research protocol

The following protocol, Figure 3-3, was designed to develop an Information Quality (IQ) model using experts' knowledge. Direct research on decision-making using Twitter is complicated, and this type of research has been conducted only in recent years (section 2.2); hence, a rigorous theory may not yet be possible. Therefore, this protocol was planned to identify common ground for discussion using the information collated through three case studies complemented by multiple Critical Decision Method (CDM) expert interviews (unit of analysis). The aim was to create a descriptive IQ model that addresses Twitter quality dimensions and the naturalistic decision-making process to support this social media platform's IQ challenge.

Figure 3-3 summarises the research protocol described in the next two sub-sections. In section 3.3.1, the researcher describes the phases of development of a framework model. The data required to develop the model was collected using a three-phase approach. The literature review (Chapter 2) was used to identify existing quality dimensions and models previously used. This information is used as a reference point for the first and second phases of the research protocol, which involves analysing three real major incidents as case studies. Influenced by the Naturalistic Decision Making School (NDMS), the researcher decided to use case studies complemented by interviews using the Critical Decision Method (CDM). Information was gathered using an array of data sources, including observations, posts from Twitter, news articles, and Virtual Operation Support Team (VOST) official reports (section 3.4).

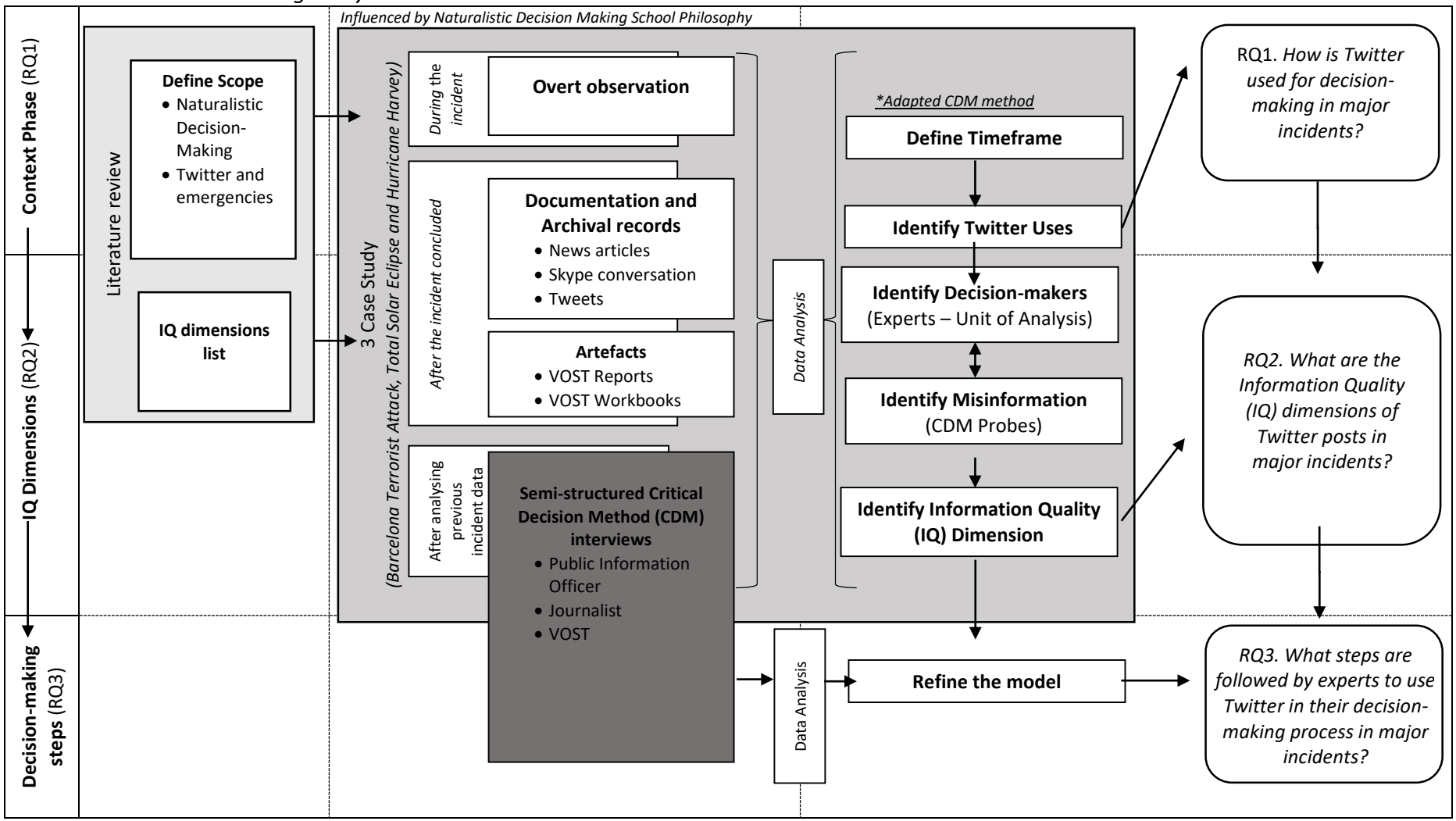


Figure 3-3 Research protocol summary

Data collected provided insight into research question 1 and 2. The key objective was to enumerate all relevant attributes/dimensions of data quality (RQ2) while acquiring context to understand further the use of Twitter for decision-making in emergencies (RQ1). Then, multiple Critical Decision Method (CDM) interviews were used to refine the model and establish dimensions relationship (phase 3). The steps followed to perform the CDM interviews are outlined in section 3.3.2. Data triangulation allowed the researcher to define case studies and decision timeframe, identify Twitter uses, select suitable decision-makers, identify probes (misinformation in Twitter), identify relevant information quality dimensions, and outline the steps used by experts in their decision-making process while evaluating Twitter information. This research protocol allowed to address this research objective.

3.3.1. Phases of development

The development of the research protocol was designed to fulfil the objective of this research:

> ***'To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents.'***

This objective is achieved by answering three research questions within three-phase, which are directly interlinked with the literature review and the methodology applied as illustrated in Figure 3-3 (page 124).

The literature review (Chapter 2) helped define the requirements by identifying the research gap and existing Information Quality (IQ) dimensions. This information was used to build three case studies using multiple data sources. Evidence gathered supported the development of the context phase and, therefore, identification of Twitter use for decision-making. Building on these findings, IQ dimensions were identified. Finally, the model development phase benefited from expert interviews' input and supported creating the IQ descriptive model.

The first phase (context development) aimed to identify the use of Twitter for decision-making in emergencies. Therefore, it answers the Research Question (RQ) 1 derived from the literature review (Chapter 2):

> *"RQ1. How is Twitter used for decision-making in major incidents?"*

The researcher utilised three real-world case studies to answer this research question and support developing the second and third phase of this study. The selection of these cases is aligned with the beliefs outlined by the Naturalistic Decision Making School (NDMS) and gather real-life experiences from decision-makers in Emergency Management (EM).

The three case studies were selected based on the research ability to identify expert decision-makers. Additionally, cases represent different disaster types and phases. By utilising different data sources, multiple pieces of evidence were collated to define and showcase decision-making tasks performed for emergency management with information obtained from Twitter.

The second phase, selection of IQ dimensions, built on the use of Twitter for decision-making in emergency management. However, it focused on the IQ dimensions detected within the decision-making process and utilised by different decision-makers. Therefore, this phase provided evidence to answer the second research question (RQ2):

> *"RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?"*

The literature review (Chapter 2) provided an overview of the information requirements described by previous researchers in emergency management (section 2.3.3) and the IQ dimensions outlined in Information Systems (IS) (section 2.3.2). Fifteen dimensions were used as the baseline for analysis; however, additional information attribute detected was evaluated and considered for the development of the descriptive model in the third phase.

Lastly, the relationships between the different IQ dimensions discovered in the previous phase was researched. By doing so, emergency management experts outlined in the

adapted Critical Decision Method (CDM) interviews the process followed to evaluate Twitter information. They answered RQ3 and supported the development of the framework model:

> *"RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?"*

While the three-phase were implemented initially under a linear approach, feedback from each was used to assess previous findings and provide additional validity to the research.

3.3.2. Case studies and adapted Critical Decision Method (CDM) steps

Using a three-phase approach, the researcher profited from the case study and CDM methodologies' characteristics to define six steps to follow. Three case studies were selected and used to identify experts in social media use in major incidents. They described their decision-making process to identify and evaluate rumours and misinformation. The researcher used six steps to articulate this research. Those are:

- **Step 1:** Defined Timeframe – Built context of each case study. Defined incident.
- **Step 2:** Identified Twitter uses – Addressed RQ1
- **Step 3:** Identified decision-makers – Unit of Analysis
- **Step 4:** Identified Rumours – CDM Probes
- **Step 5:** Identified Dimensions of Information Quality (IQ) – Addressed RQ2
- **Step 6:** Model Conceptual relationship – Addressed RQ 3

The collection of evidence in the case studies provided insight into six different outcomes. The researcher defined each case study timeframe, evaluated Twitter uses, identified decision-makers for interviews, selected rumours to be used as potential probes during the Critical Decision Method (CDM) and identified dimensions of Information Quality (IQ) (Table 3-7) while the descriptive model was refined through the CDM interviews.

	RQ1		RQ2			RQ3
Source of evidence /outcome	Step 1: Define Timeframe	Step 2: Identify Twitter uses	Step 3: Identify decision-makers for interviews	Step 4: Identify rumours	Step 5: Identify dimensions	Step 6: Model
Overt mediated observation	✓	✓	✓	✓		
Documentation and Archival Records • Newspapers • Tweets • Communication	✓	✓	✓	✓	✓	
Artefacts • Workbook • Reports		✓	✓	✓	✓	
Interviews	✓	✓	✓	✓	✓	✓

Table 3-7 Sources of evidence alignment with outcomes and research questions

Field notes were used as evidence to produce meaning and a better understanding of emergency and the use of social media being studied (RQ1). Additionally, it helped provide insight into key elements (the identification of decision-makers, rumours and potential IQ dimensions) to answer RQ2. Three types of documents /archival records were collected to inform the case studies' development: news articles, tweets and internal communication. Data collection from news articles, tweets, and internal communication provided evidence to define each case study timeframe better while supporting the identification of Twitter uses, decision-makers for interviews, rumours, and dimensions of Information Quality (IQ). Their collection and data analysis provided insight for research question 1 and research question 2 and supports the development of each case timeline, selection of interviews participants and CDM probes to provide answers to the research question

An adapted CDM is used as a data collection technique to refine the model developed in Phase 2. It also provided information to answer RQ2 and RQ3. This method validity and reliability has been evaluated in different domains (Hoffman, Crandall, & Shadbolt, 1998), and it is adapted to fit the purpose of this research. CDM is based on semi-structured interviews. Steps followed to capture the data and its alignment with the case study are described in Table 3-8.

Step	Definition	Research Strategy Overview
Define the task or incident under analysis	Non-routine, emergency, or extreme incidents	3 case studies (section 3.2.2)
Select CDM probes	Selection of probes to elicit knowledge from Subject-Matter Experts (SMEs) to gain insight into the decision-making process. Probes are defined before the analysis is conducted to prevent irrelevant or non-compliant information.	A recorded decision by VOST, published article or tweet
Select appropriate participant	After identifying the incident and the probes, the selection of appropriate participants is paramount. The SMEs are primary decision-makers within the incident analysed according to the unit of analysis defined.	Active VOST member, Journalist, Public Information Officers (PIOs)
Gather and record the account of the incident	The CDM can be used for incidents observed by the researcher or incidents described from memory by the participants involved. It is required to obtain a full description of the incident from the SME.	Evidence gathered in the case study and questions in the interview.
Construct incident timeline	After an account of the incident is gathered, a timeline of the incident can be constructed. The goal is to provide the analyst with an accurate view of what occurred, including the time and duration of each event. The timeline should include details of both physical events (e.g., alarms going off) and cognitive details (i.e., what the person being interviewed thought and perceived while the incident was occurring).	The incident timeline is constructed using the input of the SME and other sources of evidence from the case study.
Divide the incident into key phases or decision points	After it is certain that the analyst has a cogent understanding of the incident, usually this is completed alongside the SME, and the incident is divided into four or five phases.	Interviewee incident recall
Use CDM probes to query participant decision-making	The analyst should delve into each incident phase identified in step 6, using the CDM probes that were selected during step 2. This should be completed using the probes in the context of an unstructured interview - the goal is to determine the SMEs decision-making process within each phase.	Probes presented to the interviewee and questions related to Cues sought, Knowledge used, Goals pursued, Actions taken
Transcribe interview data	From audio recording once the interview is completed.	Transcribed by own researcher
Construct CDM tables	By displaying the CDM probes with their associated answers in a tabular format.	Content analysis and CDM tables

***Table 3-8 Adapted CDM process from Staton, Salmon, Rafferty, Walker, & Jenkins* (2005)**

Define the task or incident under analysis

Within the Critical Decision Method (CDM), the first step is defining the task or incident under analysis. In this research, its definition is performed using the information gathered in the case studies and previous research.

Three case studies were selected to represent each of the three-phase emergency models: before, during and after. As described in section 3.2.2, the case study selection was opportunistic. However, the selection of tasks within the case studies followed the following premises:

- Incident where decisions have been made using Twitter or information obtained through Twitter.
- Incident where decisions have been made before, during or after a non-routine, emergency, or extreme incident.
- Incident where decisions have been made by an expert in the use of social media for emergency management

Each incident and task is described in each case study section (section 4.1 and 4.2). The definition of the incident has supported the selection of CDM probes.

Select CDM probes

The selection of CDM probes was motivated by the objective of this research. First, it was paramount to identify a piece of information (outcome) on Twitter or from Twitter that has been qualified as a rumour or piece of misinformation. Therefore, in order to evaluate the use of social media for decision-making, a microblogging post (tweet) must have prompted a documented outcome (Figure 3-4).

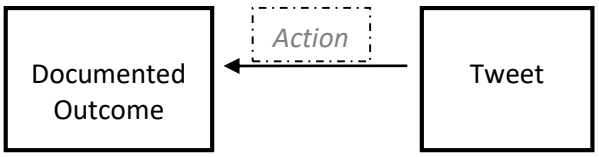


Figure 3-4 CDM probes selection - first criteria

Then a set of candidate alternatives must exist (Figure 3-5), in order to be considered a decision. In this case, we only investigated two candidates alternative: '*the tweet*

information was used as part of the decision-making process' – or - *'the tweet information was not used as part of the decision-making process'*.

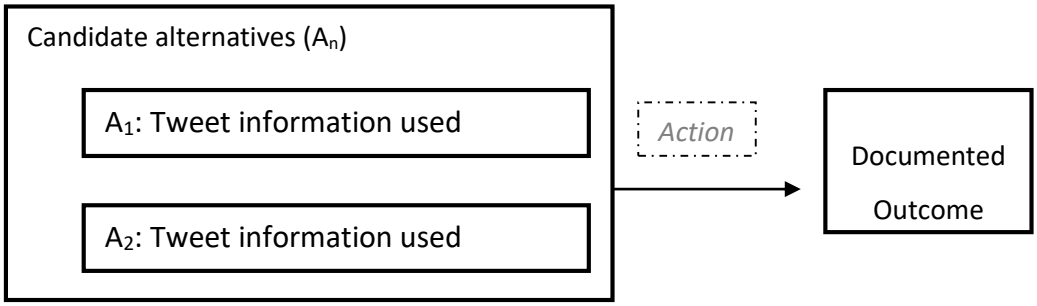


Figure 3-5 CDM probes selection - second criteria

It was assumed that each candidate alternative was evaluated against a set of control variables that had a potential state of nature associated. The analysis looked into control variables related to its associated IQ dimension.

Identified probes and the rationale to select one or another are explained for each case study within section 4.4. The identification of specific CDM probes also helped to identify relevant stakeholders to interview (section 4.3).

Probes were previously evaluated and classified using the First Draft initiative (Wardle, 2017) seven categories of disinformation:

1) False connection: News with headlines, visuals or captions that do not support the content
2) False context: Genuine content but shared with a false contextual information
3) Manipulated content: Content or images but this is manipulated to deceive
4) Satire or Parody: Content created with no intention to deceive but has the potential to fool people
5) Misleading content: Uses news articles to frame an issue or an individual to mislead users
6) Imposter content: Genuine sources are impersonated
7) Fabricated content: Content 100% created to deceive and harm people

The selected probes were presented to the appropriate participants.

Select appropriate participant

The selection of the right participant is paramount for the success of this research process. In section 3.2.2, the unit of analysis was described. Their inclusion is aligned with the selection of the right type of participant. There are three potential expert groups in the use of Twitter for decision-making in emergency management: journalists, Public Information Officers (PIOs), and Virtual Operation Support Team (VOST) members. Within these three categories, it is paramount to identify the person who took the decision using each CDM selected. In order to do so, the CDM probe had to be linked with the decision-maker. The following considerations have been taken into account for each type of decision-maker.

- **Public Information Officers (PIOs):** First, PIOs are suitable interview's participants as their role in risk communication include the debunking of misinformation.
- **Journalists:** A growing body of literature is related to Twitter use by journalists to find newsworthy information items. Therefore, it is not strange that verification practices in evaluating the information have been further developed in the area (e.g. Brandtzaeg et al., 2015; Diakopoulos et al., 2012). In this research, journalists were considered if they published an article during one of the incidents where Twitter information was used. Furthermore, the articles selected must discuss the concept of misinformation or rumours.
- **Virtual Operations Support Teams (VOST):** The selection of VOST members as interviewees for this research guarantees the access experts in the use of social media for decision-making in emergency management. VOST members were considered as potential interviewees when a decision was recorded in the VOST Workbook or through a tweet.

Gather and record the account of the incident

The CDM can be used for events observed by the researcher or incidents described from memory by the participants involved. Background information about each selected probe was collected to ensure its suitability using a triangulation approach (e.g.

combining different data sources such as Skype conversation and Workbook input). Additionally, questions related to each incident were included in the interviews.

Construct incident timeline

For the purpose of this research, a timeline of the incident was built based on the chronological development of two storylines: emergency development and decision-maker personal partaking.

First, context information is gathered to provide the reader with a description of the emergency. It allowed the researcher to recognise the uncertain elements of the situation unfolding and identify cascading events when applicable. For each case study, events and emergency tasks are outlined using information from different data sources. Data gathered from newspapers and observation notes support the identification of activities taken place before, during and after the emergency.

Secondly, the personal timeline of the decision-makers was evaluated. After identifying probes and suitable interview participants, their expertise and involvement in the emergency were assessed. This refers to their involvement with the emergency together with their input on the incident development. The researcher inquired on the decision maker's role during the incident, and decisions faced as part of its participation. Questions related to the personal timeline were also included in the CDM interview to ensure the validity of the decisions inferred by the researcher.

The development of the timeline supports the division of the incident into key phases and decision points.

Divide the incident into key phases, or decision points

Each probe selected is directly relevant to a specific participant; however, all probes within a case study are presented to all interviewees. Six key phases were initially expected for each probe: (1) Participant access /finds Twitter information; (2) Participant decides to consider the information; (3) Participant decides to analyse the information; (4) Participant decides the validity of the information; (5) Participant decides to act upon the information. In any of the decision points, the decision-maker may decide not to pursue the analysis. However, for this research, the researcher used

an inverse approach where any probe considered had a recorded outcome from the decision-making process. Five potential outcomes for this decision-making phases were envisaged: (1) the participant report to team members (e.g. using Skype in VOST); (2) participant shares this information using Twitter (e.g. tweet in a VOST profile or emergency organisation official account); (3) participant shares this information in other media platform (e.g. a newspaper article); (4) a related emergency management task is created and deployed; or (5) information is recorded (e.g. added to Workbook).

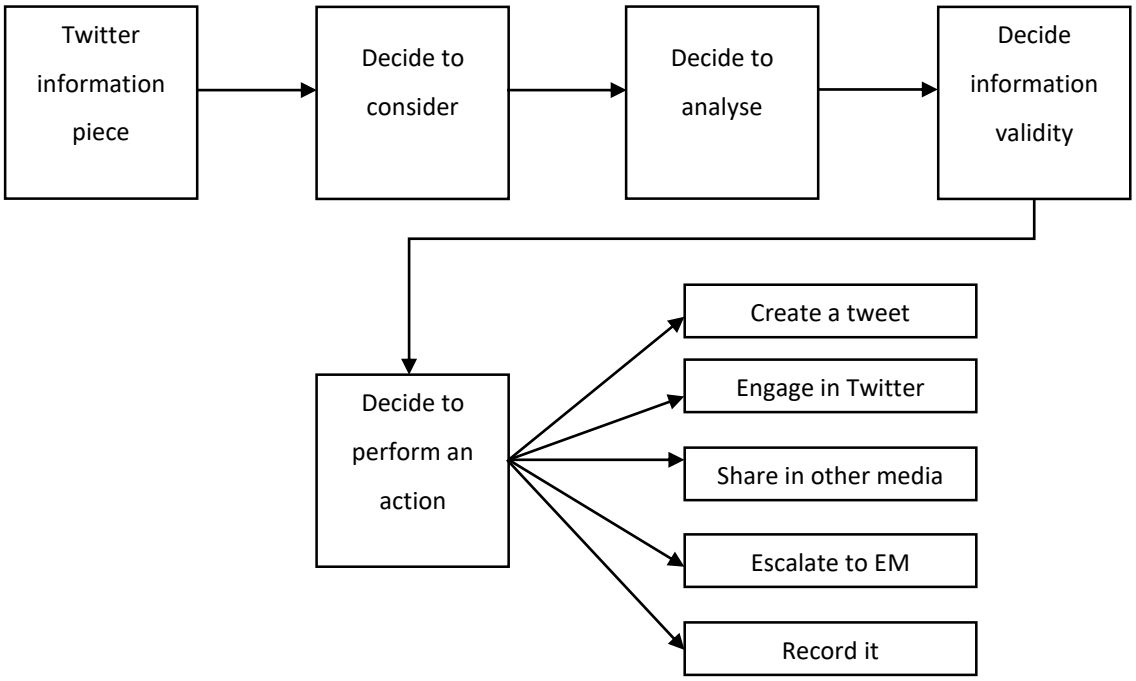


Figure 3-6 Decision points

The most relevant decision-making points were the *'decision to analyse'* and the *'decision about the information validity'* as they were related to the analysis of the information and its associated Information Quality (IQ) dimensions.

Use CDM probes to query participant decision-making- Semi-structured Interview: Instrument 1

Critical Decision Method (CDM) probes were used to query identified decision-makers. CDM interviews allowed the researcher to collect the decision-makers process while evaluating Twitter information and its veracity for emergency management purposes. The researcher asked identified participants a series of structured and open-ended questions. An interview guideline was developed to support the interview process and

ensure that all key questions were asked (Appendix 6). As there are three case studies, the probe section was adapted to include the relevant probes for each emergency. Other than that, the structure of all interviews was the same. It allowed the researcher to ask for clarification and additional questions as required to understand the approach followed by each decision-maker thoroughly. When a new question was added, a record was made and included in the transcription. When requested to explain the probes, the researcher did not mention any Information Quality (IQ) dimensions; however, the researcher used the interview guide to analyse the description provided and align each IQ references to the IQ dimensions identified in the literature review. Clarifications were requested when required.

The interview guide is available in Appendix 6. The sequence of activities are outlined as follows:

Before the interviews, selected participants agreed to be recorded for posterior analysis (appendix 5). The interview used several CDM probes (four, five or six depending on the participant) to query participant decision-making. All interviews were performed using Skype, and probes showed to the interviewees by sharing the computer's screen. A total of 718 minutes were recorded (all of them over 1-hour duration).

The first section of the interview was designed to evaluate decision-maker expertise and their involvement within the emergency used for the case study. Questions were designed to capture their personal timeline and identify their role. Then relevant probes were presented. Participants were required to explain their understanding of the material presented and if they were familiar with that information piece for each of them. If they were aware of the presented misinformation piece, they were requested to describe their decision-making process to evaluate it. Otherwise, they were asked to assess that information piece then and there and describe their mental process.

Each interview concluded by presenting them with a list of IQ dimensions and asking interviewees to organize them according to their importance for decision-making in the presented context. Participants were encouraged to mention other IQ dimensions as they thought it was opportune. This approach enabled SMEs to elaborate on their

answers further and summarise any additional thoughts. The establishment of the correlation between IQ dimensions was not attempted as part of this research, but it enabled the researcher to identify the conceptual importance of the presented dimensions.

Transcribe interview data

Upon agreement with participants, all interviews were recorded and transcribed. The recording of interviews has multiple benefits for the posterior analysis. It provides a *'truer'* record of what was said, allows to collect interviewees direct quotes, and there is an opportunity to review the conversation a posteriori for additional evaluation (Walsham, 2006). The researcher transcribed all interviews and provided each participant with a copy of their interview's transcription for validation purposes.

While it is a time-consuming activity, there are multiple benefits of transcribing your own interviews, including a closer look at the data collected, facilitating central themes identification and awareness of the similarities and differences between participants' accounts (Bryman, 2012). To ensure confidentiality, the researcher identified each participant by their case study reference (i.e. BTA for Barcelona Terrorist Attack, EC for the solar eclipse, and HH for Hurricane Harvey) and the order in which they were transcribed (1, 2, … n). For example, the findings are presented by referring to the first coding interview as Interview 1.

Additionally, the researcher took notes to facilitate the transcription and analysis of the same. Answer for each question was considered before the interview, and a note recording template set in advance. Potential answers were included, and the template was reviewed after each interview to include lessons learned and prepare better for the next data collection opportunity. This preparation supported the preliminary findings of the interview analysis and the construction of CDM tables.

Construct CDM tables

The last step outlined by Staton et al. (2005) to perform CDM interviews is the development of CDM tables.

These tables are built based on the relationship between Cues sought, Knowledge used, Goals pursued, and Actions taken. Their development was performed along with the data analysis, which included coding, categorising and evaluating data collected.

3.4. Source of evidence selection: data collection techniques

Data collection is the exercise of gathering data from the sample to answer the research questions (Bryman, 2012). Different data collection techniques can be used for qualitative, quantitative, mixed and action research methodologies (section 3.1.2). Each technique is more or less aligned to one or another methodology according to its intrinsic characteristics. The researcher has based the selection of sources of evidence and data collection techniques considering the nature of investigation and objective, the scope of the inquiry, financial resources, available time and the desired degree of accuracy.

Techniques were compared according to these set of variables:

- **Nature of investigation and objective:** As previously discussed (section 3.1.2.), the research method and objective play a vital role in the research design and therefore, in the selection of the appropriate data-gathering technique. Quantitative research mainly use tools that allow testing variables and provide statistical results (e.g. surveys). On the other hand, qualitative research favours tools that allow researchers to have more in-depth conversations (e.g. interviews).
- **Scope of the inquiry:** The inquiry scope can be represented by the sample size and the complexity of the research question. Larger samples are more challenging to analyse using tools such as focus groups or face to face interviews. On the other hand, complex enquiries are more comfortable to analyse by using tools that enable to ask additional questions.
- **Financial resources:** Data collection is usually conditioned to the funding available. Data in research is usually classified as primary, secondary and tertiary in relation to the interaction between the researcher and the data collection process. As more distance between the researcher and the raw data, less

expensive is the investigation; however, lower is the findings' reliability (Blaikie, 2010). For example, a telephone survey will have a higher cost than an online questionnaire – telephony and interviewer cost.

- **Time available:** Time has two different connotations. The first is related to the time to gather the information, and the second to the length of time required to analyse the data gathered measured as the volume of data gathered. Additionally, research can be time-sensitive. For example, observation techniques facilitate to capture of data when the event is happening. On the other hand, some techniques can collect more data than others and, therefore, require a significant amount of time to analyse the information collected. Techniques associated with quantitative research, such as surveys, collect fewer data and are faster to analyse. While qualitative techniques, such as interviews, are more time-consuming (Blaikie, 2010).
- **Degree of accuracy:** Two instances are considered here: accuracy to collect data, and accuracy to interpret the data. For example, self-administered surveys can have a lower degree of accuracy since the researcher is not present to solve enquiries during the response process, or respondent can suffer questionnaire fatigue (Harwell, 2011). On the other hand, tools designed for quantitative research have a less subjective interpretation of the data since it bases its finding on statistical information.

The evidence of these research case studies was collected through a combination of documents, archival records, interviews, overt observation and analysis of artefacts. Table 3-9 (page 139) aligns the type of source of evidence with the case study evidence used for this Research. These are further described below the table.

The use of documents and archival records provided each case study with further insight into decision-makers and their decisions. Three types of documents /archival records were collected to inform the case studies' development: news articles, tweets and internal communication.

Source of Evidence	Evidence Description
Overt observation	- Overt observation during the incidents
Documentation and Archival Records	- News clipping and articles in the mass media - Communication transcription (Skype conversation) - Tweets
Artefacts	- VOST Reports - VOST Workbooks
Interviews	- Semi-structured interviews using Critical Decision Method (CDM) to Public Information Officers (PIOs), journalists and Virtual Operations Support Team (VOST) members

Table 3-9 Summary of this research case studies source of evidence

Each type of evidence source included several evidence records to ensure a better insight into each case study, and they combined samples of primary, secondary and tertiary data.

Tertiary data is data analysed by another researcher (Blaikie, 2010). Tertiary data is mostly collected during literature review processes but can also include statistical data published in a report or official reports. For example, Virtual Operation Support Team (VOST) reports used in this research included statistical data collected from third-party Twitter analytics software.

Secondary data is data collected independently by others. There are two potential aims to use secondary data sources: (1) investigate new or complementary research questions; (2) verify findings of previous research (Heaton, 2008). Secondary data have five sources: Governmental and regulatory bodies, companies, the press, other academic researchers, and private sources (Cowton, 1998). Data can be gathered by accessing reports, publications or their databases. Example of secondary data used in this research includes VOST workbooks and newspapers articles.

To conclude, researchers collect primary data through experiments, observation or direct communication with respondents (Kothari, 2004). Primary data has multiple techniques for data gathering. It has been suggested that researchers are *"limited only by their imagination"* (Quinlan, 2011, p. 220). In this research, primary data was collected through overt mediated observation and interviews.

The next six sections provide the reader with information about the source of evidence compiled to create the three case studies; they are used to develop the Information Quality (IQ) model to reduce the uncertainty during the evaluation of emergency-related microblogging posts for decision-making. Data collection was performed according to when the data was available to the researcher, translating in Figure 3-7 Data Collection Process.

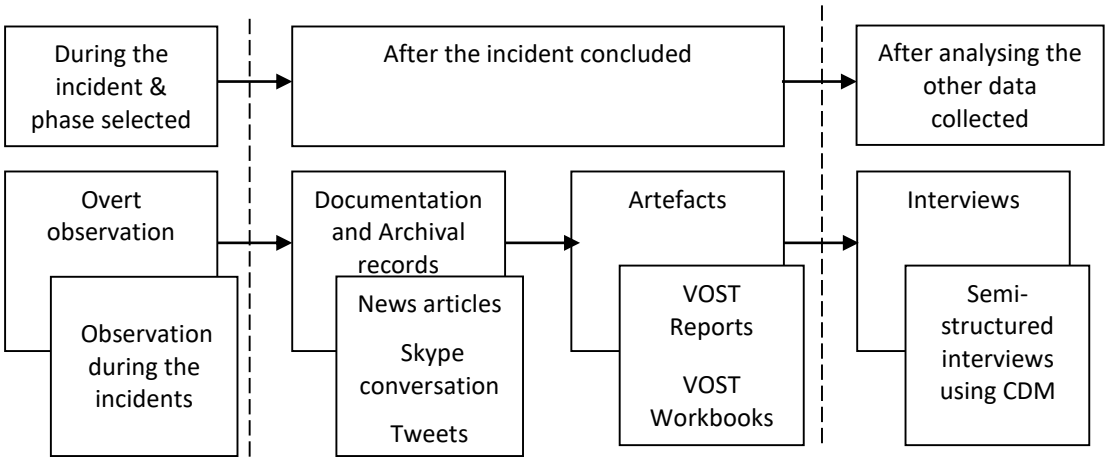


Figure 3-7 Source of evidence data collection process

First, the overt observation was performed for each incident (section 3.4.1). Fieldnotes were the first data collected for each case study as it was done in real-time while each emergency unfolded. Then documents and archival records were collated to provide insight into the case study, inform the selection participants, and identify rumours used as probes for the second phase of the model development. Additionally, the use of artefacts created by VOST supported these outcomes (section 3.4.5). Finally, interviews were used to illustrate better social media's use and process for decision-making by the different emergency stakeholders involved in the three case studies analysed (section 3.4.6). Each of the following six sections provides a summary of each data collection method, how the researcher collected the relevant data, an overview of the number of records, its contribution to these research outcomes and the alignment of each data source with the three research questions.

3.4.1. Mediated observation

Observation methods are described as "*systematic observation, recording, description, analysis and interpretation of people's behaviour"* (Saunders, Lewis, & Thornhill, 1997, p. 186). This research has used overt mediated observation as a source of evidence to develop the three case studies. Data gathered has been mostly primary; however, secondary data was also analysed by accessing communication feeds (e.g. Skype, Tweets) from the group observed.

According to the type of observation used, there are two types of overt observation: participant and structured (Saunders et al., 1997). Participant observation (also referred to as ethnography or field research) is when the researcher becomes part of the group, community or organisation studied (Blaikie, 2010; Bryman, 2012; Saunders et al., 1997). Additionally, the observation can be overt or covert (Bryman, 2012). Researchers can access the group by introducing themselves (overt) or without disclosing their identity (covert). It is paramount to understand that secrecy can have ethical issues associated (Saunders et al., 1997). As the information evaluation, in this case, has been treated as an individual activity, the researcher had no impact and had no potential bias during the overt observation.

As summarised in Table 3-10, overt participant observation (computer-mediated) was used to observe Virtual Operation Support Team (VOST) Oregon in Case Study 2 and 3; while others unit of analysis (e.g. VOST Catalunya, Public Information Officers (PIOs), and journalists) were observed using structured observations. These groups structured observations had the aim of quantifying the frequency of the actions observed and used a quantitative data collection technique (Blaikie, 2010; Saunders et al., 1997).

ID	Case Study	Type of Observation Used	Description
1	Barcelona Terrorist Attack	Structured Overt – Secondary	Overt observation of the Twitter feed. 12 hours.
2	Oregon Eclipse	Participant Overt – Primary & Secondary	Overt observation as part of the group of Internal communication, and documents generated by the group.
3	Harvey Hurricane	Participant Overt – Primary & Secondary	Overt observation as part of the group of Internal communication, and documents generated by the group.

Table 3-10 Summary of overt observation: Case studies methodology applied

The overt observation was recorded using field notes before, during and after each emergency. Using an open-ended narrative, the researcher wrote qualitative notes during each incident, intending to remember and record the behaviours, activities, events, and key elements of the emergency.

Field notes included descriptive and reflective information, including factual data, behaviours, conversations observed, ideas, questions, and thoughts prompted during the observation. The following guidelines were considered to capture descriptive and reflective observations (Emerson, Fretz, & Shaw, 2011; Pyrczak & Bruce, 2017; Wolfinger, 2002):

- Description of the emergency and observation physical setting.
- Description of the social environment and the way in which participants interacted within the setting. It included patterns of interactions, frequency of interactions, the direction of communication patterns, and patterns of specific behavioural events (e.g. conflicts, decision-making, or collaboration).
- Description of the observed participants and their roles in the setting –, including number, country and background when available.
- Description of the meaning of what was observed from the perspectives of the participants – as applicable.
- Record of exact quotes or close approximations of comments that related directly to the purpose of the study.
- Note ideas, impressions, thoughts, and any criticisms that the research had about what was observed.
- Inclusion of any unanswered questions or concerns that arose from analysing the observation data in real-time.
- Inclusion of insights about what was observed and speculation as to why a specific phenomenon occurred. Clarification was sought during interviews as applicable.
- Record of any thoughts regarding any future observations (e.g. other case studies).

The researcher aimed to be accurate, organised using chronological records, descriptive, reflective, and overall focused on the research problem.

In the terrorist attack observation, the researcher observed how the communication flowed between the different stakeholders through Twitter and other mass communication media. The overt observation started on the 17th of August, minutes after the attack. Observation of the unfolding events was done through mediated channels in real-time. While the researcher had not access to the activated Virtual Operation Support Team (VOST) at the time, due to the sensitivity of this activation, their activity was observed using their official Twitter account. Similarly, accounts from the Catalonian police (@Mossos) and the coordinating emergency organisation (@EmergenciesCat) were monitored for updates in the incident and detection of rumours management. The observation lasted until the 19th of August 2017 and covered 12 hours. The researcher recorded three pages of observation using field notes.

In contrast, the researcher had better access to decision-makers activities during the eclipse and Hurricane Harvey. The researcher gained access to the relevant Virtual Operation Support Team (VOST) by contacting their team leaders. This access allowed to perform a participant observation. For the eclipse, the researcher joined the VOST activiation on Friday 18th of August 2017. The researcher was introduced to the team, and the motivation of joining the activation was made aware to all participants. Team members provided training concerning the use of the group artefacts (see section 3.4.5 for the description of these), and they offered to answer any questions during the activation. A total of 21 hours were observed over four days. The time difference between Ireland and Oregon (USA) limited the observation time allocated to this case study.

In Hurricane Harvey, the VOS team observed was active from the 31st of August until the 7th of September 2017. The participant observation performed during this period accounted for a total of 37 hours. VOST group activities were mostly recoded through Skype conversations which were analysed as part of the internal communication source of evidence (section 3.4.4).

3.4.2. News clipping and articles in the mass media

During risk communication, emergency managers collaborate with mass media to inform citizens before, during and after any incident. While there are different mass media channels, written news provide researchers with the ability to perform more rigorous analysis. Newspaper articles are used as an information source by researchers in multiple disciplines such as journalism, historians, linguists and information sciences (Tanacković, 2014).

In this research, the collection of newspaper articles allowed the researcher to gather documented evidence related to the incident while identifying the use of Twitter (RQ1) and rumours (RQ2) identified by journalists.

Table 3-11 summarises the steps followed by the researcher for each case study. It describes the methodology followed, the search parameters used in the search engines, the number of news articles retrieved and the final number of articles considered for analysis (after removing duplicates).

The data collection was performed using a combination of desktop research and opportunistic findings. The researcher used the search engines Google (News tab), Yahoo and Bing to identify published articles. Additionally, overt observation, the use of social media networks, the analysis of Virtual Operation Support Team (VOST) artefacts, and feedback gathered from interviews allowed the researcher to identify relevant articles for this research.

For each case study, the researcher predefined search terms in advance. These keywords were used in different search engines (i.e. Google, Bing, and Yahoo) employing a Boolean combination of the following: emergency name, location and an uncertainty related keyword. Common search terms used in the three case studies were: Rumours, False Information, Fake News, Social media, Social Networks, Twitter, August 2017, Misinformation. In addition to these, *'Terrorist attack'* and *'Barcelona'* were used for the Barcelona case study; *'Oregon Eclipse'* and *'Total Eclipse Oregon'* for the eclipse one; and search terms *'Harvey Hurricane'* and *'Texas'* for the last case study. Synonyms were researched and considered to capture different search results; however, they were

disregarded as not many news articles were found. Results were sorted by relevance to capture the most critical information. The timeframe was limited for each incident. In the Barcelona terrorist attack, the search was limited to the 13th of August to the 31st of August 2017. In the Oregon Eclipse, the search was limited to the 15th of August to the 22nd of August 2017. Lastly, in the Harvey Hurricane, it was narrowed to the 25th of August to the 14th of September 2017.

With the search parameters defined, the researcher developed a Python script to web scrap the search engine results (appendix 7.3). The script accessed the webpage; it selected the data to capture, and then it organised the information into structured elements. Data retrieved for each article included: Title, Published date, Newspaper, URL and Summary (Table 3-11). For each case study, the information scrapped was outputted and saved in a CSV file for further analysis. Links accessible in the first three search pages were considered for data analysis.

	Case Study	Methodology	Search Parameters Description Differences	Search Parameters Description Commonalities	News articles retrieved	Final dataset (after removing duplicates)

1	Barcelona Terrorist Attack	• Desktop Research
		  ○ Google News
		  ○ Bing
		  ○ Yahoo
		• Opportunistic Findings
		  ○ Observation of Twitter feeds
		  ○ VOST artefacts
		  ○ Interviews mentions
		  ○ VOST Conversations
			• 13th to 31st of August
			• Keywords: Boolean combinations of *Terrorist attack, Barcelona.*
				• Keywords: Boolean combinations of *False Information, Fake News, Misinformation, Social media, Social Networks, Twitter, and August 2017.*
				• Languages: English, Spanish and Catalan
				• Results sorted by relevance
				• Results limited to first 3 pages
					• 681 articles from 208 newspapers	• 497 news articles

2	Oregon Eclipse		• 15th to 22nd of August • Keywords: Boolean combinations of *Oregon Eclipse, Total Eclipse Oregon*		• 178 articles from 114 newspapers	• 167 news articles
3	Harvey Hurricane		• 25th of August to 14th of September • Keywords: *Harvey Hurricane and Texas*		• 390 articles from 163 newspapers	• 281 news articles

Table 3-11 Summary of news articles: Case studies methodology applied

3.4.3. Tweets

In the last decade, multiple scholars have explored the use of social media as an information source for research (Fan & Yan, 2015). Twitter is one of the most accessible social media platforms to output information, as there are low entry barriers. Ethical implications of this social media platform were reviewed in section 3.1.3.

The researcher analysed methods and approaches to find relevant information. Bruns and Burgess (2012) suggested tracking information (tweets, hashtags) over time, identifying key stakeholders (users) and mentions of key concepts, as well as conducting network analysis. Data collection from Twitter is usually performed using specific keywords or hashtags (S. Kumar, Morstatter, & Liu, 2013); however, in this case, information about specific Twitter users (Virtual Operation Support Team (VOST), journalists and Public Information Officers (PIOs)) was sought. Hence, tweets posted by them were considered. Table 3-12 summarises the origin of the tweets for each case study.

ID	Case Study	Description
1	Barcelona Terrorist Attack	• 262 tweets published from @VOSTcat debunking information. Original content and RT from PIOs and journalists. • Collected from 17th of August to 18th of August (2017) at 20:41h (Spanish time)
2	Oregon Eclipse	• Tweets identified through VOST reports and Newspapers articles
3	Harvey Hurricane	• Tweets identified through VOST reports and Newspapers articles

Table 3-12 Summary of tweets: Case Studies methodology applied

Twitter profiles for the three VOST activated teams were reviewed. However, participating teams in the Oregon Eclipse and Harvey Hurricane did not publish /shared information during their activation. On the other hand, VOST Catalunya in the Barcelona Terrorist attack (case study 1) shared content using their Twitter profile during the incident. This is a noticeable difference between the three case studies and the organisation of different VOST. Due to the sensitive nature of the terrorist attack, the researcher did not have access to Skype conversations or VOST artefacts for this case

study. Therefore, the researcher used Twitter to obtain documented outcomes of the decision-making process followed by the VOST team activated (@VOSTCat).

The researcher collected the tweets published by VOST Catalunya (@VOSTcat) in real-time using the Twitter Application Program Interface (API). Virtual Operation Support Team (VOST) specialises in the analysis of data from social media to support any emergency; however, in the BTA, they supported risk communication by creating tweets and the amplificatio official messages (retweets). On the 19th of August 2017 (10:50 am), @VOSTcat Twitter account had a total of 12.7K published post, 3542 followers and 2991 likes. This team, between 17/08/2017 6:23h and 18/08/2017 20:41h, published two hundred sixty-two tweets.

The key data analysed was published in @VOSTcat account; however, @VOSTSpain data were also collected but not included. The exclusion of these data was motivated by the number of duplicated tweets between the two accounts. @VOSTSpain focused on amplifying @VOSTcat messages, and therefore, a high number of retweets (RT) were part of the dataset.

3.4.4. Communication transcription (Skype conversation)

Direct access Virtual Operation Support Team (VOST) Oregon group allowed the researcher to access the group Skype conversation transcript for the Oregon Eclipse (case study 2) and the Harvey Hurricane (case study 3). The monitoring activity was coordinated through a Skype group chat (VOST Oregon, 2017g). The Eclipse conversation was downloaded from Skype on the 23/08/2017 at 19:00h and the Harvey conversation on the 10/09/2017 at 10:00h.

3.4.5. Artefacts: reporting tool and listening reports

Artefacts, such as software systems, form the core of research in Information Systems (Prat, Comyn-Wattiau, & Akoka, 2015). In this section, the researcher considers an artefact any given information tool developed to transfer knowledge. In this context, VOST teams use two artefacts to record their findings and report them to their activating organisation. These two artefacts are VOST reporting tool and VOST listening reports. Table 3-13 summarises the information collated from both artefacts.

ID	Case Study	VOST reporting tool	VOST listening reports
1	Barcelona Terrorist Attack (BTA)	• Not applicable	• Not applicable
2	Oregon Eclipse (EC)	• 89 entries (64 without duplicates) • The input of 12 team members • 150 monitoring hours	• Three listening reports (2 for before the event)
3	Harvey Hurricane (HH)	• 368 entries (366 without duplicates) • The contribution of 14 members • 100 monitoring hours	• Four listening reports (all for after the event)

Table 3-13 Summary of VOST artefacts: Case Studies methodology applied

VOST members record their findings in a shared Google Workbook document (reporting tool). This workbook is licensed under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License. This workbook is the primary reporting tool for VOS teams, and it has several sheets where team members capture the event information.

Access VOST Workbook was granted for two of the three case studies: Oregon Eclipse (EC) and Harvey Hurricane (HH). This access was permitted after the researcher became an active member of both activations. It included discoveries for both activations, including potential probes considered for interviews.

Using the VOST reporting workbook, each day a report is compiled by the Team leader detailing the key search findings. The pdf document is shared with team members and sent to the organisation that has activated the VOST. Relevant results are escalated directly to key stakeholders during the day. After the report is submitted, the team leader achieves the searches from the day before, providing space for new findings. These reports provided additional insight into social media use during incidents, and they were used to respond to RQ1 and RQ2. A total of 7 reports were collected for these activations, but VOST reports were not available for the Barcelona terrorist attack.

In the Eclipse case study, VOST findings were reported to the activating organisation through at least three Social Listening reports (VOST Oregon, 2017b, 2017c, 2017a). The

first report was created on the 17th of August, the second one on the 19th and the third one on the 20th.

The researcher had access to four reports created for Hurricane Harvey. The workbook information (VOST Oregon, 2017d) was used to compile these. They were created on the 1st, 2nd, 4th and 5th of September respectively.

These reports were composed by merging the information from the *'Oregon VOST Workbook for Hurricane Harvey'* (VOST Oregon, 2017e) */ 'Oregon VOST Workbook for Oregon Eclipse'* (VOST Oregon, 2017f) and observations from the Harvey Skype Chat (VOST Oregon, 2017h).

3.4.6. Adapted CDM interviews

The researcher used semi-structured individual interviews based on the Critical Decision Method (CDM) in this research. Interviews can be used for qualitative and quantitative research questions, and therefore, for mixed methodologies. Interviews cannot be self-administered and require an interviewer to ask the questions. There are different classification proposed by scholars such as:

- **Structure, semi-structured and unstructured** (Bryman, 2012; Quinlan, 2011): it refers to the degree of standardisation employed during the interview. A structured interview is also considered as part of survey research. It is a quantitative method and aims to measure respondents' answers by standardising how interviewer ask questions and record answers (Bryman, 2012). Questions are mainly closed, closed-ended, pre-coded or with a fixed choice. Semi-structured interviews start with a defined structure, but the interviewer has reasonable freedom to vary the order of the questions or ask further clarifications. The unstructured interview provides the freedom of formulating questions as required. Typically the researcher has a list of topics to cover as a guideline. Semi-structured and unstructured interviews are sometimes conferred as in-depth interviews, oral history interview, life history interview, and focused interviews (Bryman, 2012).

- **Face to face, by telephone, online** (Quinlan, 2011): This classification is specific to the setting where the interview takes place. Two additional variations are CAPI and CATI that refer to interviews conducted over the phone and in-person, but they are computer-assisted (Bryman, 2012).
- **Individual or in groups/ focus group** (Small, 2010): This classification denotes the number of persons interviewed at once. Group and focus group interviews are commonly used in marketing research, and it allows group interaction where users may challenge others statements providing greater insight into why certain opinions are held. It is mostly used in semi-structured and unstructured interviews (Bryman, 2012).

The researcher used online semi-structured individual interviews, adapting the Critical Decision Method (CDM) within each case study. The CDM has a predefined research protocol to select interviewees and inform the content of the interview. As Figure 3-8 illustrates, interviews took place after analysing the other sources of evidence and were nurtured by the case study findings. Probes and participants were selected based on the finding of the tweets, Virtual Operation Support Team (VOST) reports and VOST Workbooks analysis. Moreover, the incident context was gathered from observations, internal communication and news articles.

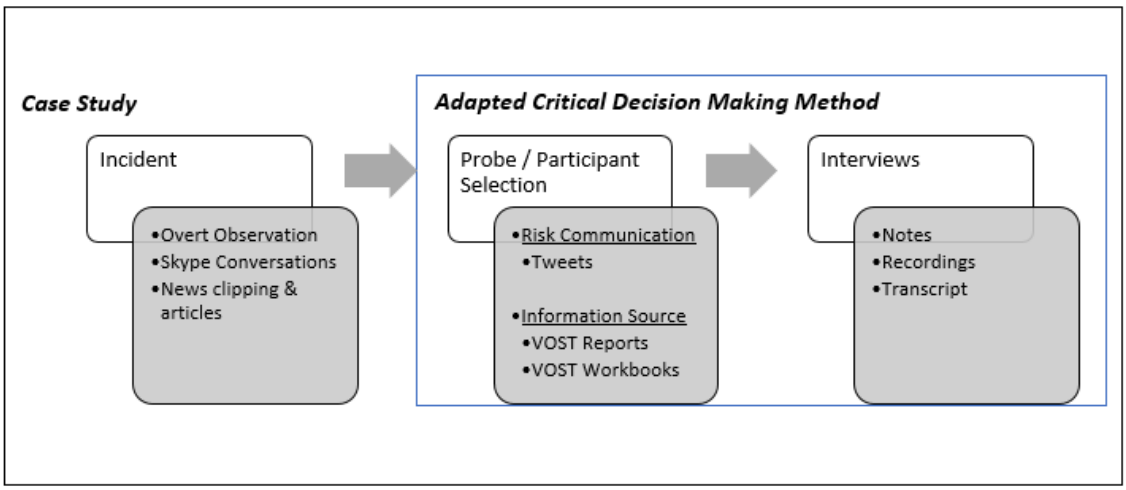


Figure 3-8 Adapted CDM interviews within the case study methodology

CDM technique is designed for collecting data about an incident that has happened in the past (Flanagan, 1954). Interviewees were asked to remember their decision-making

process followed in classifying a piece of information as rumour or miss information in a major incident.

By interrogating decision-makers through semi-structured online individual interviews, the researcher collected evidence of their experience in the case study and in general with social media during emergencies (RQ1). Additionally, the interview was embedded in the case study and designed using the CDM, which proposes the use of probes to recall the decision-making process in interviewees. Probes were extracted from the artefacts generated by the VOS teams, tweets within their Twitter profile, and news articles. The researcher gathered evidence a priori that showcased that the selected interviewees were familiar with the relevant probes, and they had classified each piece of information as a rumour in at least one of the outlined artefacts.

Appendix 6 includes the interview guide followed by the researcher. Probes were presented to relevant participants to capture their internal decision-making models in the specific context presented. They were asked to describe the piece of information (tweet), outline when they evaluate it, and the process followed to identify it as a rumour. Strategies and information quality dimensions were identified, and the order of the actions/process followed was noted by the researcher.

For instance, a probe selected illustrated a shark swimming on a motorway (Figure 3-9).

Figure 3-9 Probe example

Interviewees quickly declared that this tweet was a rumour. Some participants saw this image in previous hurricanes (experience) and discarded the information. They also outlined that their decision was based on the utility of the information, its timeliness, the reputation of the source, and lastly, the comparability of the information, in special the representational consistency of the image. They highlighted that the image had been manipulated, and inconsistencies were visible. Findings are presented in Chater 4.

The description of 75 decision-making processes was documented through the interviews. Five Barcelona Terrorist Attack (BTA) Subject-Matter Experts (SMEs) were showed 6 probes collected in this case study. They defined 30 decision-making processes. Four interviewees evaluated 5 Eclipse (EC) probes providing insight into 20 decision-making processes. These four participants were also active in the Hurricane Harvey (HH) case study, and therefore reviewed probes 11 to 16 (5 additional) allowing to capture information about the impact on their process depending on the type of emergency analysed.

Interviews as a source of evidence enabled the researcher to understand better Twitter use, the identification of decision-makers and other rumours, identification of Information Quality (IQ) dimensions, and refinement of the process followed to evaluate the information. This process supported the model refinement and answered research question 3.

3.4.7. Case studies: summary of sources of evidence

Evidence for the case studies was collected through four sources of evidence types: observation, documents and archival records, artefacts and interviews. The complexity of the data collection process was different depending on the access to the information source and each specific case study. For instance, the collation of news articles required a more significant number of steps than the access to the group internal communication. Table 3-14 summarises the source of evidence, and the data collection process followed for each case study.

The first emergency observed (chronologically speaking) and used as a case study was the Barcelona terrorist attack that took place in August 2017. This case study describes

the response phase since the beginning of the attack until the threat was reduced. During and after the incident, four sources of evidence were collected. It included 497 newspapers articles, 262 tweets addressing misinformation, 5 interviews and multiple observation notes.

Observation of the incident unfolding and the team activity was performed over a period of 12 hours and during the incident. This was accomplished through mediated channels as multiple stakeholders were located in different locations (e.g. emergency control room, their house, workplace). The Barcelona terrorist attack evidence source differs from the other two case studies as it includes tweets published by a Virtual Operations Support Team, but excludes any artefact and internal communication. This difference resides in the access provided to the researcher in this case study and the organisational approach of the team covering this incident. The use of Twitter as a risk communication tool in this accident was more active than in the other two case studies and provided greater insight. The interview participants' selection was based on the findings from the 262 tweets managing disinformation and the 497 newspaper articles analysed. It supported the selection of 6 probes and five key decision-makers.

The second case study focused more on preparing for any potential emergency before the Solar Eclipse events in Oregon (August 2017). Information from this case study describes decisions made before, during and after the incident. Four sources of evidence were collected and summarised on multiple documents, including 167 newspapers articles, 1 VOST Workbook (VOST Oregon, 2017f), 2 VOST listening reports (VOST Oregon, 2017b, 2017a), 2120 Skype messages (VOST Oregon, 2017g), 5 interviews and multiple observation notes.

Source of Evidence	Description	Barcelona Terrorist attack	Oregon Eclipse	Hurricane Harvey
Overt observation	The researcher observed and took field notes from events unfolding, social media activity and VOST coordination.	12 hours	21 hours	37 hours
Archival Records & Documents	Twitter text (addressing misinformation)	262 tweets from @VOSTCat	N/A	N/A
	News articles	497 articles	167 articles	390 Articles
	Skype conversations	N/A	2120 messages	1926 messages
Artefacts	VOST Workbook (reporting tool)	N/A	89 entries	368 entries
	VOST listening reports:	N/A	✓ August 17, 2017 ✓ August 19, 2017	✓ Sept 1 2017 ✓ Sept 2 2017 ✓ Sept 4 2017 ✓ Sept 5 2017
CDM Interviews	Interviews with Subject-Matter Experts (SMEs)	6 tweets were selected as interview probes. 5 interviews sections	5 rumours were selected as interview probes. 4 interviews sections	5 tweets were selected as interview probes. 5 interviews sections

Table 3-14 Case studies' evidence sources summary

Overt observation played a vital role in collecting and analysing the other sources of evidence and maintaining the chain of evidence. 167 newspaper articles were reviewed and analysed to obtain contextual information and to identify expert journalists. Observation played a vital role to identify experts in the other two categories, public information officer and VOST members. It was performed through the Oregon Virtual Operation Support Team (VOST) communication channels and through the official sources' Twitter feeds. VOST Oregon is a virtual team in the area of Emergency Management (EM) that support major incidents (e.g. emergencies and disasters) in the estate of Oregon (USA). This team has 90 members, of which 12 were active on this incident (VOST Oregon, 2017f). Through overt observation and the researcher involvement in this group, it was possible to access their internal communication channel (Skype group) and two types of artefacts created during the activation: 1 VOST Workbook (VOST Oregon, 2017f) and 2 VOST listening reports (VOST Oregon, 2017b, 2017a). For each incident, a VOST Workbook is created and shared with all team members. The *'Oregon VOST Workbook for Oregon Eclipse'* was created by the team leader on the 3rd of June 2017 and updated with relevant information a priori the event started (VOST Oregon, 2017f). The team leader shared the workbook with all participants through the Skype channel (VOST Oregon, 2017g). Each remarkable information piece is commented on through the VOST Oregon Skype channel and duly noted in the VOST Workbook. Every 24 hours or any other time agreed between VOST and activating organisation (public information officer), the team leader compiles and produces a VOST Listening report using the information collated in the VOST Workbook to provide a summary of the main findings. The analysis of these documents has provided further evidence for the case study and helped to identify probes for the interviews.

Additionally, access to Skype conversations was granted as part of the research efforts by VOST Oregon. Involvement of the researcher with the team may have had a limited impact on the topics discussed in Skype as members of this group have actively supported previous researchers in the area of emergency management and social media (e.g. St. Denis et al., 2012, 2014).

The third case study, chronologically speaking, provides insight into Harvey Hurricane's decision-making, which impacted Texas and caused a flooding emergency.

Different VOST teams were activated to support the emergency response and recovery. During and after their activation, four sources of evidence were collected and summarised on multiple documents, including multiple observation notes, 390 newspapers articles, 1 VOST Workbook (VOST Oregon, 2017e), 4 VOST listening reports (VOST Oregon, 2017d), 1926 Skype messages (VOST Oregon, 2017h), and 5 CDM adapted interviews.

Overt observation with Skype conversations supported the data gathering and posterior analysis of the artefacts collected as it provided context to identify the decision-making process. For this event, a total of 14 team members actively contributed to compile information for the VOST Workbook. They amounted to a total of 145 full-time social monitoring hours. Data collated was used to create at least four social listening reports included in this research. Following the same approach that with case study 2 (Oregon Eclipse), information gathered in the newspapers, communication transcripts and VOST artefacts supported the selection of interview participants and decision-making probes.

The next section describes the analysis process followed to review all the data sources outlined in this section while ensuring the integrity of its findings and maintaining an unbroken chain of evidence.

3.5. Data Analysis for the case studies and Critical Decision Method (CDM)

This section provides a summary of the data analysis process employed in this study. Data were analysed, keeping in mind three fundamental principles:

1) Use of multiple sources to converge evidence
2) Each data source had an evidentiary base and a finding report
3) The maintenance of the chain of evidence

The type of data collected impacted the data analysis techniques considered. Sources of information described in section 3.4 are, on its core, qualitative data, either primary, secondary or tertiary.

The data analysis performed was inspired by the CRoss-Industry Standard Process for Data Mining (CRISP-DM) framework (Figure 3-10), which outlines six steps, including (1) Business understanding, (2) Data understanding, (3) Data preparation, (4) Modelling, (5) Evaluation and (6) Deployment. These steps were modified to meet the needs of this research. The researcher approached each source of information following five steps: business understanding, data understanding, data preparation, coding, evaluation and reporting.

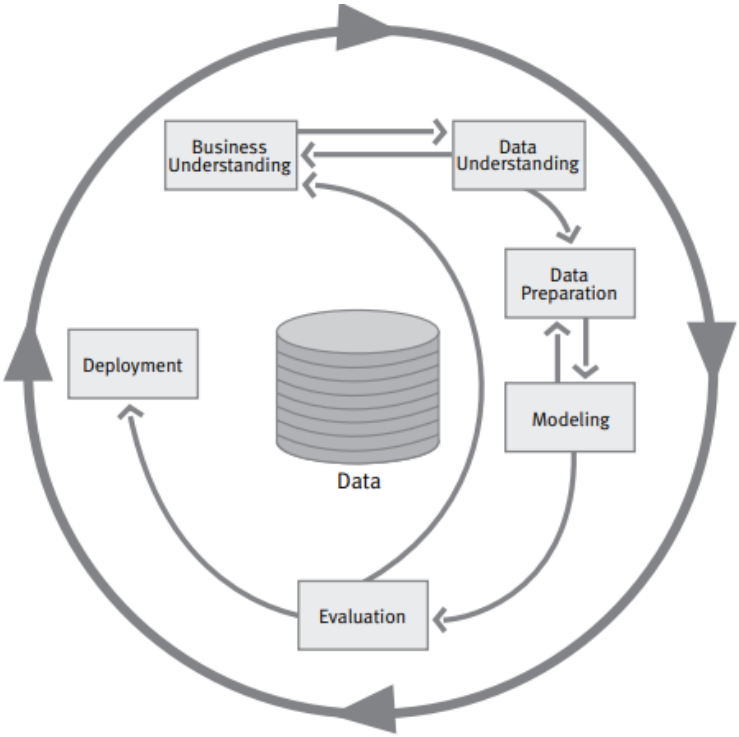


Figure 3-10 Crisp DM data analysis

In this research, the business understanding step was achieved through informal conversations held with practitioners during two FP7 S-HELP project workshops in 2016 and one H2020 Medi@4Sec workshop in 2017, combined with the literature review described in Chapter 2. These activities allowed the researcher to understand the requirements further to address this research's objective, answer the three proposed research questions and select a suitable methodology, as described in section 3.2.

Data understanding started with the data collection (e.g. overt observation) and proceeded with all the activities required to become familiar with the data. Data preparation describes all the operations required before the data can be analysed and

coded. It includes transferring the documents to a more dataset format (e.g. from word to excel or to a coding software). Coding denotes the process of classifying the data collected into categories for a better understanding of the information. All process was then evaluated, and reports for each data source generated.

3.5.1. Data understanding and preparation

The majority of data collected had a qualitative component; therefore, it was paramount to understand the data type in order to establish the parameters to prepare it for analysis. Table 3-15 (page 160) provides a summary of the data retrieved which included 14 pages of observation notes, 262 tweets, 103 pages of Skype conversation, 1261 news articles, 2 VOST (Virtual Operation Support Team) Workbooks, 7 VOST reports and over 12 hours of audio recorded interviews.

The researcher first read /listened to all data to create a mental model of the information available. In order to codify the information and keep an accurate record, each source of information was prepared for exploration. This section describes the steps taken to ensure content integrity while modifying the format for data analysis.

Notes: overt observation and interviews

Overt observation notes were analysed at the same time that they were written and while the researcher was conducting the interviews. Field notes were converted into a draft report within 24 hours of the observation to avoid the loss of additional details and the interpretation. Notes contributed to answering RQ1 and RQ2 of this research and were combined with other sources of evidence.

Communication Transcripts

The Skype conversations were copied and pasted into a word document. They had the following format:

'[dd/mm/yyyy hh:mm:ss] Skype user name: Message Link'

4046 messages were transferred from word to excel for further analysis using these headings: Date, Time, User name, Message, and link. The time variable was modified to account for the time zone difference between the researcher and the participants. All participant's names were anonymised.

Source	Step	Barcelona Terrorist Attack (BTA)	Solar Eclipse in Oregon (EC)	Hurricane Harvey (HH)
Observation Notes	Data understanding	3 pages	5 pages	6 pages
	Preparation	Word document		
Tweets	Data understanding	262 tweets (fake information)	Not applicable	Not applicable
	Preparation	Exported to CSV format	Not applicable	Not applicable
Skype conversation	Data understanding	Not applicable	5 pages with 1,835 words. Includes date, hour, name and message	98 pages with 38,149 words. Includes date, hour, name and message
	Preparation	Not applicable	Transfer word to Excel. Manipulate hours as it was in Irish time. Divide the text into different headings: date, hour, person, message, link	
News articles	Data understanding	681 articles from 208 newspapers HTML format	190 articles from 114 newspapers HTML format	390 articles from 163 newspapers HTML format
	Preparation	Excel for structured data and HTML format for content and images		
VOST Workbook	Data understanding	Not applicable	1 excel	1 excel
	Preparation	Not applicable	Transform document into the dataset for coding	
VOST Reports	Data understanding	Not applicable	3 PDF	3 PDF and 1 Word document
	Preparation	Not applicable	Transform documents into the dataset for coding (PDF to CSV format)	
Interviews	Data understanding	MP3 audio records		
	Preparation	Transcription of 4 hours and 28 minutes of recorded interviews	Transcription of 4 hours 30 minutes of recorded interviews	Transcription of 3 hours of recorded interviews

Table 3-15 Summary of data preparation and manipulation

Tweets

Using Twitter Application Program Interface (API), 11 variables were outputted: Published Date, Screen Name, Full Name, Tweet Text, Tweet ID, App, Followers, Follows, Retweets, Favourites and Google Maps. The dataset analysed included 262 tweets created to address misinformation (139 in Spanish, 102 in Catalan, 15 in English and 6 in French).

Five variables considered for analysis:

1) **Published date:** it provides a context of the message over time (Day and Hour)
2) **Tweet Text:** content analysis (search for duplicates)
3) **Tweet ID:** it is the unique dataset identifier, and it links to the Twitter database so messages can be retrieved online
4) **Retweets:** The number of times that a message has been shared. It indicates the reach of the message.
5) **Favourites:** The number of times that a message has been marked as a favourite. It indicates the perception of the users in relation to the message.

The researcher first applied basic statistical analysis. Qualitative and quantitative data was analysed using suitable techniques (e.g. mean, mode, median). This exercise was performed to obtain a basic understanding of the data captured.

Two variables that indicate the messages' reach and the receivers' perception are Retweets and Favourites variables. Retweets (RT) indicate the number of times that a message was shared. The dataset's messages were retweeted a total of 9025 times with a mean of 34.64; however, the mode and median values (0 and 9 respectively) and the standard deviation (94.66) indicate that the dataset is skewed to the left. Indeed, 25 messages posted were not shared by any user.

Furthermore, 50.38% of the dataset's messages were shared less than 10 times (including 0). However, there are messages they are five messages that were shared more than 300 times, with the message most shared reaching up to 848 shares. Also skewed is the variable favourites as Table 3-16 basic statistics demonstrate concerning its mean, mode, median and standard deviation. The dataset includes 4,260 times that

messages were marked as a favourite with a mean of 16.26 times. The skewness is less acute; however, there is still a relevant difference between one message shared 448 times (max), and 186 messages marked as favourite less than 10 times.

	Sum	Mean	Mode	Median	Standard Desv.	Max	Min
Retweets	9,075	34.64	0	9	94.66	848	0
Favourites	4,260	16.26	1	6	41.44	448	0

Table 3-16 BTA - Basic Statistics of @VOSTcat: variables Retweet and Favourites

Content analysis was performed to report case study findings and support the Critical Decision Method (CDM). This dataset analysis provided evidence to select the tweets/rumours used as a probe for the CDM semi-structured interviews. Additionally, it helped to identify key decision-makers, uses of Twitter from different stakeholders, and supported the timeframe development.

Web scrapping: Newspapers

News articles published before, during and after the different incidents were sourced from national and international newspapers. The researcher developed a python script to web-scrap online news articles. The output of the python script was saved in a CSV file. For each case study, the following information was retrieved: Title, Researcher, Published date, Language, Newspaper, Search Engine retrieved from, and URL. After merging the output of the different search engines, duplicate entries emerged. These were removed before the data analysis. After removing duplicates, the dataset was analysed using basic statistics to understand better the information retrieved. The summary of the dataset compiled is as follows:

- **Barcelona Terrorist Attack (BTA):** The initial dataset comprised 681 news articles. After removing duplicates and out of topic news articles, 497 articles from Spain and other countries were analysed. The top 15 newspapers within the dataset are Express.co.uk, Daily Mail, Mirror.co.uk, La Prensa de Honduras, El Pais, The Guardian, HSB Noticias, The Independent, El Periodico, Infobae.com, El Mundo, La Vanguardia, El Observador, CNNEspanol.com, and BBC News. They represent 40.64% of the dataset. A trend was detected in the Spanish papers to provide updates using one single web page in a newsfeed format (e.g. El Pais, El

Mundo). This approach decreased the number of pages published by these journals but provided more abundant information on their articles.

- **Solar Eclipse (EC):** The retrieved dataset comprised 178 news articles that were reduced to 167 after removing duplicates. There are 28 newspapers represented with more than one article accounting for 51.69% of the dataset. The researcher made all efforts to ensure that the most important newspapers in Oregon had were included in the findings. Therefore, 12 news articles from OregonLive.com were part of the dataset (6.74% of the sample).
- **Harvey Hurricane (HH) and Floods Newspapers articles:** A total of 390 articles were initially interrogated. After removing duplicates and out of topic news articles, a total of 281 articles were analysed. Like the Barcelona case study, the researcher saw many newspapers using newsfeed formats to provide information updates on one page instead of creating new article pages (CNN Español, 2017c; Hicks & Selby, 2017). Newspapers with a more significant number of news articles in the dataset include Washington Post, USA TODAY, KTRK TV and BBC News.

Virtual Operation Support Team (VOST) Listening Reports

A total of 9 listening reports in pdf and word were made available to the researcher by VOST. Each report followed a similar structure:

- Date
- Summary
- Major themes from social media
- Possible points of confusion /miscommunication /rumours
- Emerging themes
- State government mentions
- Relevant Twitter links since the last report:
- Metrics

Bullet points were used to report the main findings with hyperlinks to relevant pieces of information embedded in the text. Images were added as considered relevant. Reports entries were transferred within the following headings: Report date, category, content, and URL.

All eclipse reports (VOST Oregon, 2017g) followed a similar structure and included the following headings: Summary, Major themes from social media, Possible points of confusion /miscommunication /rumours, emerging themes, state government mentions, relevant Twitter links since the last report, and Metrics. The team leader used bullet points to describe the team findings. A total of 20 bullet points were used to convey the information. Additionally, the *'Metrics'* section included ten images being the category reporting more information.

Topics reported in both reports were the same. They were in its majority information about transport-related updates (36.68%). Only one bullet point referred to the #MilliFire fire (ID 13) which was active in the area. Another VOST team monitored this emergency, and some members were active in both groups. The metrics category provided information related to social media activity on particular Twitter. It described the hashtag mentions, reach, impressions, most influential users, most engaging users, most active users, top hashtags, top languages, most retweeted tweets, and its location on a map.

Hurricane Harvey reports followed a similar structure but with different headings. The first two reports included donation information from social media, links to donations groups, locations for donations (originating from and head to if possible), volunteer information from social media and possible points of rumours and scams for donations and volunteers. While the last two reported the findings within warehouse space, medical supplies, mass care, pet needs, shelter offered, donations of general goods or funds, and donations with unspecified destinations. The sections summary and relevant links were presented on the four reports. A total of 94 bullet points were used to convey the information.

VOST Workbook

VOST Workbooks include as standard 15 excel sheets (Table 3-17). The majority of these sheets provided interesting information related to the VOST activation. However, the researcher focused on the analysis of the data related to the three research questions. First, each tab was evaluated concerning its contribution to the basic understanding of

the case study and the ability to provide insight into the research questions (appendix 3).

Tab	Description
Cover	Provides contact details of the workbook and team leaders
ONBOARD INTRO	Description of VOST Oregon and tools used
ICS 204 Modified	Assignment list, including missions and objectives
Check-In / Out	Register of members and 'working' hours
Key Websites & Resources	List of websites and social media searches to support monitoring and listening activities.
Search Results	Reporting tab when team add findings in different sections by date
Mini assignment 1	Findings of a specific task requested by the team leader concerning drone images
RAPTOR Event Info	List of all events planned during the Eclipse Event, including location, expected attendance, location, links to social media and search parameters for monitoring
General availability Table	Table to monitor the availability of the members in advance
Team members	List of contact details of team members
VOST activity log	Team Leader and VOST team members enter their key activities, along with date/time activity took place
Parking Lot	Tab to capture all of the ah-ha moments, lessons learned and items to potentially follow-up on after the incident.
Time Zone Lookup	The tab that includes time differences of relevant countries and cities in the world
Change Log	Track of the changes on the main template.
INSTRUCTIONS	Description and instruction to members for the VOST Eclipse.

Table 3-17 Description of VOST workbook tabs **(VOST Oregon, 2017f)**

The most relevant sheet for this research is the *'search results'* tab. Members can classify messages as one of the following categories: general awareness, urgent - hot issues - sensitive issues, drone and event fly-over links, critical emergency info, rumours/confusion/fake posts/images, positive sentiment comments/info, negative sentiment comments/info, or individual needs/requests/questions.

The researcher's most relevant area was the category *'Rumours/Confusion/Fake Posts/Images'*. This section included the team member's name who has decided that a piece of information can be considered within this category. This helped to identify irrelevant probes and key decision-makers for the CDM interviews ensuring the chain of evidence.

Each entry in the dataset was qualified, including date, time, name, summary, website Uniform Resource Locator (URL), action requested, action completed by, and notes. The format used was not suitable for the analysis required; therefore, it was transferred to an excel dataset where each entry was qualified, referring to report included, date, category, content, and website URL.

Oregon VOST Workbook Template - based on Pacific Northwest (PNW) VOST Workbook Template v4.0 – was used by the team leader to create the *'Oregon VOST Workbook for Oregon Eclipse'* on the 3rd of June 2017. It was modified to make it ready for rapid Oregon VOST activation as needed, and the team leader added three additional tabs: instructions tab, on-board intro tab, and new search results tab.

Key websites and resources monitored included Twitter, Facebook, Instagram, YouTube, Reddit, Inciweb incident page[23], RMCC[24] Current Activity Update, National Weather Service (NWS) Medford, NWS Pendleton, NWS Portland, Medford Fire Weather Information, Pendleton Fire Weather Information, Portland Fire Weather Information, Medford Interagency Communication Center, United States Forest Service (USFS) (Region 6), Region 6 Twitter List, Grants Pass Chamber of Commerce PDF, Oregon (OR) State listing of Fire Departments (A to L), OR State listing of Fire Departments (M to Z), Oregon Humane Society Technical Animal Rescue Team (OHSTAR), Real-Time Wildfire Map + Fire Danger (The Oregonian), Medford - Grants Pass FB Interest List (public), Smoke map, Air Quality Index Map - Oregon Department of Environmental Quality (DEQ), NASA Worldview (Night) - Large Fire Detection, and NASA Worldview (Day) - Clouds, Smoke, Large Fire Detection, between others. Additionally, two local news organisations were monitored: The Oregonian and Statesman Journal (VOST Oregon, 2017e).

During this activation, the data captured in the workbook was collated by twelve members who monitored social media and online resources during an accumulative of

[23] Inciweb: USA interagency all-risk incident information management system. It provides to the public and the Public Affairs community with a single source of incident related information and a standardized reporting tool. Website: https://inciweb.nwcg.gov/
[24] Regional Medical Coordination Center (RMCC) in the USA

150 hours. A total of 64 messages were recorded in the workbook, including their URL and small description.

To support the Harvey activation, VOST Oregon created on the 31st of August a Workbook based on the PNW VOST Workbook Template v4.0. Definition of the team mission was also shaped on that date and recorded on the ICS sheet:

> *'Monitor Hurricane Harvey Donation Collection Request Information for Dallas, Corpus Christi, Beaumount, Houston - Facebook, Blog, Twitter, and Reddit. Report activity that needs to be addressed by logging it on the Search Results sheet in the workbook and escalating the Skype room to be addressed. You may either refer to it by Line Number from the Search Results sheet or paste the item to be handled. The PIO will determine how to respond and the Team Lead will assign the task or fulfil the PIO assignment if no one else is on duty.'* (VOST Oregon, 2017e)

The mission was reviewed and refined on the 2nd of September to meet better the activating organisations (FSU VOST[25] and the Federal Emergency Management Agency (FEMA) in the United States of America Voluntary Agency Liaisons) requirements. To support the mission, key websites & resources were identified and added to the worksheet. Twitter searches for this activation were also detailed and included: #harveyRescue, #harveySOS, #harveyflood, #harveydonations, #harveyhelp, #harveyrelief, #HouRecovers, #hourecovers, #peopleareawesome, #hurricaneharvey, #volunteerharvey, #harveyvolunteer, #harveyheros, #harveyhelpers, #houstonstrong, #texasstrong.

In the search tab, a total of 368 entries (366 without duplicates) were added which accounted for 100 monitoring hours of 14 members. An additional tab was created to report Scams (donations /volunteers) which included two entries.

Interviews

[25] FSU VOST (Florida State University Virtual Operation Support Team) website : http://em.fsu.edu/research.php

In addition to taking notes, interviews also were audio-recorded with interviewees' permission. All interviews were transcribed into a word document and then transferred to an excel file for data analysis. For each interview, the researcher included the interviewee's unique identification, date, case study reference and transcription of each answer. Different probes were presented depending on the case study; each probe ID's reference was noted to maintain the chain of evidence.

Interview and other data sources were objected to basic statistics and then codified.

3.5.2. Coding: content analysis and CDM tables

After basic statistics, content analysis was performed using codes. Content analysis involves the scrutiny of documents or communication contents. It is mostly used in communication research (Quinlan, 2011) but applicable to any qualitative methodology. Qualitative and quantitative techniques can be used to analyse the content by coding it or identifying phenomena amongst which connections are established (Blaikie, 2010). Some researchers pinpoint the relationship between this data gathering technique and literature review (e.g. Quinlan, 2011); however, some content analysis research can be hardly classified as literature review (e.g. content analysis of tweets).

Coding of the content analysis was performed to all qualitative sources of evidence. Codes are labels assigned to data (Miles & Huberman, 1994) which helps the retrieval, organisation and interpretation of the findings. The researcher first identified categories and conducted an open code approach. Open coded analysis assists the delineation of concepts, and it is adapted from the grounded theory approach. Grounded theory suits researchers that start their research process without a pre-defined theory in mind and allow theory to emerge from the collected data (A. L. Strauss & Corbin, 1998). Therefore, the theory is grounded in reality. This approach facilitated the achievement of building a descriptive model by exploring how decisions are made in naturalistic environments through expert's input.

Additionally, the researcher used the emergent themes analytical method proposed by Wong (2004) for the Critical Decision Method (CDM) data analysis where broad patterns are identified. Categories and codes were evaluated continuously and merged through

a comparative analysis based on their similarities and differences. The researcher kept theoretical memos about the categories created and their potential relationship with other categories. At the end of the process, similar categories were grouped and then verified against previous findings.

In this research, content analysis was used to answer the research questions outlined and supported the adapted CDM method implementation. Content analysis was used in all sources of evidence within this research, including news clipping and articles in the mass media, communication transcription (Skype conversation), Tweets, interviews transcripts, VOST Reports and VOST Workbooks. First, news articles were classified within categories to provide background information for the proposed case studies, and they provide examples of the use of social media in these incidents. Articles related to misinformation and rumours published during the incident were further analysed using content analysis. The material collected informed the researcher about rumours and misinformation identified by journalists and provided further insight into the probes selected for the CDM method.

Similarly, VOST workbooks, tweets and reports were coded. The aim was to extract the relevant information from documented outcomes. An outcome is considered documented when a blog /news article/ report refers to an action taken upon the information extracted from a tweet, among other control variables. This analysis facilitated the identification of Public Information Officers and VOST decision-makers. Additionally, findings supported the identification of Information Quality (IQ) dimensions and provided evidence for this purpose.

The researcher is aware of the limitation of having just one coder. As Miles and Huberman (1994) described, it may affect the reliability of the coding process. In order to minimise this impact, information sources and documents codified as first instances were reviewed a second time after the full coding was completed.

3.5.3. Evaluation and reporting

The last step is to evaluate the data and create reports. The researcher evaluated each information source individually and then within the context of each case study. The

methodology selected encouraged the triangulation of the data obtained, and similar patterns in different sources of evidence were detected as part of the process.

In a final stage, all sources of evidence were merged to evaluate similarities and differences between the three case studies selected and the input of ten Subject-Matter Experts (interviewees). General findings are reported within the next chapter, while differences are outlined as potential future research lines.

3.6. Synthesis of research approach

Chapter 3 has described the research process strategy designed to fulfil this research objective. By means of a theory-discovery approach, experts' decision-making processes were analysed using grounded theory to build a novel descriptive Information Quality model.

After evaluating the philosophical grounding of the Naturalistic Decision Making School (NDMS) and the methodology used by researchers in similar studies, the use of real case scenarios combined with experts input was deemed necessary to gather knowledge outside a theory-testing laboratory setting. Accordingly, a three-phase approach (context, Information Quality (IQ) dimensions identification and model development) was proposed to ***'develop a descriptive IQ microblogging model that supports the decision-making process in emergency management'***.

These three-phase approach, based on three case studies and multiple Critical Decision Method (CDM) interviews, allowed the researcher to answer these Research Questions (RQ):

- *RQ1. How is Twitter used for decision-making in major incidents?*
- *RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?*
- *RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?*

Multiple sources of evidence were collected to provide suitable responses (Table 3-18). The combined analysis of all these data allowed the researcher to understand further

how Twitter information is shared /consumed for decision-making, infer which IQ dimensions impacted the decision-making process, and what steps followed in social media emergency management experts (Chapter 4).

			CDM Interview Sections						
Phases	Steps	Case Study	Experience	Experience in SMEM[26]	Team activation	Goal of activation	Verification Protocol	Probes	Other comments
Phase 1	Step 1 - Timeline	x			x				x
	Step 2 - Use Twitter (RQ1)	x			x	x			x
Phase 2	Step 3 - Selection Decision-Makers	x	x	x					x
	Step 4 - Selection Probes	x				x		x	x
	Step 5 – Dimensions (RQ2)						x	x	x
Phase 3	Step 6 – Relationship (RQ3)						x	x	x

Table 3-18 Alignment of findings and methodology

As outlined in Table 3-18, this research's methodology supported the collection of evidence for each step of the outlined phases. Chapter 4 informs the findings by describing the case studies timeline (step 1 in section 4.1.), describing the use of Twitter (findings of step 2 in section 4.2.), description of selected decision-makers experience (step 3 in section 4.3.), description of the probes (step 4 in section 4.4.), Information Quality (IQ) dimensions (step 5 in section 4.5.) and lastly outline the steps followed in the decision-making process (step 6 in section 4.6).

[26] SMEM: Social Media for Emergency Management

Chapter 4. Twitter IQ dimensions in emergency decision-making

The use of Twitter information for decision-making has multiple challenges related to Information Quality (IQ) and information uncertainty. As described in Chapter 2, any decision, independent of the context, has a level of uncertainty associated with it. However, decisions in naturalistic environments (e.g. emergencies) are intrinsically different as problems are ill-defined in uncertain and dynamic environments where multiple stakeholders interact in a context of high time stress and high stakes. The literature review (Chapter 2) indicated that decision-making could be enhanced through IQ. Furthermore, high-quality information reduces uncertainty levels and supports decision-making processes.

Traditionally, citizens depended on information shared by organisations as part of their risk communication strategies. Likewise, emergency organisations had limited access to information gathered by citizens who were first-hand witnesses. In recent years, information flow between citizens and organisations has improved through the use of social media platforms such as Twitter in major incidents. However, the use of Twitter – as a risk communication and information source tool - contains specific challenges related to IQ (e.g. big noise, information shift, inaccuracy of information) increasing decision-makers' uncertainty levels.

The researcher evaluated existing IQ literature in the area of Information Systems (IS), Emergency Management (EM) and Twitter. A gap was identified while trying to ascertain a process to reduce uncertainty level while evaluating Twitter IQ for decision-making in major incidents. Therefore, to utilise this platform for emergency decision-making, further research was required. This research objective is as follows:

> **To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents.**

The methodology chapter demonstrated that performing research in emergency decision-making is not exempt from difficulties. As described in Chapter 3, the researcher considered multiple scenarios while selecting the appropriate methodology, data sources and data triangulation analysis techniques. The reader was presented with the researcher journey to select, gather, prepare, analyse and evaluate suitable data to fulfil this research objective.

To ensure the validity of findings and to be ethically correct at the same time, this research was performed in naturalistic environments and outside a laboratory setting. The difficulty of observing individual decision-making processes in naturalistic environments (e.g. emergencies) and Twitter and the challenge of mapping participant's mental models required the use of multiple sources of evidence in combination with the Critical Decision Method (CDM) interviews. As outlined in Figure 4-1, the researcher used a three-phase protocol to define the context, identify relevant IQ dimensions and establish the conceptual relationship between these using three real-life scenarios and input from Subject-Matter Experts (SMEs). Three incidents that took place in August 2017 were selected as this research case studies. A terrorist attack, a solar eclipse and a hurricane were used to identify Subject-Matter Experts (SMEs) to perform ten adapted Critical Decision Method (CDM) interviews that outlined 75 decision-making processes. Six steps were followed to manage the data gathered while maintaining an unbroken chain of evidence. Those are explained after Figure 4-1.

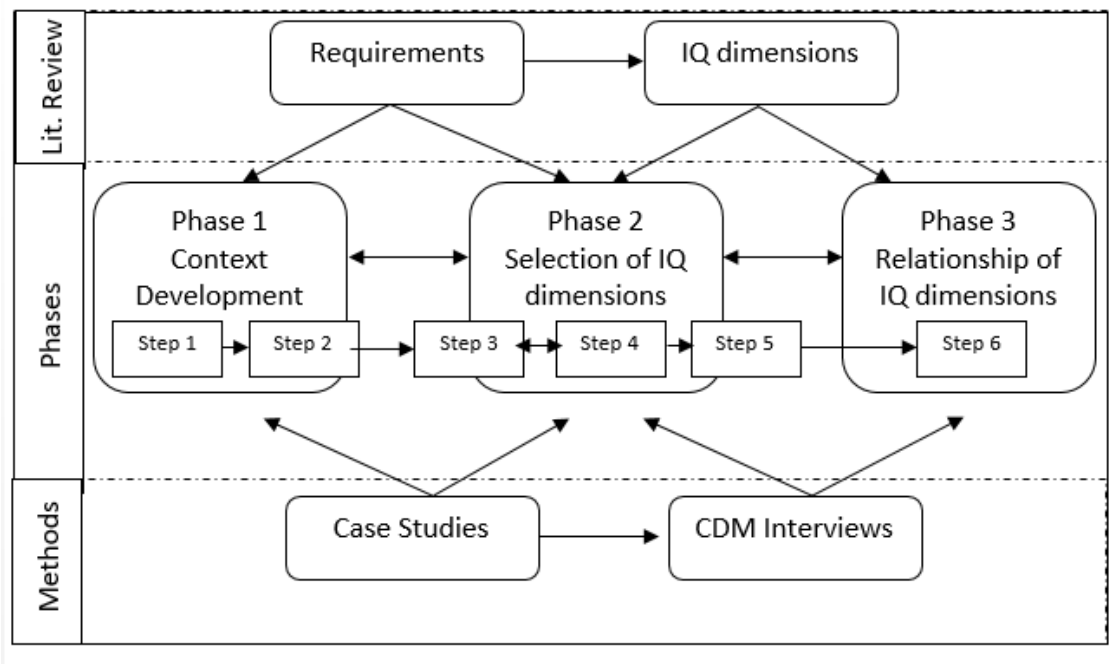


Figure 4-1 Research protocol alignment with literature review

Evidence collected through multiple sources as part of the case studies in conjunction with interviews' findings were utilised to answer the following Research Questions (RQ):

'RQ1. How is Twitter used for decision-making in major incidents?'

'RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?'

'RQ3. What_steps are followed by experts to use Twitter in their decision-making process in major incidents?'

Answers were obtained through the operalisation of the following steps:

- ✓ **Step 1: This first step defined each case study timeframe.** The three cases selected are presented in section 4.1: terrorist attack, solar eclipse and hurricane. The context of creating a Twitter IQ descriptive model is presented through the lessons learned from previous research and the three case studies timelines. Each case study includes the description of actions taken before the emergency, key elements of the incident and activities undertaken after the event. The aim was to understand the decision-making process better and define uncertainty challenges that emergency stakeholders had to overcome.

- ✓ **Step 2: The second step**, section 4.2, **described the observed uses of Twitter to reduce uncertainty from a production and consumption perspective**. Evidence was gathered from four decision-making processes related to the use of Twitter to reduce uncertainty:
    - (Section 4.2.1.) the decision to tweet;
    - (Section 4.2.2.) the decision to retweet or engage with content;
    - (Section 4.2.3) the decision of using Twitter information to document news;
    - And (Section 4.2.4) the decision of escalating information from Twitter to Emergency organisations

  For each of these, the benefits of using Twitter are described, case study evidence is presented, and challenges and decision-making solutions are discussed.

- ✓ **Step 3: The suitable identification of the unit of analysis.** Section 3.2.3 defined the required unit of analysis traits for this research. The selection of participants (Subject-Matter Experts) had to address critical characteristics about their social media experience for emergency management and their role within the case studies (i.e. evidence collected of at least one decision-making outcome using Twitter). Section 4.3 describes the interviewees' appropriateness and evaluates their internal and external validity for this research.
- ✓ **Step 4: Identification of probes.** For the correct implementation of the Critical Decision Method (CDM), a researcher must identify specific probes to elicit knowledge from Subject-Matter Experts (SMEs). Section 4.4 outlines the probes describing the rationale for their selection, case study context and level of uncertainty associated with the situation. All of them were rumours identified and evaluated by at least one decision-maker interviewed.
- ✓ **Step 5: Identification Dimensions of Information Quality (IQ).** Through data triangulation from case studies sources in combination with the SMEs' input, section 4.5 describes the IQ dimensions relevant to the use of Twitter in decision-making in major incidents. This section addressed RQ2.
- ✓ **Step 6: Descriptive Model.** The last step aligned itself with operationalising the response of RQ3. It benefits from interviewees' answers while evaluating the

interconnection between the different IQ dimensions identified in step 5. Furthermore, the researcher establishes IQ conceptual relationship to assess Twitter IQ. Section 4.6 provides the reader with a description of these findings.

Step 1 and Step 2 inform RQ1. The information collated using steps 3 to 6 responds to research question 2 and research question 3. The chapter concludes with a summary of the main findings (section 4.7).

4.1. Case studies timeframe (August 2017)

A qualitative multiple case study approach was adopted (Yin, 2009) to better define the context required for developing a Twitter Information Quality (IQ) model. The selection of these case studies was opportunistic as emergency and disaster incidents are rarely *'predicted'*; but they satisfy multiple parameters related to the access decision-makers from different background, geographical areas (the USA and Europe) and type of emergency analysed. This section provides background information for the three incidents utilised. All of them took place in August 2017. Table 4-1 summarises their main traits. The first case study refers to the Barcelona Terrorist Attack (BTA), a man-made emergency in Spain. The second case study describes the solar eclipse (EC) in Oregon (USA) emergency-related incident, mostly with technological implications, that has a preparation phase of over two years. The last one is the natural emergency declared for the hurricane Harvey (HH) in Texas (USA). See section 3.2.2 for further information about the selection of the case studies.

ID	Interviewees identification	Name	Location	Type of Incident
1	BTA	Barcelona Terrorist Attack	Europe, Spain, Catalunya	Human causes Terrorist Attack
2	EC	Total Eclipse	USA, Oregon	Potential Technologic causes Eclipse. Fire in the area.
3	HH	Hurricane Harvey and Flooding	USA, Texas	Natural causes Hurricane Harvey. Consequent flooding

Table 4-1 Case studies Background information for case studies

Multiple sources of evidence were employed including Twitter feeds, news articles, and interviews to identify decision-makers and key decision-making points using Twitter as

a data source (see section 3.3.2). The next three sections provide background information of these case studies, including the definition of the incident under analysis and a timeframe of each incident. Section 4.1.1 provides the background of the Barcelona terrorist attack (BTA), section 4.1.2 summarises the Total Solar Eclipse (EC), and 4.1.3 describes the Hurricane Harvey (HH) case study.

4.1.1. Case study 1 – terrorist attack (Barcelona, Spain)

The first case study analysed is the Barcelona Terrorist Attack (BTA). During a terrorist attack, there is a fundamental need to acquire information to restore some sense of normality (Lachlan et al., 2009). Researchers have previously analysed the use of Twitter during this type of emergencies. Bartlett & Miller (2013) evaluated 112 papers related to the contribution of social media and its capabilities in the area of counter-terrorism. Examples of previous terrorist attacks analysed through Twitter data include Mumbai (India) 2011 attack researched by Gupta (2011) and Oh, Agrawal, & Rao (2011, 2013), Boston Marathon attack 2013 reviewed by Sutton, Gibson, Spiro, League, & Fitzhugh (2015), and 2013 Kenya terrorist attack analysed by Simon, Goldberg, Aharonson-Daniel, Leykin, & Adini (2014).

This case study focuses on decisions made during the Barcelona Terrorist Attack (BTA) using Twitter. This section describes the information of before, during and after the incident. Information gathered from Twitter, newspapers, overt observation, and interviews were used to build the incident timeframe. The Catalonian and Spanish Virtual Operation Support Team (VOST) were self-activated (Susaeta, Lane, Tondorf, & Tymen, 2017) and supported risk communication activities.

The 2017 Las Ramblas Terrorist Attack (Barcelona, Spain) occurred on the 17th of August 2017. Therefore, data collection focused on this period, which includes Wednesday, the 16th, to Friday, the 18th of August 2017, and it refers to three locations: Alcanar, Barcelona, and Cambrils (Figure 4-2).

Figure 4-2 Barcelona terrorist attack (BTA) map (Bolon et al., 2017)

The BTA was at least the sixth time in the past few years that assailants using vehicles as deadly weapons struck a European city (BBC Mundo, 2017a; Bolon et al., 2017). Similar attacks took place in March and June 2017 in London, on October 2017 in New York, on July 2016 in Nice, and on December 2016 in Berlin (CNN Español, 2017a; Schachtel, 2017; Shvartsman, 2017; Trevelyan, 2017). According to the global terrorist database from the Maryland University (USA), from 2004 until August 2017, a total of 47 attacks took place killing 618 people in Western Europe (Pereda Puñales, 2017). In this case, the Islamic State in Iraq and Syria (ISIS) claimed responsibility for the BTA (Burns, Burke, & Worden, 2017; Walsh, Bolon, & Karasz, 2017).

This event was utterly unpredicted, and consequently, it had a high level of uncertainty. While emergency organisations were prepared for a potential terrorist attack, the preparedness phase for this specific incident cannot be fully accounted for. Background information collected a posteriori (for example, the official report created by the Catalan police- Comissaria General d'Informació (2018)) enables the reader to understand better decisions made during and after the attack. This report also highlights the similarities of the BTA with previous terrorist attacks. The Catalan police described the similarities between the Barcelona attack with the Nice (10/07/2016), the Berlin

(19/012/2016) and London (22/03/2017) attacks, while the follow-up terrorist's actions in Cambrils (Tarragona, Spain) were similar to the London attack on 03/06/2017. This section describes the BTA timeline, including actions that led to the attack, Las Ramblas runover and the recovery process that followed up. Figure 4-3 (page 182) outlines the response timeline, and it is described as follows.

The United States of America Central Intelligence Agency (CIA) had alerted Spanish police about a potential attack in Barcelona (Baquera, 2017; La Prensa de Honduras, 2017b). The Ripoll[27] imam, who provided information to the Spanish secret service while he was in prison in 2014, was identified as the mastermind behind the terrorist attack (Minder, 2017). Terrorists had initially planned to rent a large truck to cause a catastrophic explosion but desisted as the driver did not obtain the necessary permission. Unable to rent the truck, they planned to load three vans with explosives (Oms, Montesinos, Velasco, Gallardo, & Polo, 2017). However, while preparing the explosives, their house in the small town of Alcanar exploded, killing two persons and wounding sixteen (Sànchez, 2017). Therefore, they went to plan C: the massive run-over. A posteriori analysis of the documents found at the explosion scene contained details of the outlined terror attack plans (Burns et al., 2017).

In 2017, Spain was in level four (of five) in the emergency scale for a terrorist attack. Accordingly, emergency organisations were prepared for a potential attack. As described by a Public Information Officer (PIO):

> ***BTA4:*** *Within the Ministry of the Interior[28], the communication manager of Mossos d'Esquadra, the Catalonia police, and I together with the head of communication of the department, we had been analysing other terrorist attacks in Europe, mainly, but also some in the United States in order to prepare a communication strategy just in case there was an attack in Catalonia. We did not prepare because we had information that one could happen, but because being on level four of five, it was a possibility.*

[27] Ripoll is a town in Catalunya (Catalonia, Spain)
[28] Ministry of the Interior (Ministerio del Interior) is a department of the Government of Spain responsible for public security, the protection of the constitutional rights, the command of the law enforcement agencies, national security, immigration affairs, prisons, civil defence and road traffic safety.

While the terrorist attack was unforeseen, emergency management teams had worked in advance to plan a potential terrorist attack in the city. They had identified key topics and detailed how the information would be presented to the public. As described by the PIO, the importance of Twitter for mass communication is such that it had to be part of any communication strategy designed.

> ***BTA4****: We have seen that social media, especially Twitter, had to be a key part of the strategy.*

On the 17th of August 2017, a white Fiat van veered off the road and into a crowd outside the Plaça de Catalunya metro station (Barcelona). Younes Abouyaaqoub, 22, drove a van into the busy La Rambla in the Spanish city, killing 13 people and injuring 130 others (Sánchez, Ibáñez, Vargas, Savall, & Jané, 2017). La Rambla is a famous tourist path in the city of Barcelona, Spain, passing through Plaza de Catalunya, the nerve centre of the city and the old port (Esparza, 2017a; Piérola, 2017).

Islamic State (ISIS) claimed responsibility for the attack. Figure 4-3 summarises the timeframe of the operative response. The attack occurred at 5 pm, and the terrorist fled the scene (BBC Mundo, 2017a, 2017b). Emergency responders and police arrived in the area to capture the perpetrators and attend to the injured (Blosse, 2017; El País, 2017a). The zone was in a lockdown leaving thousands of citizens trapped within the perimeter and a large number of tourist and citizens without access to their hotels and homes (DW, 2017; Herraz Ventura, 2017; VoaNoticias, 2017). At 6.30 pm, the police identified a second van presumed to be a getaway vehicle in Vic. At 7 pm, the terrorist protocol was activated in Catalonia and the *'jaula'* (*'cage'*[29]) operation in Barcelona city to capture the terrorists (Sánchez, Vargas, et al., 2017). Thirty minutes later, a man was killed when he attempted to drive through a police roadblock in the town of Sant Just Desvern, on the outskirts of Barcelona (La Prensa de Honduras, 2017a; C. Moore, 2017). By then, the Catalonia police (Els Mossos) had access to the van hire information, and they were actively looking for the named driver as the main suspect. At 8 pm, he was arrested after

[29] Translated from Spanish to English: jaula = cage

turning himself in. He said that his passport and ID were stolen and that he played no part in the attack (Cortés & Sáiz-Pardo, 2017). At 9.30 pm a second suspect was arrested.

On Friday at 1 am, the terrorist team perpetrated a car attack in Cambrils, 70 miles to the south of Barcelona (Bolon et al., 2017). Attackers, who wore what appeared to be explosive belts, drove an Audi A3 car into pedestrians and then knifed six civilians and one police officer (BBC Mundo, 2017b; Del Ser, 2017). Police killed four alleged terrorists and injured one who died as a consequence of his wounds (Sini, 2017; VoaNoticias, 2017).

Between 8.30 am and 9.45 am, the police arrested a third person in Ripoll, and they identified the right van driver (Oms, Montesinos, et al., 2017). At 11.30 am, the overall death toll was 14 citizens. By Friday night, five killed in Cambrils were named. The police were still hunting three suspects.

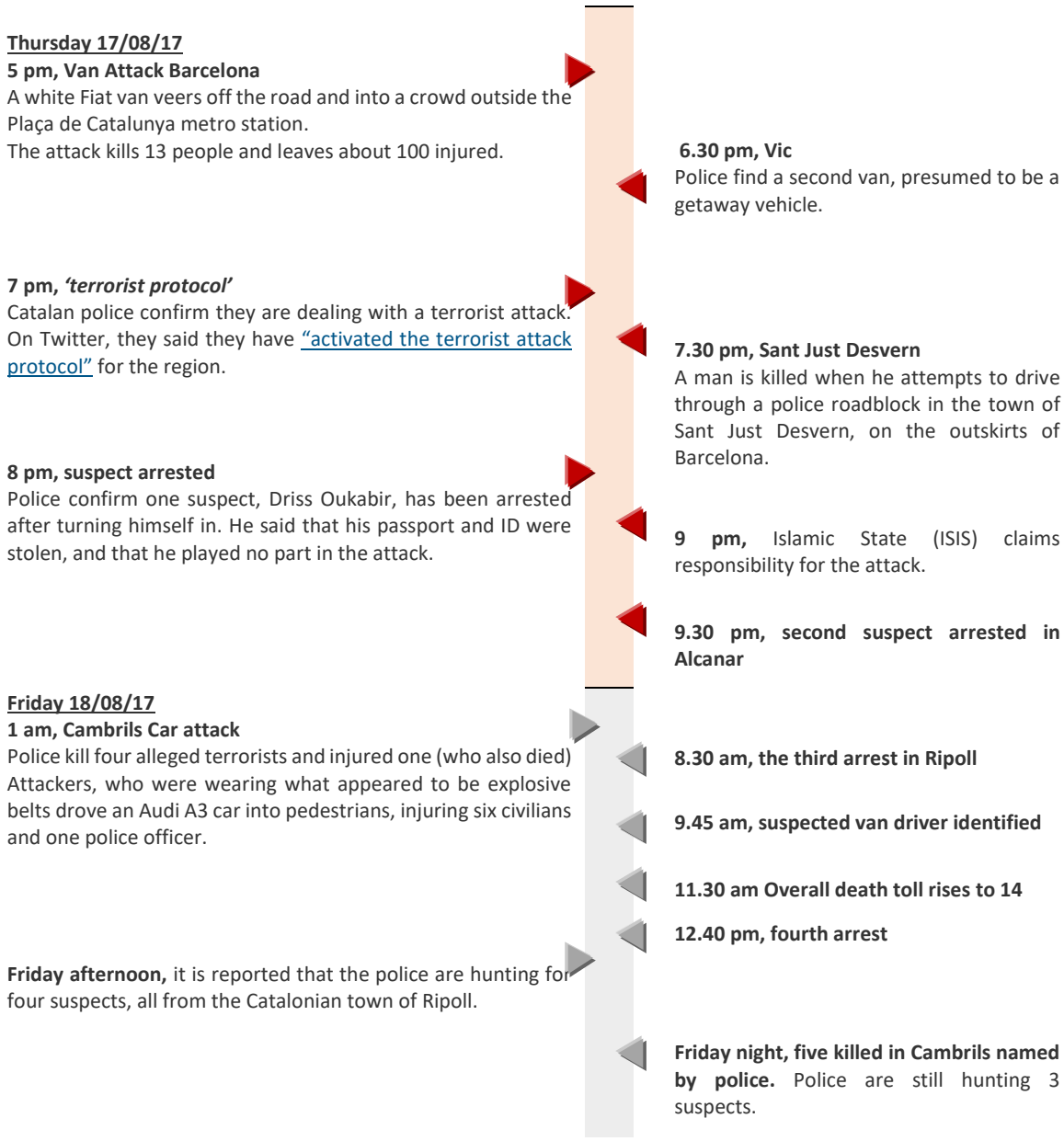


Figure 4-3 Barcelona terrorist attack response timeline

Following the terrorist attack, BTA, and the operation to capture the terrorist attack, citizens and emergency responders started the recovery phase. Injured and family of victims were attended to in hospitals and different points of the city. Psychological support was also made available to victims and family members (Oms, Montesinos, et al., 2017).

Three days of mourning were declared by the government of Catalonia (Cliff, 2018) and bereavement acts took place in Plaza Catalunya where attendees shouted: '*no tenim*

por' ('We are not afraid') [30] (Robinson, Burke, & Hawken, 2017). Politician, citizens and emergency responders alike attended bereavement acts. Additionally, they used Twitter to condemn the attack. Cities across the world also paid respect to Barcelona victims using their landmarks (CTVnews, 2017).

Four days after the run over, the driver was shot dead (Del Ser, 2017; Esparza, 2017b). The police killed Younes Abouyaaqoub on the 21st of August 2017 (Comissaria General d'Informació, 2018).

4.1.2. Case study 2 – solar eclipse (Oregon, USA)

The second case study refers to the 2017 total solar eclipse observed from Oregon. While a solar eclipse is not per se an emergency, the researcher found that emergency stakeholders organised themselves as they were responding to one. The potential cascading events derived from a large population attending to an eclipse (e.g. health implications for direct solar observation, man-made and technical fires, traffic jams, limited access to basic goods) prompted risk communication and situation awareness requirements before, during and after the incident.

A total solar eclipse occurs once every 12 to 18 months when the sun with a diameter 400 times wider than the moon's but is 400 times farther away is blocked by this satellite (McMullan & Woollaston, 2017) casting a shadow onto Earth (Craig, 2017). The case study focuses on the 2017 Oregon Eclipse (USA) which occurred on the 21st of August 2017. The first state within the Path of Totality (100% darkness) was Oregon. The eclipse passed over nearly 100 cities and towns in Oregon (Campuzano, 2017a) and over a space of 112 kilometres wide in 90 minutes (Beawiharta, 2017; Fernandez, 2017; Infobae, 2017a). This solar eclipse was the first total eclipse to traverse the United States of America (USA) in 99 years. It was the first USA coast to coast eclipse, Oregon to South Carolina, since 1918 (D. Adams, 2017; Freedman, 2017; Infobae, 2017b; Reuters, 2017a; V. Strauss, 2017) and the first USA total eclipse since 1979 (Hetter, 2017). This incident generated more than 20,000 events in more than 80 countries (Europa Press, 2017). According to the USA National Aeronautics and Space Administration (NASA),

[30] Translation from Catalan to English: 'No tenim por' = 'We are not afraid'

approximately 500 million of people in the USA could see first-hand the eclipse (Infobae, 2017a). The next total solar eclipse in the USA mainland will occur on April 8th, 2024 (Wall, 2017).

A limited body of research has been found in the area of social media usage for eclipses. Tsytsarau et al. (2014) studied the dynamics of news events and their relation to changes of sentiment expressed online. Their research included, amongst other events, a solar eclipse event and sentiments expressed on Twitter.

The 2017 Solar eclipse (EC) was a natural predicted incident. The path of totality (Figure 4-4) was around 70 miles wide (McMullan & Woollaston, 2017; Wall, 2017). At 10:19 am (Pacific Time), the eclipse started in Madras, Oregon (Boyle, 2017; Infobae, 2017a). Over 588 events were planned within the state of Oregon to welcome this event (incident from now on), and a large number of out-state visitors were expected to visit the area (VOST Oregon, 2017f). Accordingly, emergency responders were on standby to support traffic and emergency-related incidents as required.

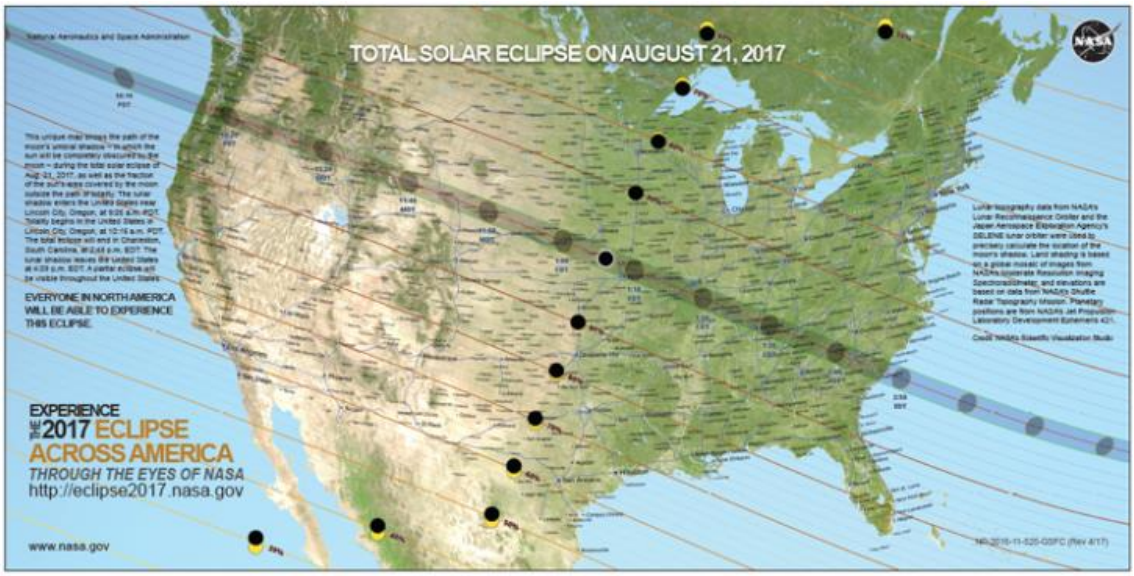


Figure 4-4 Solar eclipse's (EC) trajectory in the USA (Source: NASA, 2017)

This case study provides information about the three incident phases (pre, during and after the eclipse); however, a more significant number of decisions and Twitter information was found before the incident. This event was predicted years in advance, and therefore, the researcher was able to organise better the preparedness and observation of any potential emergency during this incident. The opportunity to observe

the use of social media for decision-making from inside, as part of a Virtual Operation Support Team (VOST), was presented to the researcher through the network built on Twitter. Therefore, this case study benefited from access to informal communication channels (Skype), the information collated in the VOST Workbook and two team's reports. Additionally, information gathered through observation, tweets' analysis, and newspaper articles facilitated integrating the Critical Decision Method (CDM) to this case study.

This section describes the Oregon Solar Eclipse (EC) timeline, including its preparation, the *'2 minutes and 40 seconds'* event and the activities that followed the incident. Figure 4-5 describes the summary of these activities.

A large number of visitors were expected in the totality path within Oregon. During the preparedness, multiple journalists provided updates to citizens about emergency management activities taking place. For example, they reported that Lysa Vattimo (EC facilitator) spent the two previous years coordinating the town's planning efforts with more than 50 local, state and federal agencies (Beawiharta, 2017). According to Andrew Phelps, director of the Office of Emergency Management:

> *'state officials have never planned for an event quite like this*' (Schmidt, 2017).

The Oregon emergency coordination centre geared up to coordinate activities before, during and after the eclipse (Beawiharta, 2017). Within the Oregon estate, Public Information Officers (PIOs) and official sources representatives planned actions to share information with citizens and stop rumours or the spread of misinformation (Schmidt, 2017). With the purpose of monitoring and reporting social media activity to the Oregon Office of Emergency Management, the VOST Oregon team was activated on Friday, 17th of August 2017. The main objective was to monitor and report newsworthy messages posted on social media and the Internet. They were asked to keep an eye on social media for post related to the eclipse in the area of Oregon and reported any rumours and hot information. Event journalists, citizens, volunteers and other emergency management organisations used Twitter to share, communicate and access information.

For this purpose, several hashtags were pre-defined and promoted by official sources before the event started, including #OREclipse and #OREclipse2017. Additionally, more generic hashtags were also monitored, including #Eclipse and #Pathoftotallity.

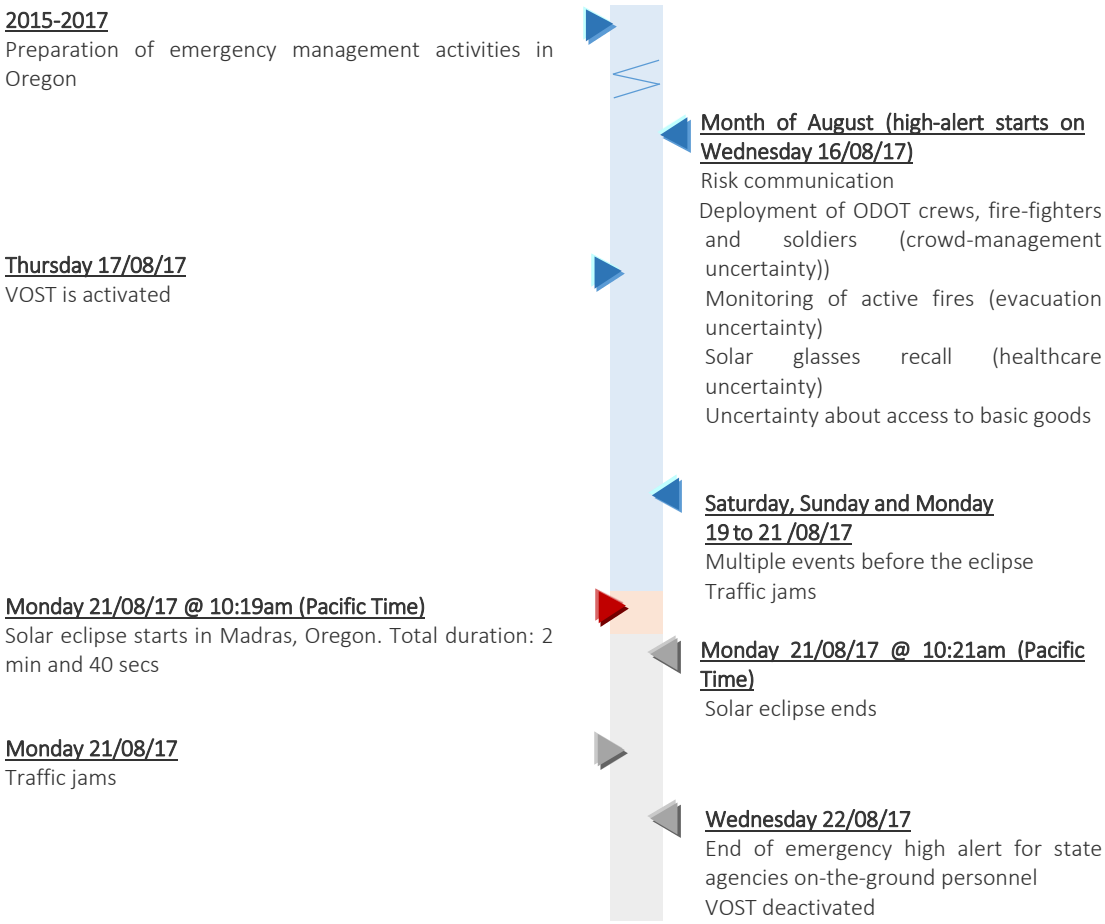


Figure 4-5 Solar eclipse in Oregon timeline

State agencies began their on-the-ground eclipse work on Wednesday and remained on high alert until August 22nd (Schmidt, 2017). Additional human resources were put on standby by Oregon Gov. Kate Brown, including six aircraft and about 150 soldiers and airmen (Boyle, 2017). Oregon Department of Transportation (ODOT) crews (KTVZ, 2017) and fire-fighters (Beawiharta, 2017) were posted at strategic locations.

The Lincoln County Emergency Management prepared its team for a range of potential hazards according to its likelihood, including wildfires, hazardous material transportation accident and even a distant tsunami (L. Tobias, 2017). The biggest concerns were traffic jams (Ma, 2017; Schmidt, 2017), accidents (L. Tobias, 2017),

change in tides (Hendricks, 2017; L. Tobias, 2017), gas stations and food store shortages (Boyle, 2017), and crowd management and fires (Beawiharta, 2017).

Crowd management and transportation

Visitors' number projected rounded the millions of tourists (Kavanaugh, 2017a; Ma, 2017; Schmidt, 2017) with between 100,000 to 250,000 in Madras (Boyle, 2017; Press, 2017). Salem, as the state capital, was also expected to be busy (Oliver, 2017). Multiple events took place in Oregon including Oregon Solarfest, Oregon Eclipse at Big Summit Prairie, Moonshadow Festival in Prineville, Pandyfest near John Day, Mystery of the Eclipse Explained in Baker City, the Total Eclipse Festival near Baker City and the Oregon Star Party at Indian Trail Spring (Boyle, 2017). Some of them brought speakers, artists, workshops, and musical acts together (Auerbarch, 2017; Hallenbeck, 2017; V. Lee, 2017; Scott, 2017). For instance, The Oregon Solarfest draw together representatives from NASA, Lowell Observatory and other astronomical organisations (Boyle, 2017). According to the VOST Workbook a total of 588 events, some of them with camping facilities, were scheduled to take place before /during the eclipse. All events' organisers did not report their expected attendance, but according to VOST, at least 140,465 participants were expected in the region for these events. Oregon Emergency State Department projected an influx of 1 million visitors.

Traffic jams were anticipated before, during and after the event as the road infrastructure is limited in the area (e.g. two lines roads) (Boyle, 2017). Authorities representatives warned that the eclipse could mean up to a week of congestions on roads (Ma, 2017). Motorists were advised to travel early to avoid watching the eclipse from their cars (KTVZ, 2017).

The Oregon Department of Traffic (ODOT) agreed to regularly update the local press, www.TripCheck.com, 511 phone number[31], their Facebook and Twitter social media accounts (KTVZ, 2017; Ma, 2017).

[31] 511 phone number provides travel information in Oregon. The information is the same as displayed on www.TripCheck.com (Oregon Department of Traffic's website)

On Thursday, the first traffic jam was reported in the U.S. Highway 26 for 20 to 30 miles for one single event, and photos of the traffic jam were posted on Twitter by the Oregon State Police (Ostrower, 2017; Zorthian, 2017).

While traffic before the eclipse was expected to be an issue, authorities warned about after the event situation (KTVZ, 2017; Ma, 2017). Emergency organisations were expecting a gridlock and cities lockdown after the event as solar eclipse watchers could leave the event minutes after the show ended (Austin, 2017; Beawiharta, 2017; Schmidt, 2017). Fears were also shared related to a last-minute plan to change locations due to the weather forecast (Press, 2017).

Some people expected to see the eclipse from the air. Alaska airlines planned a flight to allow passengers to see this event (Campuzano, 2017b). Additionally, the Madras airport (Oregon) expected 400 planes to land in their facilities (Campuzano, 2017b). Before the eclipse, a small aeroplane crashed near the Madras airport and VOST members were requested to check on Twitter for any evidence of a fire starting in the area due to this accident. A fire brigade was sent to the area shortly to minimize the risk and assess the situation.

Fire

The eclipse took place during the peak wildfire season (Press, 2017). Oregon State Parks launched a state-wide open-flame ban beginning Wednesday, prohibiting all campfires, tiki torches and candles (Schmidt, 2017). A priority for emergency management organisations was to prevent further fires. First, responders had planned for months evacuation activities based on the worst-case incident (i.e. gridlocked roads for fire engines) (Beawiharta, 2017). During the preparedness phase, several active fires were in the area, and many visitors were expected. In fact, Oregon State was managing 12 fires at the time, with four of them near the path of totality (Schmidt, 2017). VOST was requested to review information about a large group of Japanese tourists who were rumoured to require evacuation as they were close to an active fire.

Supplies and accommodation

Shortage of water and food supplier was expected (Ma, 2017); therefore, locals were advised to stock up on water, groceries and gasoline (Boyle, 2017; Press, 2017). The eclipse was seen as a business opportunity by many and prepared accordingly (Boyle, 2017; Hetter, 2017). Hotel rooms were sold out near the 70-mile-wide zone of totality, and many people were planning to camp (Boyle, 2017). Local shops, petrol stations, banks, and hospitals were also preparing for visitors' influx (Press, 2017; L. Tobias, 2017). It was projected that solar eclipse could impact the economy in the tens of millions (Boyle, 2017).

Solar glasses were also a business opportunity for many companies. Multiple chains (e.g. Kroger, Walmart, REI, Toys "R" Us, Lowe's, Best Buy and 7-Eleven) and websites sold them (Guarino, 2017; Tompor, 2017) while other businesses used them as marketing material. The eclipse had good weather projections (Schmidt, 2017), and people were advised to source safety glasses well in advance. A leading supplier of solar lenses, Arizona-based Thousand Oaks Optical, reported that his company had sold enough of its filters in that year alone to produce roughly 100 million pairs of glasses (Gorman, 2017).

The importance of wearing glasses was noted by different journals (e.g. Lafrance, 2017; Watts, 2017). Concerns were expressed about health issues derived from direct solar observation. Before and after a full solar eclipse, light radiation could affect viewers' eyes (Lafrance, 2017), causing eclipse blindness or retinal burns (Tompor, 2017). NASA recommended using U.S. manufactured glasses from one of the following companies: American Paper Optics, Rainbow Symphony, Thousand Oaks Optical, and TSE 17 (Lafrance, 2017). The use of fake glasses was warned by many (e.g. Gorman, 2017; Tompor, 2017; Wall, 2017) as suitable eclipse glasses should adhere to the ISO 12312-2 international safety standard and not be older than three years (McMullan & Woollaston, 2017; Wall, 2017). Free glasses were provided in libraries (Guarino, 2017; Tompor, 2017) some of them funded by Google (McMullan & Woollaston, 2017). For those who were unable to attend, the eclipse was streamed online through websites and social media by multiple organisations, including NASA and CNN (McMullan & Woollaston, 2017; RedUsers, 2017).

The event was so unique that some business and schools planned to close for the day (Boyle, 2017; V. Strauss, 2017) and even an electric company was making previsions for an expected change of demand in their supply network (Broussard, 2017). Due to the arrival of people, it was expected a limited phone coverage during the incident in some areas (Ma, 2017; Schmidt, 2017; L. Tobias, 2017) as cellular towers could be crippled by the volume of people texting, calling and posting photos (Beawiharta, 2017).

The eclipse took place around 10 am with a duration of 2 minutes and 40 seconds in Oregon (Ernst, 2017; Infobae, 2017c). Weather reports suggested clear skies; however, fear of some wildfire smoke covering some Oregon areas was stated (Vance, 2017). People packed city parks and crammed them into campgrounds for the event (Kavanaugh, 2017b). The solar eclipse was watched by 260 passengers on a Virgin Atlantic flight and by millions of people around the world (Godfrey, 2017).

The eclipse lasted 90 minutes over USA soil (Ordoñez, 2017). Multiple journalists informed about Mr. President Trump watching the eclipse without glasses from the White House (Astorga, 2017; Cowen, 2017; Diario Perú21, 2017; Ghose, 2017; Huffingtonpost, 2017; Kirchner, 2017; Lachenal, 2017; Molloy, 2017; Ortiz, 2017; D. Perry, 2017; Wilts, 2017). They used Twitter images to back up their story. The difficulties of finding glasses were reported on the day, and VOST monitored some glasses recalls made by companies who previously distributed them for free as part of their marketing activities.

The solar eclipse was streamed live through different websites and platforms (Amos, Rincon, Matza, & Baker, 2017; Becker, 2017; CNN Español, 2017b; NBCNews, 2017; Ruiz, 2017; Today, 2017; Wells, 2017). The researcher followed the eclipse using Periscope on Twitter. Millions live-streamed the event or loaded photos snapped on smartphones to social media (Kavanaugh, 2017b).

The eclipse was prepared for over two years as a major emergency; however, it took place without any significant complications. The selection of this case study is deemed suitable as it showcases uncertainty before the incident and how information inaccuracy can impact risk communication preparedness.

Some business owners questioned the number of visitors projected as they did not perceive the influx of visitors estimated (Schmitz, 2017). Furthermore, there were no massive traffic jams before the eclipse; however, as predicted, some took place after the event as people tried to leave at the same time (Kavanaugh, 2017b; Schmitz, 2017). VOST stayed active after the eclipse to monitor traffic updates and report any accidents. Drivers experienced traffic delays in the road U.S. 97 near Madras and on I-5 between Salem and Portland (Kavanaugh, 2017b). Aside from a few traffic jams, the eclipse mainly came and went uneventfully (Lehman, 2017). No human-caused wildfires were reported before, during or after the eclipse. In fact, '*the Oregon Department of Forestry reported just 23 new fires from Aug. 18 to Aug. 23, burning less than 22 acres. Typically, Oregon could have expected 32 fires during that time period*' (Schmitz, 2017).

4.1.3. Case study 3 – hurricane (Texas, USA)

The final case study is the Hurricane Harvey and following cascading events (i.e. Texas Flooding). A hurricane is a type of storm that is formed over tropical or subtropical waters. They are classified by the Saffir-Simpson Hurricane Wind Scale, a 1 to 5 rating that determines the property's potential damage. The Hurricane's season starts on June 1st and concludes on November 30th, even if they can occur any time (National Oceanic and Atmospheric Administration, n.d.). Hurricane Harvey was the first major hurricane to make landfall in the USA since 2005 (Mooney, 2017) and the strongest hurricane to hit Texas since 1961 (Patrick, Schulz, Guillote, Dickson, & Decker, 2018).

While the scientific community usually predicts this type of emergency, the impact on different areas is in its majority uncertain for citizens and emergency responders. Many scholars have researched the use of Twitter during hurricanes. For example, Hurricane Sandy was analysed by Lachlan, Spence, & Lin, (2014) and Gupta et al., (2013), Hurricane Irene by Freberg et al., (2013), and Hurricane Sandy by Lachlan et al., (2015). Areas investigated included evaluating fake images posted on Twitter during Hurricane Sandy (Gupta et al., 2013b).

The case study presented by the researcher focuses on understanding the use of Twitter for decision-making. This section describes the information of before, during and after the incident. However, due to the intrinsic properties of this emergency type and its

devastating consequences, a larger volume of information was found in the after-emergency phase, therefore during the recovery. Information gathered from Twitter, newspapers, overt observation, and interviews were used to build the incident timeframe.

Public Information Officers (PIOs) collaborated with press and volunteer organisations to manage information during this disaster. The Virtual Operation Support Team (VOST) of Florida was activated and acted as the coordinating team for other supporting VOSTs including VOST Oregon. The researcher had established contact with the Oregon team in the case study 2 and interviewed members active in the Hurricane Harvey emergency.

As described in Chapter 3, multiple sources of evidence were used, including interviews, informal communication channels (Skype), reports, virtual observation, tweets analysis and newspaper articles. The researcher used this information to define this case study. Information sources permitted to gather a transversal understanding of the situation through evidence of citizens, journalists, emergency responders and PIOs.

Figure 4-6 shows the Hurricane Harvey path from its origin as a tropical depression to become a major hurricane. This image was shared in the National Hurricane Center Tropical Cyclone Report on Harvey. Hurricane Harvey (HH) was born as a tropical wave on the 14th of August on the African coast. It travelled through the Atlantic sea direction to the United States and developed at the east of the Windward Islands (Blake & Zelinsky, 2017). It passed over the Caribbean Sea from the 17th to the 23rd of August. On the 22nd, Harvey was downgraded to a tropical wave, entered the Gulf of Mexico; however, the warm waters made him become a hurricane on the 24th of August. It reached a category four on the Saffir-Simpson and landed near Rockport on the Texas coast on Friday the 25th of August (Patrick et al., 2018; Yeomans, 2018).

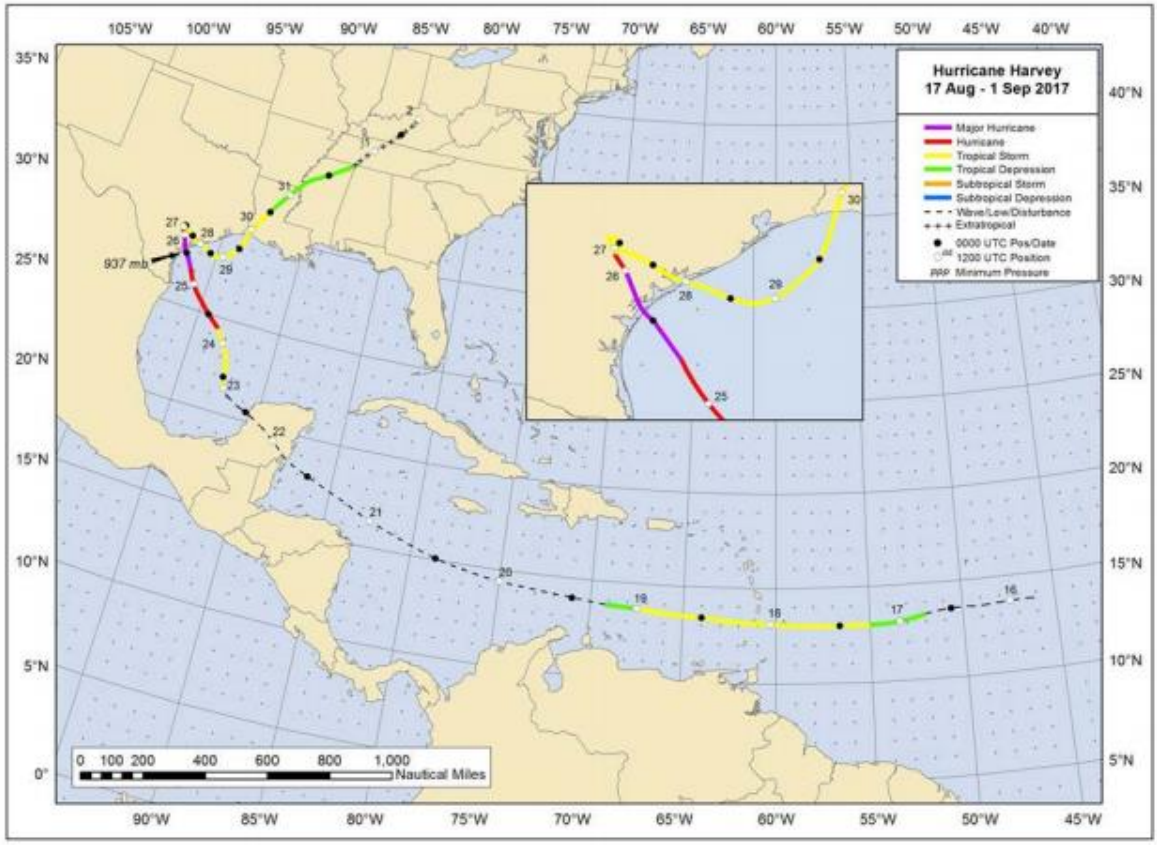


Figure 4-6 Path of Hurricane Harvey (HH) (Blake & Zelinsky, 2017)

The hurricane brought winds of 215 kilometres per hour and around 3.5 meters of water in some areas (BBC Mundo, 2017c). It was projected that the rainfall would be approximately 100 centimetres of water in the area, including Texas City, which tends to get flooded (Reuters, 2017b). On the 26th and 27th, Harvey brought heavy rain inland. The hurricane was downgraded to a tropical storm on Saturday, 26th (Katzowitz, 2017; Milstein & Rosenbaum, 2017). Tornados followed the hurricane, further damaging the area (ABC, 2017; Jervis, May, & Stanglin, 2017; Phipps, Levin, Lartey, Weaver, & Russel, 2017). Harvey brought flooding to Texas even near the coastal areas and Houston (BBC Mundo, 2017c; Hall, 2017). The waterfall required to release water from damps, increasing the flood level in the area (Hicks & Selby, 2017; Phipps et al., 2017).

On the 28th, Harvey diverted its course offshore. The downgraded tropical storm landed in Louisiana with heavy rainfall on the 30th of August. Figure 4-7 summarises the Hurricane Harvey (HH) timeframe.

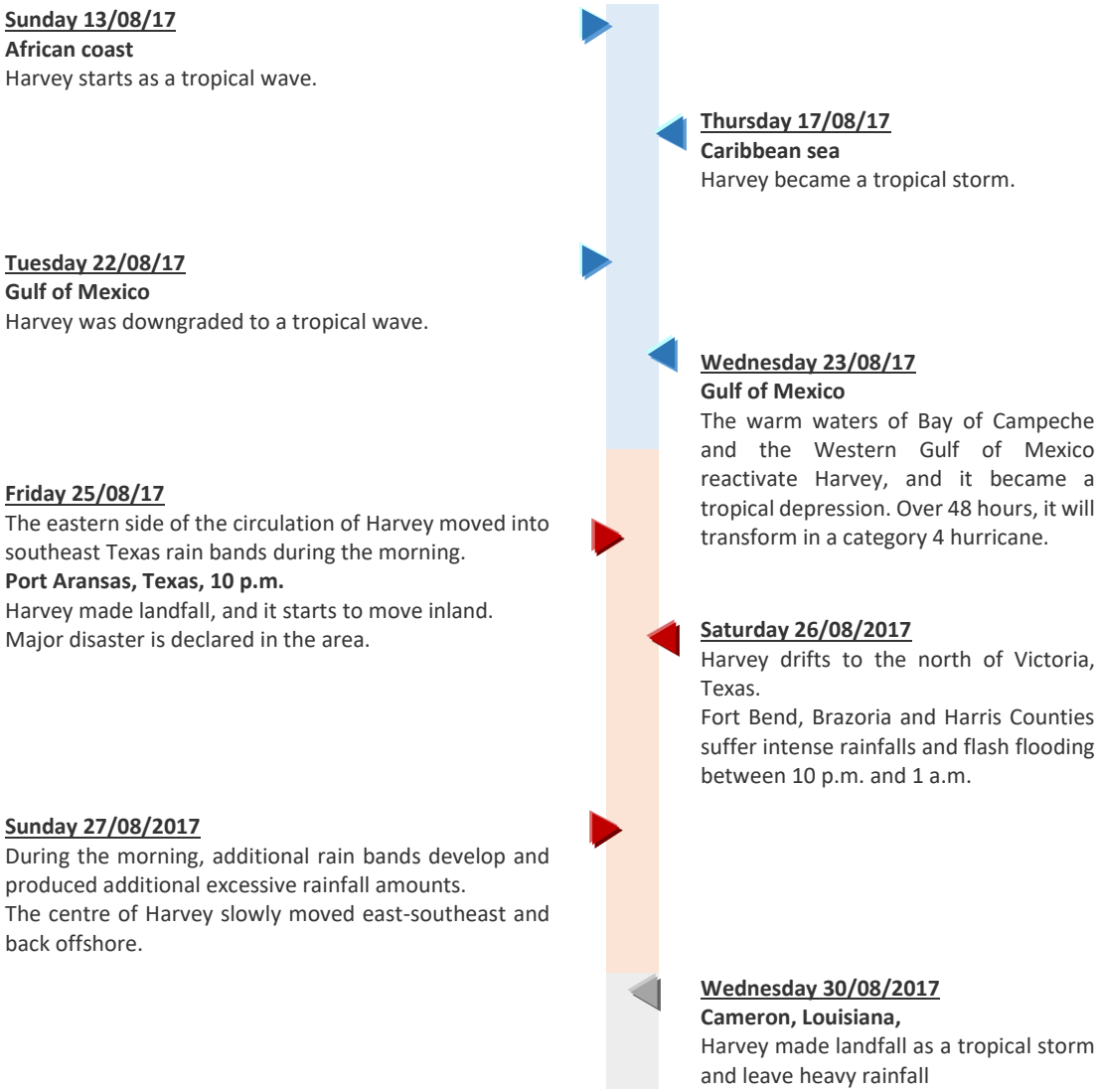


Figure 4-7 Hurricane Harvey timeline (Adapted from Blake & Zelinsky, 2017)

The National Hurricane Center had previously advised of the potentially devastating impact of Hurricane Harvey in Texas, mostly in the South (Moraes, 2017). It was expected that some swaths of South Texas would be *'uninhabitable for weeks or months'* (Moraes, 2017).

Accordingly, the Federal Emergency Management Agency (FEMA), the Texas Division of Emergency Management, local agencies, non-profit and faith-based organisations, and the private sector were activated to respond to this emergency by pre-positioned supplies and personnel in the state. After Mr. President Trump issued a major disaster declaration in the area on August 25th, around 31,000 effectives (FEMA employees,

other federal agencies, and the National Guard) were deployed to assist during and after the hurricane (FEMA, 2017). Additionally, the governor of Texas, Greg Abbott, activated three thousand national guards (Reuters, 2017b).

During the response phase, 911 lines[32] became quickly collapsed, receiving on Wednesday more than 1,000 calls per hour (Hicks & Selby, 2017; Homer & Reux, 2017; Williams, 2017). Therefore, an increase in pleas for help was seen in social media.

> *'Art Acevedo, Houston's Chief of Police, [stated] social media tools like Twitter, Nextdoor, Periscope and Facebook became a 'de facto 9111 system' during the crisis — playing a 'huge role' in his department's response to Harvey and certainly saving lives during the late August'* (Keen, 2017).

Emergency managers used social media to support risk communication and rescue efforts. For example, the Houston Office of Emergency Management and the Harris County Sheriff's Office used Nextdoor[33] and other related platforms to post emergency information and communicate directly with residents (L. Silverman, 2017; Webb, 2017). However, emergency managers warned people not to only rely on social media for help (Kaser, 2017; L. Silverman, 2017; Stelter, 2017).

Hurricane Harvey (HH) devastation was evident after the incident. Infrastructure was affected, including a chemical factory that registered an explosion (CNN Español, 2017c). The damage amounted to $126 billion and a total of 68 fatalities (Feuk, 2018; Insurance Journal, 2018). Researchers found that 81% of reported deaths were due to drowning, and most of them were outside the habitual flooding zones (Union, 2018; Wright, 2018). In fact, nearly 10,000 people had to be rescued from Texas and Louisiana (Garcia, 2018) even though the danger of floods were reported in advance (e.g. Jervis, May, & Stanglin, 2017b; Kasana, 2017b). Emergency organisations and spontaneous volunteers managed evacuation activities. Organisations asked citizens with boats to support rescue

[32] Universal emergency number for everyone in the United States of America (USA)
[33] Nextdoor is a hyperlocal social networking service founded in 2008 that allows trusted connections between neighbours to exchange information, goods, and services. Website: https://nextdoor.com/

operations (Ciaccia, 2017) as response efforts were overwhelmed. Examples of evacuation activities coordinated online include:

- Twitter account @HarveyRescue, created a Google Doc for people to enter their address and any details of their request for help (Newcomb, 2017)
- Facebook group Hurricane Harvey 2017 - Together We Will Make It: coordinated unofficial volunteer groups to rescue people (L. Silverman, 2017)
- Nextdoor app was also used to coordinate rescues (Joseph, 2017)
- The app Zello was used by first responders on the ground to radioed in their locations, and dispatchers coordinated rescues (Baley, 2017)
- App to rescue people (Young, 2017)
- Houston Harvey Rescue is an open forum where people put in their addresses or the addresses of someone they knew who needed rescuing or some other kind of help (K. Sullivan, 2017)
- CrowdSource Rescue (CSR) — It allowed Houstonians and outside volunteer organisations such as the Cajun Navy to work hand in hand with public officials by posting, dispatching, rescuing, and updating rescue efforts across multiple platforms (Duffy, 2018)

The hurricane displaced more than 30,000 people from their houses (Erret, 2018). Several initiatives were set up to provide accommodation to people affected. For example, Airbnb allowed matching people seeking accommodation for free (Kasana, 2017). Different spaces were facilitated to host people, including the Houston convention centre (CNN Español, 2017c).

Food and water supplies were a primary concern after the hurricane. For example, 118,000 citizens in Beaumont (Texas) had no access to clean water (CNN Español, 2017c). Some people tried to make money from the situation by charging enormous prices for water and petrol (Young, 2017). Nevertheless, the overall society reacted by supporting affected citizens after the hurricane. For example, different celebrities and

personalities announced donations to support victims (e.g. Bosilkovski, 2017; Phipps et al., 2017).

Additionally, crowdfunding initiatives were set online (e.g. Young, 2017); however, a warning was made to citizens to be wary of seeing where they donated money as several malicious funding requests were detected (Associated Press, 2017; Martinez, 2017; Wasik, 2017). Within this context, VOST Oregon was requested to monitor the Internet and identify potential misleading requests. An internal report from VOST identified 177 tweets with the hashtag #harveydonations from August 28 (02:40 AM) to August 31 (06:41 PM) with a potential reach of 1,382,715 users (Twitonomy VOST Oregon, 2017). One of the most retweeted tweets shared an article from the New York Times, which included a list of charitable organisations and described how to avoid a scam when donating (Caron, 2017). Recovery activities were on-going for months until citizens could achieve a sense of normality. In April 2018, The Federal Emergency Management Agency (FEMA) in the United States of America and The State of Texas recognised the efforts of VOST, including the researcher by awarding a certificate of appreciation (see appendix 7).

4.1.4. Information requirements: case studies comparison

While the three case studies are different in nature, they share commonalities concerning emergency stakeholders' information requirements. This section cross-compares the three case studies described while focusing on information needs and uncertainty elements identified. Findings define the incidents under analysis, facilitate the task of gathering and recording the incident's account, and support the construction of the different incidents' timelines. These are steps of the adapted Critical Decision Method (CDM) interviews described in section 3.3.3.

The three case studies' analysis provided evidence of descriptive tweets composed by Public Information Officers (PIOs), Virtual Operation Support Team (VOST) members, journalists and witnesses /victims. Tweets providing information about the incident and cascading events were shared to update the population as part of the stakeholders' role. As described by a Public Information Officer (PIO):

> ***BTA4:*** *[The objective of] Our department of civil protection was to communicate information.[…] Basically, we did all this from the perspective of avoiding additional emergencies. Therefore, the no information, the no ability to explain what happened or not having the information about the main events, it is to say, the attack and there is one or more terrorist, number of injured, underground lines are closed, you cannot be on the street, avoid main streets, etc. it could cause new emergencies.*

The number of informative tweets posted by emergency organisations varied accordingly to the type of event and the phase. For instance, messages in the Barcelona terrorist attack (BTA) were more abundant after the emergency. In this case, Twitter was used to update emergency stakeholders concerning the on-going operation to capture the terrorists. On the other hand, the Oregon Eclipse (EC) had a more significant number of tweets posted before the eclipse. Tweets described where and when to see the eclipse, and included information about other incidents in the area (i.e. wildfires) which were in the response phase. As outlined by the Oregon Virtual Operation Support Team (VOST) monitoring report, social media was used to provide updates related to *'fuel shortage anxiety, traffic anxiety and emerging traffic problems'* (VOST Oregon, 2017b, p. ID 1). Enquiries related to active wildfires in the area were also reported. For example, *'One Hot Issue currently – Wildland fire #MilliFire FS Rd 16 & Peterson Ridge Trail System now closed. Campers in 3 Creeks area will be moved'* (VOST Oregon, 2017a, p. ID 14). In the hurricane (HH) case study, many tweets were found during all emergency phases. However, cascading events derived from the hurricane such as Texas flooding prompted a large volume of information posted online after the hurricane. Furthermore, in comparison, the recovery phase of this incident was longer that then other two described as economic and human loses were also greater.

Table 4-2 summarises the information needs identified through the three case studies. Five broad categories were recognised: (1) the magnitude of the emergency and the events unfolding; (2) the number of injured and casualties; (3) the unknown related to crowd management and people movement; (4) access to basics goods; and (5) access to governmental and volunteers support. This list does not aim to be exhaustive, but it illustrates information requirements and uncertain information detected during the three case studies' analysis.

Information needs / Uncertain items	BTA	EC	HH
The magnitude of the emergency and associated events	✓ Terrorist level ✓ Location of terrorist ✓ Potential new attack	✓ Number of attendees ✓ Fires in the area	✓ Hurricane Path and magnitude ✓ Flooding ✓ Infrastructure impact ✓ Residential / Property impacted
Number of injured and casualties	✓ People impacted in Las Ramblas ✓ Cambrils attack ✓ Missing people	✓ No victims	✓ People impacted by Hurricane ✓ People affected by flooding ✓ Missing people
Access to basic goods		✓ Glasses ✓ Petrol ✓ Food	✓ Petrol ✓ Water ✓ Food
Access to governmental and volunteers support (return to 'normal' life)	✓ Translators ✓ Psychological support ✓ Blood donation ✓ Accommodation		✓ Access to shelter ✓ Insurance ✓ Donations
Crowd management	✓ Re-opening of public transport ✓ Access to homes and hotels near Las Ramblas	✓ Camping ✓ Access routes (traffic jams)	✓ Evacuation notice ✓ Evacuation routes ✓ Rescue operations

Table 4-2 Information requirements: Case studies cross-comparison

As described in the above table, in the three case studies, emergency stakeholders reported the need for information to determine the emergency's magnitude. While the scientific community predicted hurricane Harvey and the Eclipse, the Barcelona terrorist attack was unexpected. In turn, during the first few minutes after the attack, emergency stakeholders were unsure about the cause. The researcher observed several tweets posted by citizens expressing their fear and asking about the event and its likelihood of being a terrorist attack. Initially, official sources reported that an incident had taken place; however, this was quickly challenged by mass media and citizens. Evidence was gathered of these moments of uncertainty and the evolution of the facts. As stated by an interviewee:

> ***BTA1****: If the official information does not talk about an attack if it does not say a terrorist attack… we cannot say a terrorist attack because we will be lying. If the first suspicious is an accident and then it evolves into a terrorist attack, then it is evident that the information is going to evolve.*

A different situation was encountered in the eclipse case study. This event was predicted years in advance. Authorities advised citizens to prepare ahead like a natural disaster (Press, 2017; L. Tobias, 2017). Therefore, citizens and emergency organisations were able to plan and allocate resources in advance. However, other incidents (e.g. fires, high tides) took place in the area simultaneously, impacting uncertainty levels.

Several active fires were in the zone days before and during the Eclipse in Oregon. Furthermore, weather conditions made it suitable for the start of fires by people camping before the eclipse or just by the touch of the exhaust of any car. In addition, people were advised not to take back roads as access to a dependable connection was unreliable. As described by Jennie Demaris, Lincoln County emergency manager:

> *'Cell phones won't be able to access maps because we only have so much bandwidth. Local cellular portals will be overwhelmed and may not be available to you'* (L. Tobias, 2017).

Furthermore, citizens requested information about the impact of the eclipse concerning technological devices such as mobile phones.

Similarly, Hurricane Harvey was predicted in advance. However, uncertainty related to the hurricane's strength and the expected damage was shared on Twitter and other media. As it can be appreciated in the Hurricane Harvey timeline description (see section 4.1.3 page 194), a hurricane's evolution can change in a few hours by increasing or decreasing its magnitude from a tropical wave to a hurricane or a storm. The uncertainty is, therefore, associated with the phenomenon itself and activities surrounding the response and recovery.

The three case studies demonstrated that uncertainty about the magnitude of the event and associated events could impact different decision-making processes such as deciding to evacuate or types of actions taken to protect property. Information request increased before predicted events (i.e. hurricane and eclipse) and during the first few

minutes after unexpected emergencies (e.g. terrorist attack). Furthermore, incidents with casualties had a surge of information demand after the incident as family and friends enquired about their loved ones.

This information need was identified in the hurricane and terrorist attack case studies. In Barcelona, the number of injured and casualties was initially unknown, and citizens created a large number of tweets related to the victims. Tweets included requests for updates and images/videos of people missing, injured or dead. Multiple stakeholders stated the delay of information provided by official sources as the main cause of uncertainty. Furthermore, citizens and journalists challenged the official numbers given by emergency organisations after the attack increasing the number of tweets posted in the aftermath.

Official sources cited one dead while other sources (i.e. journalists and citizens) decided to share the number of 13 deaths which emergency organisations later confirmed. However, casualties' misinformation was shared by the press, not only using social media. For instance, RTE News (Radió Teilifís Éireann - Ireland's national Television) reported on television, *'thirty people are dead'* (Figure 4-8).

Figure 4-8 RTE News Barcelona terrorist attack victims update (Photo taken by the researcher)

The VOST group activated during the Barcelona terrorist attack made a substantial effort (9.20% of the tweets published in their account) to request citizens not to share images of victims. Images were shocking and spread fear. It was argued that photos could reach victims' families, creating despair reactions. Citizens were encouraged to let know their loved ones that they *'were safe'* using social media instead of using phone calls to avoid collapsing the network and reaching a more significant number of friends /family at once. The researcher observed that Facebook activated the *'Safety Check'*[34] functionality in the area to allow users to mark themselves as *'safe'* and notify their network.

While uncertainty about the number of people affected was also part of the hurricane case study, information enquiries were less evident and seemed less time-sensitive. The count of the casualties was provided days after. It is relevant to mention that the area affected in kilometres by the hurricane (HH) compared with the terrorist attack (BTA) was larger, making hurricane's casualties more challenging to quantify.

A Subject-Matter Expert (SME) interviewed described that uncertainty related to the number of casualties could be observed in different types of incidents. For example, an interviewee described a similar situation in a train derailment which was observed through Twitter:

> ***EC/HH9****: [train track derailment that was in Dupa Washington] Our local news agency stations started to quote each other on the number of fatalities, so the number quickly rose from three to nine and so be able to track down how that number went from 3 to 9 when the official sources were saying 3 was actually to be able to connect the dots and being the news outlets for quoting themselves and not necessarily the official sources. So be able to actually manage that and let the PIOs know and quickly correct that inaccurate number was highly important.*

Citizens impacted by incidents usually turn to emergency organisations for advice on how to act and where to go. Events' organisers and emergency services need to rapidly detect potential critical situations in a crowd to maintain safety in mass gatherings (Wirz

[34] Facebook Safety Check feature is activated by Facebook during natural or man-made disasters to allow users in the affected geographical area to share with their network that they are safe. Website: https://www.facebook.com/help/1761941604022087

et al., 2012). The analysis of emotions using social media information, especially Twitter, can be used for crowd management and the identification of the crowd types in a mass gathering event (Ngo, Haghighi, & Burstein, 2015).

Public Information Officers (PIOs) provided advice related to crowd management as part of their risk communication strategy. In the three case studies, tweets were observed with information about areas to avoid and safety measures to follow during the emergency. The value of using social media for crowd management and situation awareness was highlighted by one of the interviewees through an example:

> ***EC/HH9****: Monitoring social media during demonstrations actually become really important after the (USA national) election and in 2016 with the inauguration, we had a large demonstration in all our campus and monitoring social media was one of the ways that we found how large the demonstration was going to be, the types of people, the different types of groups, and the potential threat that it was going to be brought to campus.*

In the three case studies analysed, evidence was gathered of crowd management using Twitter. During the terrorist attack response, the terrorist protocol was activated in Catalonia and the *'jaula' ('cage')* operation in Barcelona city to capture the terrorist (Sánchez, Vargas, et al., 2017). The zone was in lockdown leaving thousands of citizens trapped within the perimeter, and tourists and citizens without access to their hotels and homes (DW, 2017; Herraz Ventura, 2017; VoaNoticias, 2017). Police actions impacted public transport, roads and access to specific city areas such as Las Ramblas[35]. Crowd management in this emergency was more dynamic and uncertain than in the other two incidents. Neighbourhoods and cities impacted changed according to the terrorists' movements which were unpredicted and sometimes guessed. For example, a rumour was shared through Twitter and other mass media channels describing that terrorists held hostages inside a bar (García, Congostina, Guell, & Carranco, 2017; Lytvynenko, 2017). Crowd management using Twitter was done in order to guarantee citizens' safety.

Citizens' collaboration was requested online during the terrorist attack. In Barcelona, emergency management organisations shared tweets asking Twitter users not to share

[35]Street in central Barcelona where the terrorist van attack took place

information about the police actions in specific control checks within the city of Barcelona and Cambrils. It was paramount to avoid alerting the terrorist of the police actions to capture them. Also, police provided a phone and an e-mail address to share any information relevant to the attack. Police recommended that citizens stayed at home or if going out, they did not carry bags.

On the other hand, crowd management for Hurricane Harvey (HH) was governed by the hurricane's projected path. While emergency stakeholders were able to plan in advance, people looked for confirmation of evacuation notices shared in multiple channels, including Twitter. For example, the City of Corpus Christi (@cityofcc) encouraged the evacuation of specific areas highlighted in a map through their Twitter account (Carr, 2017).

People fled the impacted zone looking for dry and sheltered accommodation. Information was shared about how to arrive at safe areas and the capacity to welcome evacuees. Rumours were detected about accommodation and immigration status during HH (BBC Trending, 2017).

Also, uncertainty about evacuation increased during the aftermath of Hurricane Harvey. Several tweets warned citizens about people impersonating Homeland Security Investigations special agents. Homeland Security and Immigration and Customs Enforcement released a statement warning people of this scam (2017).

Resources were in place to support people evacuating the area. However, some citizens were unable or unwilling to leave their property and needed to be rescued. Several tweets were posted asking for help as emergency lines became collapsed after HH. For example, Harris County Sheriff Ed Gonzalez copied Houston's fire department message and alerted his followers to the whereabouts of a '*pregnant woman going into labour*' on Sunday 27th (Stelter, 2017). The bi-directional role of Twitter was also beneficial when Houston's emergency services decided to respond to tweets by seeking additional location details or letting people know that help was on the way (Webb, 2017). First responders and volunteers helped in the rescue operation and extracted survivors from flooded areas.

In contrast, crowd management in the eclipse was designed to manage people influx. Oregon journalists and emergency managers used Twitter to post messages to manage eclipse attendees. The influx of citizens expected in Oregon posed a danger related to traffic and camping. For example, a journalist informed about traffic jams before the eclipse and used an image obtained from the Oregon State Police Twitter account to illustrate it (Zorthian, 2017). Concerning camping, fears were shared about fires and higher tides before the eclipse. Therefore, citizens had to be warned of the dangers of camping on the beach (Hendricks, 2017; The Oregonian, 2017).

Moreover, several active wildfires were recorded in the area (Kavanaugh, 2017a), the importance of crowd management increased due to the number of outstate visitors:

> ***EC2****: We were actually working the fires and the eclipse. I mean the fire happened during the eclipse, so the eclipse came into what we were doing. […] So I was already working in the incident, and the eclipse was one aspect of the incident because the surge of tourist coming into the fire zone.*

The ability to accommodate people and vehicles in the area was also questioned online. Uncertainty about the impact of this was amongst the area residents. The eclipse also prompted a collaboration between social media users. For instance, the VOST team reported:

> *'Discussions of people asking for and coordination of rides to areas in the eclipse path Facebook messages on a closed group Oregon Eclipse Festival 2017' (VOST Oregon, 2017a, p. ID 15).*

Not only existing infrastructure was questioned but also the people influx's impact on access to essential goods, including petrol. Before the eclipse, several tweets were shared, referring to people queuing to fill their tanks. Additionally, there were rumours about an increase in petrol price up to $5 a gallon (Boyle, 2017). Uncertainty about access to petrol was also reported in the Hurricane Harvey case study. Evidence was collected concerning the uncertainty to access products and services to cover basic needs such as water and petrol.

It was reported that one of the city's water plants was flooded, and misinformation spread concerning water being contaminated, increasing insecurity about how safe it

was to consume tap water (Martinez, 2017). On the 31st of August, CNN (2017c) reported that the city of Beaumount (Texas) had no access to drinkable water, and citizens had to queue to access water and food. Houston Office of Emergency Management (OEM) had to belie that the water was being shut off in the area and confirm that it was safe to drink on the 27th of August (Broder Van Dyke, Lewis, & Lytvynenko, 2017; R. F. Graham & Smith, 2017).

Products' prices increased due to the imbalance between supply and demand. The Texas Attorney General's Office reported over 600 complaints concerning high-prices for water, petrol, food and accommodation:

> *'Specifically, we've seen $3.50 for gas in Houston, $8.50 for bottles of water and $99 case of water complaints. We also received a complaint about one Houston convenience store charging $20/gallon of gas,- spokeswoman Kayleigh Lovvorn said in an email.'* (Young, 2017).

Also, multiple tweets were seen under the hashtag #HarveyLootCrew describing looting taking place; however, the Houston Police Department stated that very little looting occurred during the first week of flooding (Emery, 2017).

Uncertainty was also shared concerning law enforcement and help required /available in the other case studies. For instance, before the Eclipse, it was rumoured that parking was permitted in areas not allowed.

Official sources also used Twitter in the three case studies to share support available. Citizens shared tweets summarising the contact details of relevant organisations. Information about services and other available resources such as accommodation and transportation was actively shared through Twitter official and unofficial accounts during the Barcelona Terrorist Attack and Hurricane Harvey.

It was noted that after the incidents, especially the terrorist attack (BTA) and Hurricane Harvey (HH), people enquired about how to help by becoming volunteers or making donations. In the BTA, several tweets were created offering and requesting blood donations, translation services and accommodation enquiries. The request for blood donation and translators were rumours belie by emergency organisations.

The number of volunteers after the HH and posterior flooding was noticeable. The devastation associated with these emergencies was counted in billions (Mooney, 2018). Charitable organisations requested donations, and individual volunteers offered their help to rescue victims and rebuild affected areas through Twitter and other channels (Hicks & Selby, 2017). Inhabitants with boats rescued numerous trapped citizens. People out-state offered support by donating goods or fundraising money. Official sources encouraged economic contributions as donations of items after hurricanes present challenges in the effective management of resources. Items need a safe location to be stored, sometimes do not correspond to evacuation needs and second-hand items must be sorted before distribution delaying the opportunity to support people in need.

Concerning financial donations, some scams were identified. The identification of potential frauds was a task allocated to one of the activated VOS teams. Besides, journalists published articles to aid the selection of charitable organisations and reduce the risk of donating money to people who were not involved in supporting the hurricane's response (e.g. Caron, 2017).

To conclude, information needs increased subject to the uncertainty identified by emergency stakeholders. Depending on the emergency type, specific information was required before, during or after the incident or in more than one phase. For example, crowd management information requests (e.g. best routes to go from point A to point B) were observed during and after the terrorist attack, before and after the eclipse, and in all phases for the hurricane. Information was made available through different channels, including Twitter. The next section provides evidence of how Twitter was used to reduce uncertainty from a production and consumption perspective.

4.2. Twitter uses for decision-making in incidents: Case studies comparison

It is paramount to understand past research to ensure the advance of knowledge. The literature review (Chapter 2) has showcased that social media is still a relatively new Information Communications Technology (ICT) used in Emergency Management (EM). Even in its infancy, Twitter is used more and more often by citizens, emergency organisations and journalists before, during and after any major incident. Within this

context, information uncertainty due to tweets' quality is one of the biggest challenges for decision-making (Section 2.2.3). From an Information Systems (IS) perspective, data quality can be improved during the production process and from a consumption perspective. This approach aligns with the two essential Twitter functions in major incidents described in Section 2.2.2.: as a risk communication tool and information source for situation awareness. This broad categorisation provided a framework to classify Twitter uses proposed by other researchers in the area of Emergency Management (EM). Building on previous findings and using the three case studies described in Section 4.1, the researcher gathered evidence of the use of Twitter for decision-making in naturalistic environments (e.g. emergencies, major incidents). In turn, four key uses of Twitter were identified: mass communication, interpersonal communication, information search, and trends and patterns detection (Table 4-3) and four key outcomes were evaluated as the result of a decision-making process in the case studies.

1) the decision to tweet;

2) the decision to retweet (RT) or engage with content;

3) the decision of using Twitter information to document news;

And 4) the decision of escalating information from Twitter to Emergency organisations

Table 4-3 describes each of these outcomes observed in the three case studies. The use of Twitter as a mass (risk) communication channel involves the stakeholder's decision to publish information on Twitter during any emergency phase. It is a one-to-many communication model where the decision-maker creates content, and multiple receivers can access it. Therefore, the first decision-making outcome evaluated is the *'decision to tweet'* (section 4.2.1).

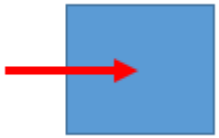
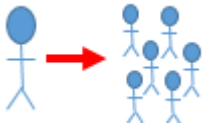
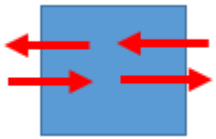
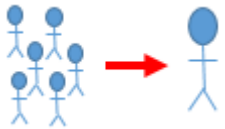
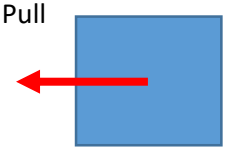
	Twitter use	Explanation	Information direction	Communication actors	Decisions Analysed (Outcome)
Information Production (Risk Communication)	Mass communication	One stakeholder push (sends) one message to multiple receivers by pushing the message on a social media site.	Push 	One to many 	• Deciding to tweet
	Interpersonal communication (Public /private message)	One stakeholder sends a message to a specific stakeholder and communication roles are exchanged during the process (two-way communication). It can be done publicly using the @ symbol or privately.	Bi-directional 	One to one	• Deciding to retweet or engage with Twitter users
Information Consumption (Situation Awareness)	Information search	One Stakeholder uses SM to access specific information	Read	Many to one 	• Escalate Information to Emergency Organisations • Share information in other media
	Trends and patterns detection	One stakeholder listens to multiple stakeholders at once by pulling the information and analysing it.	Pull 		

Table 4-3 Twitter use findings summary (RQ1)

The use of Twitter from a production perspective also includes the decision of using Twitter as a bi-directional channel. In this scenario, the sender and the receiver can interchange roles, or the receiver can amplify the message through her network. It consists of the decision of engaging with content created by a third party by using the RT (share) option, editing the message, using the '@' symbol to mention specific users or forwarding the tweet using a private message (section 4.2.2).

From a consumption perspective, the use of Twitter as an information source for decision-making is understood as the decision of searching and retrieving information from Twitter to make a decision. Information retrieval included multiple tweets through Twitter APIs or one specific tweet by manual exploration in this context. On the one hand, evidence was gathered of the decision of using Twitter for the detection of trends and patterns. This decision involves the tasks of searching, aggregating and analysing tweets for decision-making. On the other hand, the decision of using the information after reading one or multiple tweets can also prompt action. These Twitter uses were considered when the researcher had evidence of a decision made with a specific piece of information. The researcher evaluated the decision of sharing Twitter information as part of a news article (section 4.1.3) or escalating it to an emergency organisation (section 4.1.4).

While social media information can aid during other decisions, for instance, a criminal investigation, this was not included as not specific evidence was identified in the analysed case studies.

> ***EC6****: We use Twitter to share information through our official account and also to monitor social media for situational awareness, whether this is for planning operations, public information. We do not use it for investigation because of liability issues but I've seen it used in that way in the past that can be sometimes one of the best uses for it.*

All decisions considered (outcome) were made by the unit of analysis described in section 3.2.2., and addresses the information needs and uncertainty elements described in Section 4.1.4.

4.2.1. Deciding to tweet

Organisations are starting to use social media as part of mass communication during crisis and emergencies (M. W. Graham et al., 2015). Over the years, Twitter is emerging as the dominant social media tool to share information on social crises (Oh et al., 2013). Substantial evidence exists of the use of Twitter for communication purposes (see section 2.2.2). In the analysed case studies, Twitter was used as a mass risk communication tool by multiple emergency stakeholders, including the police, fire brigade, hospitals, and citizens. The decision of sharing information on Twitter had two main objectives: inform directly multiple citizens at once and create a bi-directional space of communication. This section analyses the decision of using this channel to propagate risk communication messages.

In the three case studies, the benefits of using Twitter as a risk communication tool were observed and highlighted by multiple stakeholders. The first benefit described is the ability to distribute information to a large number of citizens. As stated by one of the interviewees:

> ***EC/HH8****: All point of social media is sharing.*

Researchers had already showcased that information can be disseminated anywhere and anytime by minimising geographical distance problems using Twitter (Irfan et al., 2015). In fact, social media allows us to communicate and reach the mass public quickly and effectively (Kim & Liu, 2012). Before social media, organisations relied on the role of journalists to report and update citizens. However, drafting a press release is a slow process as the content's redaction and validation take time. As described by one public information officer:

> ***BTA4****: The process of redaction and validation of a press release made that when this was sent to the media, and the media shared with citizens then part of the information, at the moment that you press send, this had already expired o had changed, or there is a new situation. Therefore, Twitter is a basic tool. This can be appreciated in emergencies that are faster by their impact such as chemical accidents when in minutes you must send a message or in the case of the terrorist attack because of the indication that you must give to citizens and also because the media focus let's say citizens attention is immediate.*

In the case studies, Twitter immediacy improved the risk communication process by increasing the delivery speed while still ensuring the official source authority. Twitter allowed emergency stakeholders to share information without the role of a middle man. This aspect was highlighted by an interviewed Public Information Officer (PIO):

> ***BTA4****: Twitter allows us to update citizens directly*

Accordingly, strategies were created to disseminate emergency-related information effectively. For example, one of the organisations observed developed a *'Tweet sheet'*, a document that included a list of *'tweetable chunks',* which are complete sentences created from the morning press release, and scheduled its content using Tweetdeck[36] (**EC8**).

Other strategies included creating content in different languages, which allowed updating visitors and tourists as well as citizens. This action is exceptionally relevant for areas with tourists of multiple nationalities who may not be fluent in the affected area's language (e.g. tourist during the Barcelona terrorist attack).

> ***BTA1****: Another thing to take into account it is not only citizens but also visitants, and try to post information in different languages […] as there can be people travelling for pleasure or business in the crisis or emergencies affected areas and they also need to know what is happening.*

Other researchers previously highlighted the importance of updating visitors during emergencies and disasters. As stated by Nirupama & Armenakis, *"tourists are particularly vulnerable to natural disasters such as hurricanes since they might be less informed and prepared than residents of disaster-prone areas"* (2013, p. 2) – for example, during extreme heat events in Phoenix, USA (White-newsome et al., 2014).

Additionally, Twitter enabled Public Information Officers (PIOs) to support ground operatives by providing timely, relevant updates. For instance, during the BTA, citizens were asked through Twitter to stay at home while police were hunting the terrorist in Cambrils.

[36] TweetDeck is a Twitter social media dashboard application for the management of its accounts (schedule tweets, save search terms, create lists). Website: https://tweetdeck.twitter.com/

The decision of creating a tweet comprises multiple steps. First, the decision-maker must be a registered Twitter user (see section 2.2.1 for further information about publishing content on Twitter). The decision-maker must then decide if the information available should be written or not, and shared or not. The creation process can involve several control variables depending on the information and resources available. For instance, two different tweets can be created depending on the features used on Twitter, such as adding an image or activating users' Geolocation.

Creating a tweet is relatively easy, as described in section 2.2.3. However, the decision of creating content during a major incident includes a social and legal responsibility for different stakeholders. As highlighted by two Public Information Officers (PIOs):

> ***BTA4****: We have the legal obligation of informing citizens of any potential danger, provide them advice to protect themselves, and when an emergency takes place, we have to give orders, recommendations and share information.*

> ***EC/HH9****: Twitter is very helpful, I think each of the social media has real strengths. The thing about Twitter is that people are passionate about Twitter. If they use Twitter that is their first and primary go-to for everything they want to know, and they can see it in their phones so it is very mobile and these days it needs to be mobile.[…] So, Twitter is great for the go-to, and I think people who are passionate about Twitter use virtually nothing else. So, we have to be there. There is an expectation that we will be in Twitter.*

Therefore, deciding to create a tweet implies that the decision-maker believes that the information available should be shared. The decision includes a set of sub-decisions concerning the content to be added. Each of these elements has implications related to Information Quality (IQ) and how it is perceived. For example, it was acknowledged that tweets with images are perceived as more credible.

> ***EC/HH8****: I try to tell people 'do not post anything on Twitter that it is just a bunch of words, things get shared more when they have pictures', and so, we always try to have a picture so to update but sometimes we put two pictures in the update- a regular picture of the incident and then the .pdf link and we try to .jpeg whatever we can.*

Therefore, the decision of sharing content and the type of content included is vital for a successful risk communication strategy. The analysis of the case studies allowed the identification of different types of information shared on Twitter. Initially, tweets were

classified depending on the stakeholder type posting information following Reuter et al., (2014) approach: Citizen and Authority. The emphasis was then placed on the authority role as they were identified as experts in the area. Evidence of the decision of composing and sharing a tweet was collected directly and indirectly (i.e. through reports and news articles) from the three stakeholders identified as the unit of analysis (section 3.2.2.): Public Information Officers (PIOs), journalists and Virtual Operation Support Teams (VOST). The researcher also observed tweets from citizens, and while they were not actively analysed, findings helped to understand how effectively use Twitter in this context.

Thus a large number of uses were observed and can be classified within the categories outlined in section 2.2.2 of the literature review, the following findings are not by any means exhaustive, but they illustrate the information that prompted an observed and documented decision in the case studies analysed.

In the three case studies, information about the incident was related to updates of the event, support crowd management, asking for collaboration and support available to victims and their families. For example, 50.57% of tweets posted by VOST (n=261) in the Barcelona Terrorist Attack (BTA) were related to incident updates, including information about access to public transport, events unfolding, and official count of the number of dead and injured (example of this in probe 3, page 254). Emergency organisations mostly used Twitter to update citizens about their operations, ask for collaboration and outline official support available.

As the evidence shows, there are several significant challenges to be addressed to support the decision to create tweets for emergency management, especially if the tweet creator wants to support other emergency stakeholders' decision-making process. First, it is relevant to understand who the target audience for the message is. Language barriers can have a significant impact on the dissemination of messages. Secondly, decision-makers must consider what information is to be shared and the rationale behind it. Thirdly, time is a significant constraint to be addressed as (1) access information from the field team can be delayed; (2) it is required a minimum time to prepare tweet (text and images); (3) a change of circumstances can leave the

information outdated quickly, and (4) information verification can take time. Besides, during an emergency, they may be multiple emergency organisations involved and they may need coordination to share information and to establish appropriate leaderships.

To address these challenges, interviewees shared and proposed different solutions that are or could be implemented within organisations' human resources and software solutions. For instance, emergency organisations and VOST members constantly communicate using formal and informal channels (e.g. Whatsapp groups). This networking structure enables their collaboration and supports the creation of tweets. For instance, in BTA, the translation of messages to different languages was achieved by identifying VOS team members with specific language skills. Similarly, the ongoing collaboration between different emergency organisations through meetings and incident planning promoted the allocation of roles and responsibilities, so competencies were not overlaid or missed. Risk communication strategies' success was based on the organisations' collaboration and the establishment of clear leadership. All PIOs and journalists interviewed highlighted the importance of being the first person to report an event and become a communication leader. For example:

> ***BTA4****: In the design of the operation, one of the fundamental principles was to be proactive – lead the conversation.*

> ***EC/HH6****: official source must give their information quickly, or the audience will go somewhere else to get their information.*

Furthermore, the response speed to lead the conversation and become a reference point was regarded as essential for a successful risk communication strategy. In the absence of an official source, any person with information can become an information leader during an emergency.

> ***BTA4:*** *If we could not lead that information as the official source from the beginning with the information that we had contrasted everything that we did not lead, someone else would do it. Some leaderships are not created by officially but for the first person sharing information, being nearby o by the graphic content, etc.*

Therefore, in the case studies, information accessibility impacted the way that content was created for social media and in the preparation process. A Public Information Officer

(PIO) stated that '*95% of their work is preparedness',* including message preparation and network building.

> ***EC/HH6****: [During] our steady-state were we spend 95% of our time preparing for an emergency and how we are going to give information to people and social media is one of that tools that we use, including Twitter so what we are trying to do is to get out preparedness messages for our audience, have a footprint on social media, so people will know who we are during are emergency so we can share the information with them as the official source and Twitter and Facebook are right now the primary platforms that we use for that.*

Therefore, it was deemed imperative that PIOs pooled resources in advance during planning activities and when an emergency takes place to meet in the operations control room ***(BT4, EC6 and HH10)***. This location provided them with timely access to updates from the ground team, and verification activities could occur then and there. It was paramount to have access to the right information to cover basic knowledge needs from citizens and the press; nevertheless, tweeting about related actions such as forensic activities was also declared necessary. For instance, in the BTA, it helped maintain the narrative and create a more consistent discourse.

> ***BTA4****: There is a moment during the night, or maybe it was during the morning [that we tweeted] about '24 forensic people'[…] this is not vital information, that people need to know, but there is information that maintains the narrative, we will give information that we have. And for instance, it provides a dimension of the [operative] capability; it shows that all emergency operatives are working.*

In summary, solutions implemented in the case studies to ensure Information Quality (IQ) included preparing tweets before an emergency takes place, a clear structure of roles and responsibilities during multiagency communication activities and direct access updates from the operations control room. Besides, the decision of sharing information on Twitter needs to fulfil several dimensions in order to be meaningful for the reader. Interviewees believe that the Perceived Quality of Information (PQI) from a citizens perspective increases if messages are shared in the citizen's language, official sources are proactive and establish quick leadership (e.g. tweet straight away even to say '*they are working on it*'), they do not use sensitive photos but still relevant ones showcasing on-going communication with the ground team, and they build their network before an

emergency takes place. This last element refers to the decision described in the next section (4.2.2): Deciding to Retweet or engage with tweets.

4.2.2. Deciding to retweet (RT) or engage with tweets in major incidents

Social media not only enables mass communication but also enables conversation and interaction. One to one communication and the exchange of sender/receiver role can be crucial during an incident (for example, during rescue operations) when official channels are saturated. Twitter allows users to capture conversations and amplify their content through the action of retweeting (RT). In addition, two-way communication can improve decision-making in individual situations as asking questions online can help gather information. Targeted asking and network asking can impact severely on the individual decision-making process (see section 2.2.3).

Deciding to use Twitter to engage in major incidents has several challenges associated. In the next paragraphs, these decisions are described from creating meaningful conversations and the message amplification perspectives. The researcher also notes that the action of sharing messages implies some level of endorsement of the content and the source as the action of retweeting (RT) becomes part of the recommendation system.

First, it was observed that Twitter offers the opportunity to create conversations and provide further information, including rectifying messages and debunking rumours. The sample of bi-directional uses identified through the tree case study included offers of support or help, reactions of citizens and social movements, and appreciation messages. The majority of the decisions taken with this type of information was based on amplifying the message; however, some of them raised individual activities such as donations, rescue activities or attendance to events /manifestations

Moreover, Twitter enabled emergency stakeholders with the option of targeted asking and network asking. Evidence of both options was identified in the three case studies. For instance, in the Barcelona Terrorist Attack (BTA), clarification for the number of injured was asked to Virtual Operation Support Team (VOST) Catalunya (example of this

in probe 3, page 254), or before the eclipse (EC) the potential damage to electronic devices was asked to @Nasa[37] (example of this in probe 11, page 260).

All interviewees declared that contact with official sources should be based on the development of meaningful conversations. The importance of verification through targeted asking (requesting clarification to official sources) increases when the information is not openly available. As stated by an interviewee:

> ***EC/HH6:*** *Verify. Know how to verify. Knowing how to verify means looking at official sources, if you look at the official sources and you do not see anything about that then you need to ask. So, send an e-mail or ask them via social media but make sure that you verify this information with an official source first before you share it.*

Affected citizens can reach emergency organisations to get the needed support. Traditionally, contact was made using telephone through the international emergency phone number 112 or using local phone numbers. It was highlighted that while the ability to reply to tweets or send private messages exists on Twitter, emergency organisations' main challenge is to manage the amount of information due to the number of operatives required. In the BTA, their approach was to tweet information that covered the basic information needs to minimise the potential room for rumours or at least compete against the unofficial information on Twitter.

> ***BTA4****: We belied [rumours], but we did not have the capacity in relation to the timeline to deny the rumours. The message 'follow official sources' aimed to address this.*

As observed in the case studies, the number of organisations that are actively and continuously engaging with citizens through Twitter (i.e. replying to messages) is relatively low. The dangers of communicating through Twitter (due to visibility to other users and the limitation of characters) were highlighted by three SMEs. A PIO stated:

> ***EC/HH7****: One little turn of phrase can make it the wrong answer, even if you may know the right answer.*

[37] @Nasa: Official Twitter account for the National Aeronautics and Space Administration (NASA) in the United States of America

In order to address Twitter limitations, it was suggested to enable other channels that, while being online, provide a better interface to enable bi-communication.

> ***EC/HH7**: the notion of making sure that there is a way for people to get more information from you. So, loads of times Twitter is an outgoing thing for agencies, and they really do not want to spend the time finding answers on Twitter So maybe redirect to… or giving them someplace like Facebook, where they can go for further clarifications. It may not be on Twitter. So, and clarify.SO it will be the bidirectional capabilities for clarifying emergency information. [] So a lot of times the AMTs are very good answering in Facebook, not so much on Twitter so giving people the access the public page so, even if they can't comment themselves – they still can read the comment.*

In the absence of official replies, targeted questions can become network questions (for example, other citizens answered evacuation questions in the HH). Research has shown how, after any major incident, citizens come together to support each other (e.g. Helsloot & Ruitenberg, 2004). With the advent of social media and increased internet access, support has become available online through organised or unorganised citizens groups (e.g. Heldman, Schindelar, & Weaver III, 2013). According to Subject-Matter Experts (SMEs), this is the perfect setting for rumour propagation as the willingness to help, combined with the absence of guidelines, impacts Twitter users' RT decision. As stated by a respondent:

> ***BTA4**: It is clear that conditions equally than with a virus, where humidity conditions and temperature… they impact [on the spread], and the ideal conditions for a rumour to become viral during an emergency are adequate and more [if we are] appealing to the willingness to help, the willingness of the people.*

A VOST member highlighted that this willingness could be used to address the misinformation issue by encouraging Twitter users to report content to the platform when it has been identified as a rumour. In the EC case study, a Twitter account impersonating an official source was reported and removed to avoid confusion (an example of this can be found in probe 8, page 258). As described by one of the interviewees:

> ***EC/HH9**: Twitter is a lot of more supportive in managing inappropriate posts or things that are just completely inaccurately, false. They do not perpetuate the cycle of rumour, especially if you go through the reporting process.*

Collaboration between emergency stakeholders is vital to address uncertainty through Twitter. Furthermore, the benefits of socialising through Twitter during incidents are multiple, and evidence was found through the case studies.

A part of the importance of developing content suitable for Twitter, it was highlighted that to succeed in the delivery of these, organisations must focus on building their followers and socialising in major incidents:

> ***EC7****: they may want to go to all these partners and say 'hey, can you help us to amplify this message in your account, so it is reaching a wider audience'. So, for instance, Travel Oregon has 200,000 followers on Twitter, so they say 'hey can you help us to share this information, so we are reaching a wider audience that way'.*

Therefore, creating an online and offline network is highly crucial for successfully implementing any social media risk communication strategy as it helps amplify messages. As outlined in the previous section, partnership /collaborating between different agencies is essential, and Twitter enables this:

> ***EC/HH6****: we also use it as a tool to help amplify messages from our partners, and it is a way that they can help amplify our messages too.*

> ***EC/HH7****: the only time that we will ever amplify something is from a partner agency. So, because we are a type 1 team and it is interagency, we are an incident management team we go to the national forest to do with the fire I would frankly amplify evacuation information from the local sheriff, from the national forest, from any of the other co-operators, Red Cross… that things that I would amplify.*

Message amplification can be achieved through retweets (RT) and likes. People amplify messages intending to help by propagating information. However, the decision of retweet (RT) information should not be taken lightly as it can perpetuate rumours.

> ***BTA1****: Before RT or share, think twice –am I helping anyone or is this information helping anyone? And if you are not sure that the information is coming from a trusted source, and if you are not sure that this information is helping anyhow… then, do not share it.*

The Catalan police shared this flowchart (Figure 4-9) to support the decision-making of sharing content from social media. It focuses on three key aspects: Do not share

information if (1) you cannot check that information is authentic, (2) you cannot check that it is actual, and (3) sharing will not be helpful.

Figure 4-9 Verification flowchart posted on Twitter by Mossos d'Esquadra (Catalan police)

The contrasting of information was suggested by a Public Information Officer (PIO) and a VOST leader as a way to overcome this issue:

> ***EC7****: if you are following one account that it is official then so you know building yourself of what they are amplifying is how to do that because […] I doubt very much that any of the agencies would retweet the fake account*

Additionally, if an unverified message was being spread more than the official version, it was suggested that emergency management organisations should ask their network, including journalists, to support the propagation of official messages.

> ***EC/HH6**: Just really trying to socialize as much as you can in social media, in traditional media on the way that you can to let people know what the real information is.*

Therefore, message redundancy and collaboration from partners and mass media should not be undermined. Mass media's role and the importance of the decision-making process from journalism was commented on in Section 2.1.5, and case studies' evidence of journalists using Twitter information to reduce uncertainty is presented in section 4.2.3.

4.2.3. Deciding to share tweets information in mass communication media

Mass Communication Media (MCM) and journalists play a vital role in communicating emergency-related information to the population. Their role includes addressing misinformation, amplify official messages and provide updates. Despite the growing adoption of social media, not everyone has access to or know how to use these communication channels (digital divide). However, breaking news detected by journalists online (e.g. from Twitter) are used as part of articles.

In the three case studies, evidence was collected of this journalist practice where information retrieved from Twitter was used to inform and document their news articles. The benefits of Twitter to aid the decision-making process of sharing content in other MCM, mostly in online news outlets, were highlighted by multiple interviewees. Twitter's users provide the text but also multimedia resources that can be shared as evidence. For example, in the Barcelona attack, news-articles included images (e.g. Trevelyan, 2017) and videos (e.g. Campbell, 2017; LaPrensa, 2017) taken during and after the attack. A part of the content available online, Twitter provides immediacy to information access. Twitter enables journalists to gather information near real-time from different emergency stakeholders, including citizens, emergency organisations and public figures.

Citizens can report breaking news through social media as they are victims or witnesses of the events sharing information online. This aspect was evident in the BTA, where witnesses flooded Twitter with the attack's images and videos. Journalists used witnesses' tweets to document their news articles (e.g. Ian Burns, Burke, & Worden,

2017; Deen, 2017; Lopez Morales, 2017). Updates from emergency organisations posted on Twitter were also utilised.

Emergency organisations traditionally communicated with journalists through press releases. Nowadays, organisations can now distribute press releases using online channels, including Twitter. As described by a Public Information Officer (PIO), social media does not aim to replace communication with journalists, but it speeds its process.

> ***BTA4****: Independently of how many resources you may have in your press office, you won't be able to manage all the information requests or the process of creating official press releases because it is slower than the emergency dynamic.[…] The process of redaction and validation of a press release makes that when it is submitted to the media, and the media shares part of the information with the citizens, the press release is outdated, or the situation had changed, or there are new situations. Therefore, Twitter is a basic tool. But we are still working during emergencies as a traditional press office with traditional press releases, communications, press conferences, telephone attention to journalists, etc.*

Profiles from the relevant emergency organisations were consulted by journalists and used to document information from official sources. In the Barcelona terrorist attack, national and international journalists quoted tweets from the Catalonia police Mossos d'Esquadra (e.g. BBC Mundo, 2017a; Mellardo, 2017), and emergency organisations (e.g. Oms, Montesinos, et al., 2017) to report updates from different phases of the operation including Las Ramblas attack response (e.g. Polo, 2017; VoaNoticias, 2017) and Cambrils incident (e.g. Cortés & Sáiz-Pardo, 2017), and the number of injured and deaths (e.g. Oms, Montesinos, et al., 2017). To assist citizens in their decision-making process, journalists provided a sample of tweets that asked social media users not to share information about the dispositive (e.g. DW, 2017; Excelsior, 2017; Oms, Del Barrio, Polo, & Alguacil, 2017), respect victims and families (e.g. El País, 2017b; Jimenez, 2017), no disseminate rumours (e.g. VoaNoticias, 2017), and providing citizens with indications for example, *'stay at home'* (e.g. DW, 2017). These are examples of journalism's use to support emergency management organisations in their task during the response phase of the Barcelona terrorist attack.

Additionally, official accounts of politicians and personalities can be freely accessed, and tweets can be used to illustrate the information. Public figures use Twitter actively to

express their perspective, and tweets are being used as quotes. For example, in the Barcelona terrorist attack, celebrities and politicians expressed their condolences and condemned the attack (e.g. VoaNoticias, 2017). Journalists captured this information from Twitter and quoted these tweets to report politicians' and celebrities' reactions (e.g. El País, 2017c; Publimetro, 2017; TeleSur, 2017). In the other two case studies, it is also possible to identify samples of tweets. For example (Figure 4-10), Mr. President Donald Trump, a very active Twitter user, had his reaction during the Eclipse and Hurricane Harvey captured on Twitter.

Figure 4-10 HH Tweet sample - Mr. President Trump Tweet used in an online news outlet as evidence

A higher level perspective was shared by astronaut Randy Bresnik (@AstroKomrade) who tweeted from the International Space Station a support message for families, friends and Texas citizens including an image from space (Cofield, 2017).

The decision to share information retrieved from Twitter (or other social media platforms) in other media has numerous challenges associated. Some of them are similar to those faced by people deciding to share information on Twitter or to engage with information on that platform. For example, similarly to emergency organisations, information shared by journalists has a degree of credibility associated with it. Therefore, if the information shared is not correct, it could impact citizens' trust and the transmitter's reputation. As described by an interviewee:

> ***BTA2****: I have a friend who always speaks about reputation, and talks mostly to journalists. He always does it through an example. He gives you a piece of paper, a DIN-A4. He tells you to write down your name and something else. Takes the paper and show it to the conference room. Then suddenly, he crumples the paper. He returns the paper and asks you to put it in the same way that it was. Then, the people try hard to straight it again, but the paper will never be the way that it was before. Then he tells you that is your credibility from now on. It is difficult that you will have it again. Therefore, we need to take care before sharing any news.*

The decision of using Twitter data must be based on the credibility of the information source and the content displayed. All interviewees outlined the importance of checking with official sources for confirmation before sharing any breaking news. However, there is evidence that this is not always done.

> ***BTA2****: I can tell you that sometimes they are giving information and it hasn't been compared that it is not true. And they are ok to say 'we made a mistake…' That is why there are loads of times where they are using stock photos /of photos, that are not from that incident but from a previous one…*

Examples of bad practice were also identified in the three case studies, and some platforms helped to spread misinformation from and on social media. For example, in the BTA, it was reported that terrorists were inside a Turkish restaurant (La Luna de Estambul) and this information was shared from multiple national and international newspapers (example of this in probe 4, page 255).

> ***BTA5****: I know they were some media that, I think it was TV3 and la Ser, radio stations have more this need of immediacy. They said at some stage, and later they obviously rectified, but even if other media says it, we need to go back to the official sources information.*

Concerning the use of images, one journalist explained the importance of verifying photos before sharing them. Standard practice includes the use of reverse image search in Google and other search engines. He even highlighted the recurrent use of the same images in different emergency events such as a shark in a hurricane (example of this in probe 15, page 264) or specific photos of missing people (**BTA5**).

While evidence was gathered of journalists using unverified Twitter information as part of their news articles, a larger corpus was identified of journalist's efforts to reduce Twitter uncertainty by debunking rumours. Nowadays, the journalist's role also includes addressing misinformation.

> ***BTA5:*** *Media role is not only to provide reliable information but also to belie information that is not reliable.*

The decision of sharing information from Twitter has a positive impact when addressing misinformation issues. When rumours were detected, a timely news article showing the tweets and denying the information was perceived as helpful to support citizens' the decision-making process:

> ***EC6****: Also, maybe going to the media as well and saying 'we are having this problem, would you mind doing a report about it or putting something out on the local newspaper so the Oregon States Journal – can you put something out on your paper or in your website' or if in Portland you can talk to the TV stations and you can ask them if they would do a report on it. Just really trying to socialize as much as you can in social media, in traditional media on the way that you can to let people know what the real information is.*

> ***BTA5****: From our newspaper, we address different topics from social medi,a including support gestures, personal stories, and also deny rumours and unverified news that in these situations [emergency situations] need to be verified or belied.*

Examples of the collaboration between emergency organisations and journalists were detected through the three case studies. Evidence was gathered demonstrating how journalists used user-generated content from Twitter to document and demonstrate the

articles published. They used Twitter to reduce uncertainty through publishing news articles that debunked rumours, amplified official messages and provided timely updates. Journalist verification protocols (for Twitter and any other type of source) usually involves interrogating the information source and other relevant Subject-Matter Experts (SMEs). Therefore, confirming and escalating Twitter information to relevant emergency organisations (check with official sources) is part of the process of creating a news article. The next section describes findings related to the decision of escalating Twitter information to emergency organisations.

4.2.4. Deciding to escalate tweets to an emergency organisation

With the advent of social media, many citizens use these platforms to share information that could be beneficial for emergency management. While almost all emergency organisations use social media as a communication tool, there are still limitations in its use for situation awareness. Traditionally, when an emergency occurs, the relevant information is escalated using channels such as 112 telephone number, which is the first protocol to activate any emergency team. While this channel remains the main one, research published evaluates the use of Twitter to identify notable events such as earthquakes (Crooks, Croitoru, Stefanidis, & Radzikowski, 2013) or wildfires (Slavkovikj, Verstockt, Van Hoecke, & Van De Walle, 2014). However, concerns were expressed on the ability to activate operatives using this channel. For example, a Public Information Officer (PIO) expressed:

> ***BTA4****: Social media do not replace any emergency's official channel, it is not a channel where you can communicate an emergency as it can be the 112-phone number, I refer to the phone service where an emergency dispositive can be activated.*

As previous research showed, the adoption of social media by government and organisations is conditioned by specific factors, for example, the size of the community served by the department (M. W. Graham et al., 2015) or the number of staff members (Graham & Avery, 2013). Decisions made using information from Twitter proved a challenge during the incidents analysed. As emergency management consultant Rob Dudgeon described, first responders do not have the bandwidth to monitor all the social media information:

> *'It's very labour-intensive to watch [social media] and because of the thousand different ways people can hashtag something or keyword something, trying to sort out what's relevant and what's not and what's actionable is very, very difficult.'*(L. Silverman, 2017).

Nevertheless, the power of Twitter was demonstrated in the case studies. For example, after the Harvey Hurricane when a photo of an elder group in a flooded nursing home went viral and supported the decision of sending a rescue team to airlift the residents (Milstein & Rosenbaum, 2017).

The Virtual Operation Support Team (VOST) role becomes an essential element for managing social media in major incidents. As described by a VOST member, a solution to overcome the limitations of emergency management organisations is the collaboration with VOS teams (see section 3.2.2.3. for further information):

> ***EC/HH8:*** *That is the thing about VOST. When it was first created Jeff Phillips, who first created it in New Mexico, the reason he did it was because his boss told him, he wanted him to be in social media during emergencies. And he [Jeff Phillips] was the emergency manager, and he said 'when I am busy with an emergency, I do not have time to be doing social media, so how do I do both?'. And the way that he can do both was by getting this group that he called 'trusted agents' you know… So this group of 'trusted agents', they train, and they work together, and when he needed them, he will just let them go.*

Therefore, the development of a network of trusted agents is paramount for identifying information and the decision of what information should be escalated to the activating organisation.

The VOST activities analysis during the three case studies strongly influences the findings described in this section. VOST members are part of an active group of social media experts in emergency management supporting organisations to navigate through the filtering, search and evaluation of information from social media. The use of Twitter for emergency management decision-making is being tested internationally through VOST groups. There are currently three Virtual Operations Support Groups that support different geographical areas, namely Europe, the Americas, and Oceania (Figure 4-11). These three groups are coordinated by a VOST Leadership Coalition formed in 2012. Figure 4-11 illustrates the location of existing VOS teams and groups and the number of

teams in each country. It is possible to observe that countries such as Spain and the USA have a larger number of teams, indicating the growth and maturity of this network in those countries. While evaluating the option of setting up a VOS team in Ireland, the researcher learned the strict requisites to create one[38] and the process required by VOST Europe to add new members. Therefore, several countries and teams (e.g. VOSTbe in Belgium or @NiceVOST in France) that are in the first steps of becoming part of the VOST family are considered as 'in development' (marked in yellow on the map).

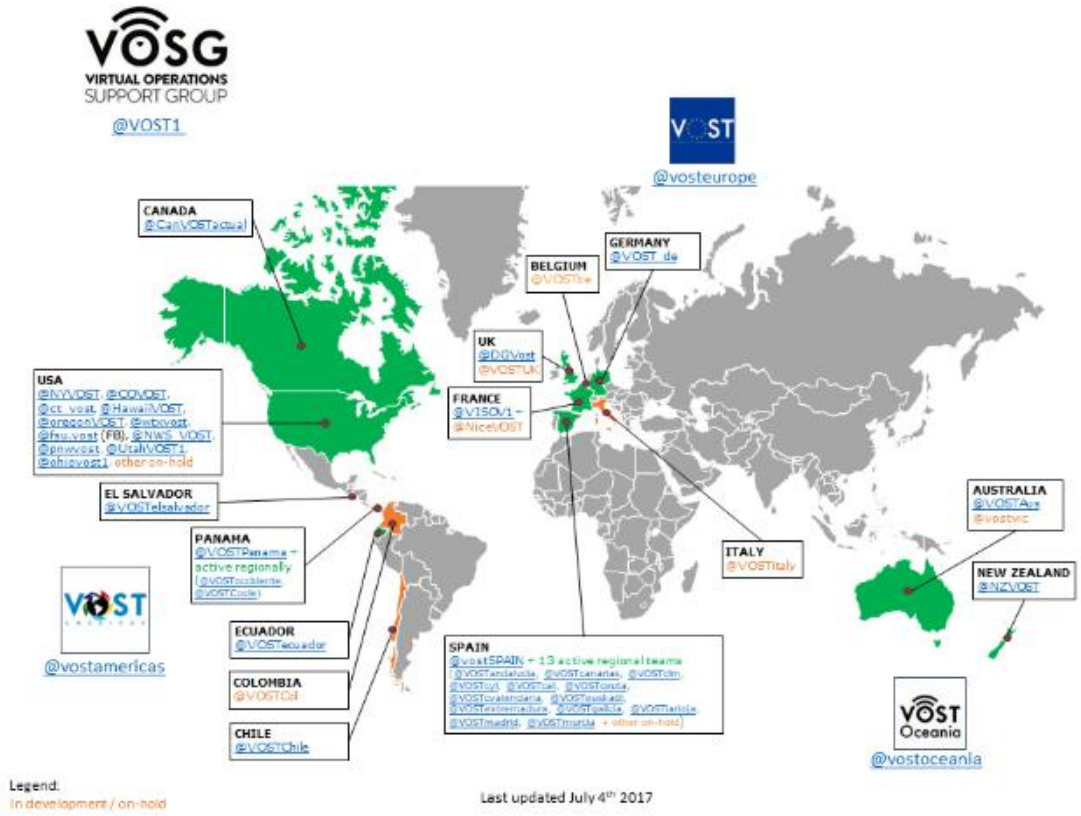


Figure 4-11 Virtual Operation Support Teams (VOST) Map (Susaeta et al., 2017)

In the three case studies, evidence was collected from teams in Spain and the USA. They escalated information to their activating emergency organisations and network. It was outlined that specific emergency organisations must activate VOST; therefore, they decide to call the team and provide them with an objective.

> ***EC6**: I was part of the decision-making process. We had coordination with other of our local partners that were familiar with VOST and were part of other*

[38] VOST must be registered as a non-profit organization, it requires the endorsement of national or local emergency organisation, and initially its members must have an emergency-related background

> *emergency information centres setups. We knew there was a load of traffic on social media in advance the eclipse. So we talk to two of our operation folks here that will be running our emergency coordination centre in the state and ask them if they would like the reports and they said 'yes they would', and then we talked with other folks in the local information centres and asked them if they would be interested in that and they said 'yes, they would. They would like to have situational awareness of what people were saying in social media so they could crack the messages in a more meaningful way or see if there was information being shared on social media that they wouldn't know anything about it.'*

It is relevant to mention that VOS teams in the BTA (@VOSTCat and @VOSTSpain) were self-activated; however, they had on-going communication with emergency agencies as they had previously collaborated in other emergencies (Susaeta et al., 2017). Their role mixed the responsibility of risk communication with the evaluation of social media information.

The use of Twitter for decision-making in this context required the prior establishment of an objective. Specific tasks provided to VOST teams for the Eclipse and Hurricane Harvey helped virtual members to narrow their search and become more effective in their reports. For example, the first mission of the Eclipse case study was related to the active fires in the area:

> ***Mission 1:*** *Monitor Fire Info Accounts for activity - Facebook, Blog, and Twitter. Report activity that needs to be addressed by logging it on the Search Results sheet in the workbook and escalating the Skype room to be addressed […].* (VOST Oregon, 2017f)

Interviewees highlighted the importance of having direct contact with emergency organisations. This close collaboration enabled that information that required action was usually escalated straight away to the organisation. In the case of VOST members, their leaders usually have a direct contact that helps them to confirm information or escalate 'hot topics':

> ***EC/HH7****: So there are the things that need to be addressed right away, so then we escalate an issue, so there I am already texting incident command telling them 'you have a problem'. An example is on one of the fires I worked in a politician in another state said that there was an evacuation of an entire town. And it wasn't true. So, we were already tracking that rumour.*

Evidence was gathered of how VOST enabled emergency organisations to gain situation awareness from citizens and other entities.

> ***EC/HH6**: So, finding different searches, basic search, getting people to and building reports so we can have that situational awareness using Twitter.*

The information collated also helped identify people's key concerns and obtain feedback concerning the official messages tweeted. Evidence of this was captured in the three case studies.

> ***BTA4**: We try to monitor to see what is happening… between other things to check if the messages that we are sending the mass media is capturing them, also to detect if there are situations that we had previously identified, and overall in that sense to identify rumours. So we can check if it is true or not, deny or confirm it or act in the case that it is true.*

Overall, Twitter enables emergency stakeholders to get additional information to support decision-making from an operations and risk communication perspective. As stated by one of the interviewees, Twitter provides emergency organisations with a competitive advantage that was not possible before social media:

> ***EC/HH8**: the thing that we find most useful is watching Twitter on any incident is that it gives us sort of I refer to it as the "over-the-fence back-garden conversation", I can listen what's happening in your neighbourhood. I can listen what you are saying to your neighbours; I can listen how you are all talking to each other without to worry about what you are hearing, what you think it is true, and what you do not think it is true. All these things we can't ever hear before. Before we ever had a clip in the newspaper to see what cover we got, that was the only input that we had. And now, it lets us kind of we can sort spot trends and rumours and things that are not true, things that seem to be causing engs, you know, or concern in a way that we can take action, you know, to do something about it.*

However, information retrieved was one element more of all the information considered by the activating organisation.

> ***HH6**: In the case of Hurricane Harvey, we will send it to FEMA, and they will match it up with information that they already have or if it information that they may not already have, then they will gather that information and they will go through their own steps to verify it so… making phone calls, corresponding with people via e-mail or just to get with official sources to determine, to verify whether that*

> *information is actually accurate or not which requires doing some research after they see it in that VOST report.*

Hence, the role of verification is still part of the emergency organisation and its internal protocol. As stated by a VOST leader:

> ***EC/HH6**: We actually rely on our team members and their judgement to an extent to be able to verify that information. […] So it is really our job to do the better that we can base on our own judgment and what we see in social media, but it is really the folks that we are sending it to that are responsible for that final vetting process and what are they going to do with the information.*

However, the decision of escalating information is left to the best knowledge of the VOST members who are trusted agents. On-going training sessions are scheduled for team members in how to identify and evaluate information:

> ***EC/HH9**: We actually do to train our VOST members, we teach them how to do and follow the breadcrumb trails so if you see a tweet or Facebook post, an Instagram or even a news article that or something that is completely different than what the official source actually puts out, try to figure out like where did they get that information based on: did they quote somebody else? Did they include a link in the article or the tweet that reference some other news station or another individual that it wasn't necessary from the primary agency and, when I say 'agency', I mean a governmental agency. So, that's one of the things that we teach our VOST members. Doble-check and do a reference check so as to how you will conduct research. So, it is peer review, and so if you are having a hard time figuring out where this information came from, then it may be some red flags.*

In conclusion, the development of critical thinking is paramount in evaluating tweets as part of the decision-making process in order to reduce the number of items that required escalation to emergency organisations.

4.2.5. Decisions observed: case study comparison

As previously described in the literature review (section 2.1.1), a decision is composed of multiple elements, including decision-maker, candidate alternatives, control variables, states of nature, outcome, decision criteria, utility and uncertainty. This section compares the four type of decisions observed in the case study using these elements.

The previous four sections described four decisions' outcomes identified through the three case studies described in Section 4.1. These sections illustrated how Twitter is used for decision-making in major incidents by three types of Subject-Matter Experts (SMEs): Public Information Officers (PIOs), journalists and Virtual Operation Support Team (VOST) members. They are the decision-makers analysed in this research, and their roles within an emergency make them treat Twitter from different approaches impacting their decision criteria and utility perception. For instance, PIOs used Twitter in the three case studies for risk communication and, therefore, decided to create tweets. Journalists also created tweets; however, further evidence was collected of the use of this platform to share published online news articles or identify events. VOST members in the eclipse and hurricane case studies did not use Twitter to share information or engage with content but focused on escalating information to the activating emergency organisation. However, VOST in the terrorist attack was active through their local, national and European Twitter profiles supporting risk communication strategies. In the case of journalists, ample evidence was collected of the use of Twitter to support news articles information.

Similarly, VOST in the United States provided solid examples of the decision of escalating tweets to emergency organisations and aided their situation awareness. Furthermore, VOST members had multiple backgrounds, including PIO and journalism, amongst others (e.g. academia, first responders, emergency managers) impacting their individual decision-making process and experience with different types of the decision outcome. Subject-Matter Experts (SMEs) are further described in section 4.3.

All these decision-makers had to consider several candidate alternatives during the described incident. Multiple control variable characteristics described them. For instance, the decision of creating a tweet included the sub decision of adding one or multiple of the following information pieces: geolocation, images, hashtags or URLs. Furthermore, any of these characteristics had unique states of nature, such as the image resolution or the spelling of the hashtag used. Multiple decision criteria were considered before any outcome was achieved. Within them, it is postulated that Information Quality (IQ) dimensions were evaluated which impacted the information verification

process followed. In the four decision-making outcomes considered, each decision's utility and uncertainty magnitude were related to the Perceived Quality Information (PQI). Table 4-4 maps the four decisions summarised in the above paragraphs. Those decisions have been further described in sections 4.2.1 to 4.2.4 against the key elements of a decision outlined in the literature review (Chapter 2, section 2.1.1). For each decision (Tweet, RT or engage in Twitter, publish a news article with a tweet, and escalate tweet to an emergency organisation), the researcher describes its outcome, the decision-maker observed in the case studies, the candidate alternatives considered, the utility, decision control variables, associated states of nature, decision criteria and uncertainty.

Decision-makers observed included Public Information Officers (PIOs), journalists and Virtual Operation Support Team (VOST) members. Not all performed the same actions in all case studies. For example, the decision *'Publish article with a tweet'* was only performed by journalists in all three case studies. On the other hand, VOST members 'Created tweets' in the Barcelona Terrorist Attack (BTA), but they did not in the other two case studies (eclipse and hurricane). For all those decisions, two exclusively candidate alternatives were considered: (1) to act, and (2) to not perform the action. For instance, in the decision 'RT or engage' each decision-maker had the alternative of engaging/interacting with an existing tweet (candidate alternative 1) or not doing it (candidate alternative 2). The decision was conditioned by different decision criteria, including the information quality, the tweet utility and uncertainty level. In addition, each tweet had different controls variables (e.g. hashtags, images) and state of nature (e.g. spellings) to achieve a candidate alternative (tweet or not tweet). For example, in the decision 'Tweet', the decision-maker needed to consider controls variables related to the text features to include in the tweet (e.g. hashtags, images) and states of nature of those (e.g. spellings of a hashtag). Examples of those were described in the previous four sections, and those selected as probes are presented in section 4.4.

Element and definition	**Tweet**	**RT or engage in Twitter**	**Publish article with a tweet**	**Escalate tweet to an emergency organisation**
Outcome *Consequences associated with implementing a candidate alternative given a state of nature.*	Create a tweet with specific states of nature	Share, like or reply a tweet with specific states of nature	Include a tweet in an article	Add tweet in VOST workbook or directly escalate to Emergency Organisation
Decision-maker *Individual or set of people who has to select an alternative.*	▪ Public Information Officer (PIO) ▪ Journalist ▪ VOST members	▪ Public Information Officer (PIO) ▪ VOST members	▪ Journalist	▪ Public Information Officer (PIO) ▪ Journalist ▪ VOST member
Decision criteria *Each dimension of an outcome which is significantly affected by choice of alternatives, and which decision-maker considers being critical in making his decision.*	▪ Information Quality (IQ) dimensions ▪ Other decision criteria			
Candidate alternatives *An alternative course of action, a candidate solution to a problem. They are mutually exclusive.*	▪ Create a tweet (multiple alternatives depending on the entities and attributes) ▪ No create a tweet	▪ Engage ▪ Do not Engage	▪ Use Twitter information in an article ▪ Do not use it	▪ Escalate Twitter information to an organisation ▪ Do not escalate

Element and definition	Tweet	RT or engage in Twitter	Publish article with a tweet	Escalate tweet to an emergency organisation
Utility *Used to identify the scalar measure of relative contribution to success. It may be done subjectively, intuitively or implicitly*	▪ Depending on the information piece ▪ Risk communication / Mass communication ▪ Provide situation awareness /other information	▪ Depending on the information piece and action taken ▪ Message amplification ▪ Information clarification ▪ Provide situation awareness	▪ Depending on the information piece ▪ Risk communication /mass communication ▪ Provide situation awareness /other information	▪ Depending on the information piece ▪ Provide situation awareness
Uncertainty *The magnitude of a decision criterion depends on the state of nature and the decision alternative. The magnitude of given decision criteria cannot be known with certainty at the time an alternative must be selected.*	Depending on the information piece			

Element and definition	Tweet	RT or engage in Twitter	Publish article with a tweet	Escalate tweet to an emergency organisation
Tweets Control variables *Characteristics that describe a candidate alternative. A change in one control variable, constitute a different alternative.*	Tweets with one or multiple of the following attributes: geolocation, Hashtags, media, URLs, user_mentions, symbols, polls, single media array of media objects.			
Tweets States of nature *A set of pertinent attributes describes nature. A 'state of nature' is identified by specifying a level or magnitude for the measure of each member of this set of attributes. There is a probability associated with each state of nature where the addition of all of them is equal to 1***.**	▪ Place object: id, URL, place_type, name, full_name, country_code, country, bounding_box, attributes ▪ Bounding box: coordinates, type ▪ Coordinates object: coordinates, type ▪ Hashtag object: indices, text ▪ Media object: display_url, expanded_url, id, id_str, indices, media_url, media_url_https, sizes, source_status_id, source_status_id_str, type, url ▪ Media size object: thumb, large, medium, small ▪ Size object: w, h, resize ▪ URL object: display_url, expanded_url, indices, url, status, title, description ▪ User mention object: id, id_str, indices, name, screen_name ▪ Symbol object: indices, text ▪ Poll object: options, end_datetime, duration_minutes ▪ Single media array of media objects: display_url, expanded_url, id, id_str, indices, media_url, media_url_https, sizes, source_status_id, source_status_id_str, type, url ▪ Media size object: thumb, large, medium, small ▪ Size object: w, h, resize			

Table 4-4 Decision-making elements observed by decision outcome (RQ1)

4.3. Experts in social media emergency management

The selection of suitable participants was paramount for successfully implementing the Critical Decision Method (CDM). In order to do so, experts were identified using section 4.2 information. Experts in this research area are people who have professional-related experience in the use of Twitter in major incidents. Furthermore, they had to be part of the case studies described in section 4.1.

This section first summarises the characteristics of the unit of analysis identified through the three case studies (4.3.1) and then describes the expertise of the ten Subject-Matter Experts (SMEs) interviewed (4.3.2).

4.3.1. Defining case studies Subject-Matter Experts

The identification of Subject-Matter Experts (SMEs) is a prerequisite for the implementation of the Critical Decision Method (CDM) (section 3.3). The researcher identified three relevant units of analysis from the literature review (Chapter 2, section 2.2.5). These were predefined in section 3.2.3:

- The first unit of analysis identified in the literature review (Chapter 2) and described in section 3.2.3.1 refers to Public Information Officers (PIOs). Their role was observed in the three case studies through tweets, news articles, and collaboration with other emergency stakeholders such as Virtual Operation Support Teams (VOSTs) and journalists. PIOs were actively in contact with the press, created tweets and provided press conferences. One of them promoted the activation of one of the VOS teams.
- The second unit of analysis included in this research are journalists (3.2.3.2). As described in the literature, journalists have the obligation of verifying information before publishing it. Furthermore, there is a growing interest in using Twitter data to document news articles as the case studies showcased in section 4.2.3.
- Lastly, the Virtual Operation Support Team (VOST) group was identified as experts in the use of social media for Emergency Management (EM). The literature showed the importance of digital volunteers in previous incidents.

However, this group differs from other types of volunteering initiatives as they are integrated with emergency organisations, and members usually have a background in EM.

This section describes the similarities and differences detected in the different unit of analysis through the three case studies. The researcher selected relevant case studies where VOST were active as the other unit of analysis were expected to be part of any major incident.

During the three incidents, Twitter activity was observed in real-time by the researcher. In the Barcelona Terrorist Attack (BTA), the researcher was alerted by an increase of activity in her Spanish network (friends and family) through WhatsApp, Twitter and Facebook. For the other two case studies, the researcher approached relevant VOS team leaders and joined the activated team (action research). In especial, emergency organisations and VOST Twitter accounts were monitored.

The researcher recognised differences between different VOST in the case studies analysis. For example, the decision of creating tweets and engaging with Twitter content (e.g. amplifying messages from official sources) was prominent in the BTA case study. Figure 4-12 shows the number of tweets published by day and hour by @VOSTCat. An increase of tweets can be observed after the incident and hours after the same.

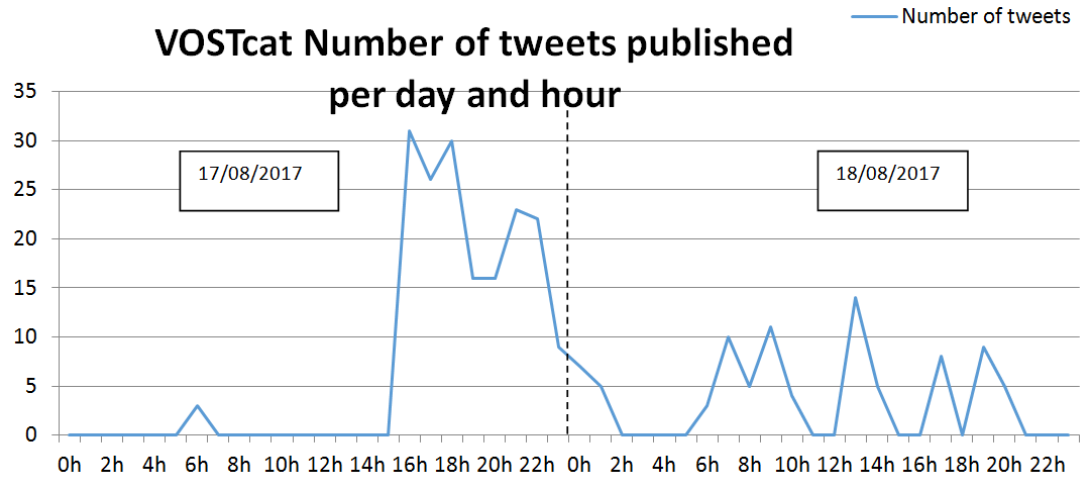


Figure 4-12 BTA- Number of Tweets posted by @VOSTcat (per day and hour)

In contrast, VOST members who had access to the official Twitter's VOST profiles for the eclipse and hurricane were reminded to not post or engage with content using that account. Accounts monitored during the BTA case study included @VOSTCatalunya, @VOSTSpain, @VOSTEurope, Catalonian police (@Mossos) and the coordinating emergency organisation (@EmergenciesCat). In the case of the eclipse (EC), local emergency organisations were monitored including accounts related to traffic updates, while for the Hurricane Harvey (HH) national accounts such as the Federal Emergency Management Agency (FEMA) in combination with state-level and local organisations in the United States of America (USA) were observed.

In the EC and HH case studies, VOST members' activity was better observed through the groups' interactions in Skype (section 3.4.4) and their annotation process in the VOST workbook and listening reports (section 3.4.5). The researcher gained access to the Oregon VOST team by contacting its team leader before the EC. Using Twitter hashtag #smemchat[39], the group actively participates in VOST's weekly Twitter chat in the States. On the 18th of August, the team leader published a tweet announcing that they were looking for volunteers to support their VOST activity during the Solar Eclipse. The researcher gained access to the VOST 101 Oregon Skype group and their Eclipse Workbook Google spreadsheet[40]. The profile of active members included first responders, students, academia and PIOs.

In the HH, the involvement of emergency organisations and VOST was of a national level. During the Harvey Hurricane, the State Florida University (SFU) VOS team was activated to support social media information management. However, as the incident developed and the emergency's magnitude became evident, additional human resources were required to satisfy all the information requirements from different Public Information Officers (PIOs) and emergency management organisations involved in the emergency. In this type of situations, the collaboration between multiple VOST is an asset, as the HH demonstrated.

[39] #smemchat hashtag created for social media emergency management chat
[40] VOST reporting tool (artefactd escribed in section 3.4.5 of the methodology in Chapter 3)

The Oregon Virtual Support team was activated as the Florida Virtual Support Team required additional help during the recovery phase. The researcher learned that VOS Teams (VOST) are activated to perform specific functions supporting affected organisations and jurisdictions. As described in Figure 4-13, each VOST has a Team Leader that reports directly to the affected organisation/jurisdiction. When multiple VOSTs are established in an area or country, a VOS Group (VOSG) may be created to coordinate the work of the VOSTs to maintain a useful span of control. The VOSG has a Group Supervisor that reports to the affected organisation/jurisdiction. In turn, the VOST Leaders report to the Group Supervisor.

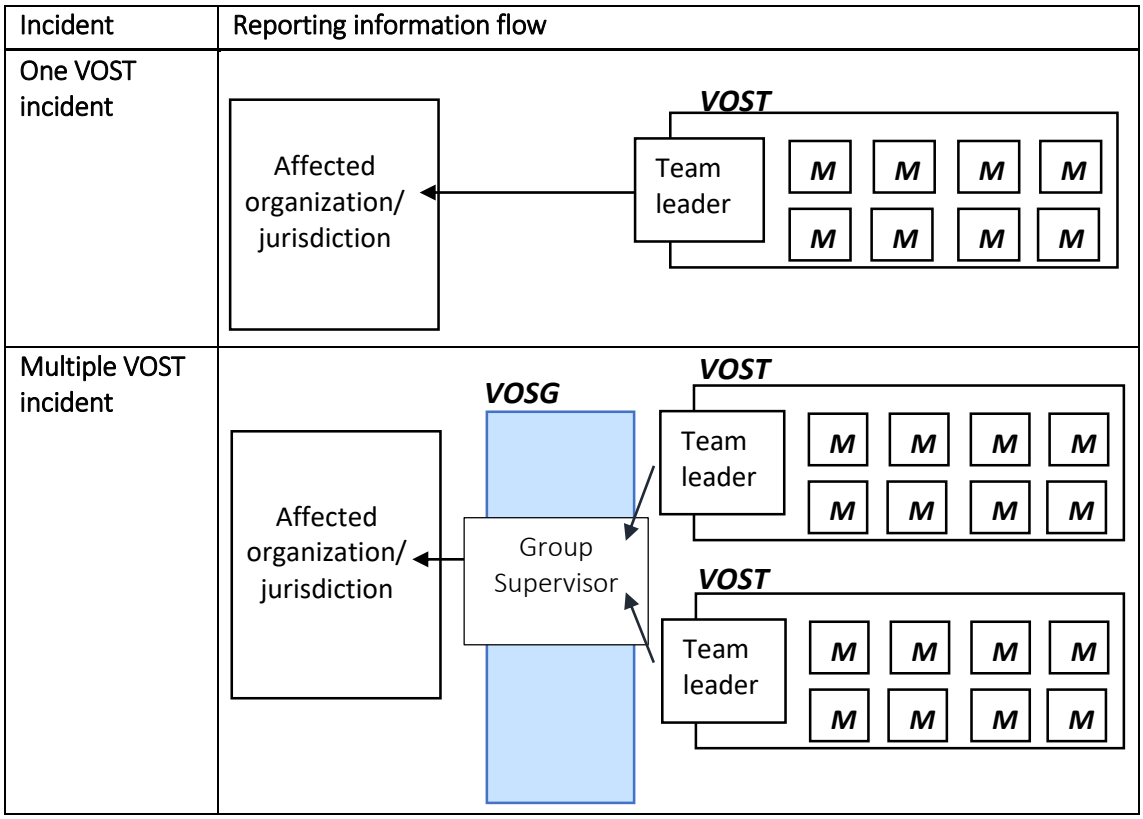


Figure 4-13 VOST reporting structure

In this case, the VOSG was coordinated by the South Florida University VOST, and Oregon VOST supported their activities. As part of the Oregon VOST, the researcher received a notification for the group activation to support the task of identifying misinformation and fake profiles claiming to collect donations for affected citizens.

In the eclipse and hurricane case studies, Skype became the primary tool for coordinating the team and supporting the decision-making process. Team members were encouraged to discuss their findings and to add them to the Workbook.

Twenty-six participants contributed during the eclipse activation posting a total of 2120 messages over 3 days. During the activation, twelve members were added to the group chat, and they were a total of 26 active participants in the Skype conversation. This is relevant as the workbook includes search findings of only 12 members (VOST Oregon, 2017f). Looking at the chat room's activity level, the team leader was the most active with 675 messages (31.84% of the dataset).

During the Harvey activation, 27 participants took part in Skype conversations posting a total of 1926 messages over 12 days (approximately 160 messages per day). The team was mobilised through Skype (VOST Oregon, 2017h) upon Texas emergency management organisations' request. Despite the leading group being coordinated from Oregon, several participants were located elsewhere, including Texas and the UK. During the activation, five new members were added to the Skype group chat. Three participants account for 52% of the messages posted on this activation.

Figure 4-14 provides an overview of the messages published by day in the Oregon VOST group. It is possible to observe that the more significant number related to the event during the activation dates: 17th to the 21st.

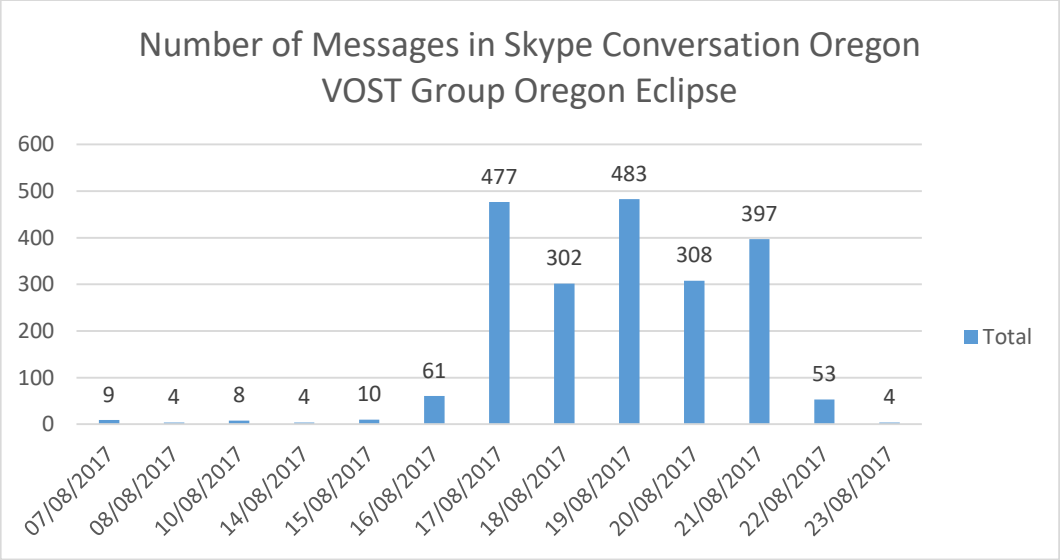


Figure 4-14 EC- Number of messages in the Oregon VOST Skype group (per day)

The busiest period in the Skype group was during office hours. The volume of messages reflects the type of virtual operators within the group, as they are allowed at work or have the time to monitor during these hours. Additionally, the event took place on a Monday; therefore, monitoring was also performed over the weekend.

Similarly, Figure 4-15 provides an overview of the total messages published by day in the Skype group chat for the Harvey Hurricane. A decrease in messages was noticed after the first five days of activation.

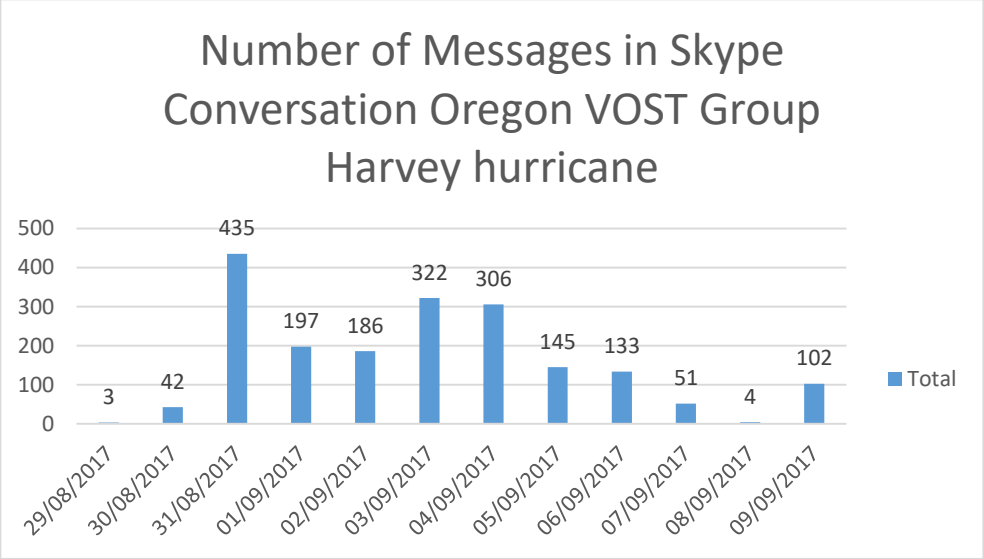


Figure 4-15 HH- Number of messages in the Oregon VOST Skype group (per day)

In conjunction with the participants' contribution to the Workbooks, the analysis of this data helped to identify relevant Subject-Matter Experts (SMEs).

In the EC, 64 messages were logged in the Workbook by twelve members who monitored social media and online resources during 150 hours. In the HH, 368 entries were the result of 100 monitoring hours of 14 members. These entries were evaluated and used as a probe to recall the decision of escalating this information to the relevant emergency organisation. Lastly, some of the items highlighted in these reports were also part of news articles. The researcher evaluated over 1054 news articles and focused on these discussing rumours and misinformation (see section 3.4.2 for a detailed description of the source of evidence). The analysis of this information helped to identify probes and relevant journalists for interviews. A trend was detected in the Spanish and American online newspapers where a single web page in a newsfeed format was

updated with relevant information as the emergency unfolded. This reporting approach decreased the number of web pages published in the HH and BTA case studies by these journals and provided rich information while showcasing the emergency timeline.

The triangulation of multiple sources of evidence helped the researcher to identify suitable candidates for the CDM interviews. A total of 47 SMEs were identified as potential participants of this study. The researcher interviewed 10 SMEs accounting for 75 decision-making processes. First, each unit of analysis was compared against the four decision outcomes described in section 4.2: (1) Tweet information, (2) RT / engage in Twitter, (3) Share tweet in other mass communication media, and (4) Escalate a tweet to an emergency organisation. Table 4-5 summarises these findings by cross-comparing each unit of analysis grouped by case study against the decision-making outcome observed. For example, in the Barcelona Terrorist Attack, Public Information Officers (PIOs) and the Virtual Operation Support Team (VOST) tweeted information about the event unfolding, while the action of composing tweets was not part of the VOST groups observed in the other two case studies.

		Decision-maker type by case study								
		Barcelona Terrorist Attack			Eclipse			Hurricane Harvey		
Decision-making Outcome observed		PIO	Journ	VOST	PIO	Journ	VOST	PIO	Journ	VOST
Production	Tweet information	✓		✓	✓			✓		
	RT / engage in Twitter			✓	✓			✓		
Consumption	Share tweet in other mass communication media	✓	✓		✓	✓		✓	✓	
	Escalate tweet to an emergency organisation		✓	✓			✓			✓

Table 4-5 Decision Outcome vs Decision-maker type (unit of analysis)

Each SMEs was evaluated individually and ranked by the evidence collected through the case studies. The researcher contacted suitable SMEs following that order to prioritise candidates with a higher quantity/relevant input for the analysed probes (section 4.4). A total of 10 SMEs were interviewed (4.3.2). The researcher stopped pursuing other potential SMEs when interviewees were not adding new information to the questions proposed. The next section describes these 10 SMEs in their decision-makers' role for one or multiple decisions outlined in section 4.2.

4.3.2. Description of the CDM decision-makers

The previous section had described what is considered a Subject-Matter Expert (SME) for this research and described them as a unit of analysis. While the interviewees' selection was based on the decision outcome collected for each case study (as illustrated in Table 4-5, page 244), their validity as SMEs for this research was further evaluated during the interviews. In particular, it was considered that people prepared for one type of emergency are not always ready for another type (Helsloot & Ruitenberg, 2004). Thus, to minimise this potential limitation in the findings, the researcher included two interview questions to define the selected SMEs profiles better. As described in Chapter 3, these questions referred to the SMEs' number of years using Twitter in major incidents and in what type of emergency incidents they used this tool.

In this section, findings of the expertise of the subjects interviewed are summarised. In order to facilitate logical generalisation of the research findings, the researcher included questions to define the SMEs profile better. As described in Table 4-6, ten interviews were performed with Subject-Matter Experts (SMEs). Three of them had experience as journalists, five of them worked as Public Information Officers (PIOs) in an emergency organisation, and seven were VOST members. Besides, five are VOST leaders, and therefore, they are in charge of managing their VOST Twitter profiles (i.e. creating a post and acting as PIOs of their group).

Interviewee ID	Public Information Officer	Journalist	VOST member	Notes
BTA1	✓		✓	Emergency Management Director (European 112 phone number). VOST leader. Ten years of experience providing emergency management Information Systems.
BTA2	✓		✓	Twenty-five years' experience as an emergency coordinator and first responder. VOST leader.
BTA3	✓		✓	Emergency coordinator. VOST leader.
BTA4	✓	✓		Set up his organisations' Twitter account.
BTA5		✓		
EC/HH6	✓		✓	VOST leader. Set up his organisations' Twitter account.
EC/HH7			✓	
EC/HH8			✓	Specialised in Fire.
EC/HH9			✓	Emergency coordinator in a University setting. VOST leader.
HH10	✓	✓		

Table 4-6 SMEs (unit of analysis) interviewees profiles

Two of the interviewees were responsible for the implementation of Twitter within their emergency organisation. This social media platform was created in 2006, and on the date of the interviews (2017), all interviewees bar one had over two years' experience in the use of social media platforms for emergency management. The interviewees' average was five years' experience with a maximum of a public information officer and a journalist with seven years' experience.

When asked about what other incidents they had previously supported emergency related-task with information from Twitter, SMEs listed the following incident types (Figure 4-16): terrorist attacks, fires, floods, health outbreaks, earthquake, snowstorms, chemicals incidents, and transport accidents (train track derailment, aeroplane crash, and bus crash). Multiple emergencies were listed under each incident type. For example, Europe-based interviewees mentioned by name a more significant number of past

experience related to terrorist attacks. These included attacks in France, the UK, and Switzerland.

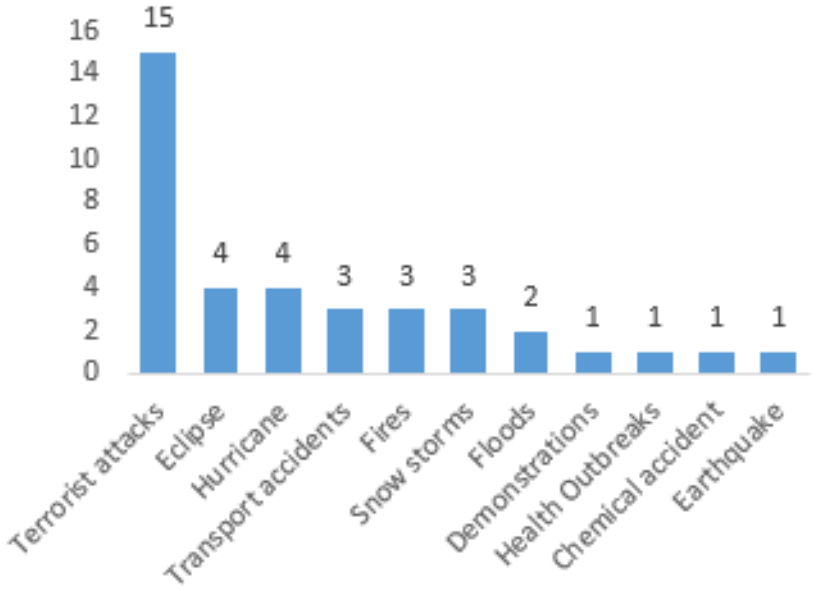


Figure 4-16 Interviewees' experience : number of incidents where they used Twitter according to emergency types

USA-based interviewees described their activation level according to Type 1 and Type 2 emergencies (larger and smaller-scale national or state level incidents). They framed their experience in social media emergency management concerning the numbers of hours activated. For example,

> ***EC/HH6:*** *I would say, overall, probably approximately 20 [VOST activations]. It is for larger activations. I consider a larger activation an activation that we put more than 200 hours.*

> ***EC/HH7:*** *so I started doing the type 1 incidents in 2012, and it has been 1,560 hours over the last 7 years.*

Despite the sample of interviewees being relatively small, the approach of using Subject-Matter Experts (SMEs) as part of the case studies increases the external validity of this study. In addition, on the interview date, these experts had a combined experience of 35 years in the use of social media for emergency management. Some of them are acknowledged leaders in their field by participating in different VOST groups or their role in emergency management international organisations (e.g. director of 112 European phone number, FEMA employee). Moreover, they provided insight into the decision-

making process from two different perspectives, creating and consuming tweets, through their reported experience using Twitter in 38 combined emergency incidents.

Interviewees were identified by evaluating the case studies' source of evidence and their role as decision-makers. In conclusion, the relevance and the validation of their input in this research reside on their previous experience and their identified role in evaluating the specific probes' uncertainty level identified as tweets (section 4.4).

4.4. Twitter probes: case studies and uncertainty implications

Through the three case studies, the researcher selected sixteen probes. Those are described in this section and represent information requirements outlined in section 4.1.4. The selection of these probes aimed to elicit knowledge from Subject-Matter Experts (SMEs) in order to gain insight into their decision-making process. As part of the interviews, the inclusion of one or another probe was motivated by the evidence collected. At least one of the interviewees had used that tweet (a piece of information) to inform one or multiple outcomes (decisions) described in section 4.2. Table 4-7 (page 249) summarises each case study probe against the decision-making evidence collected through the case studies.

As described in section 4.2, four decisions were identified: (1) the creation /engagement of a tweet, (2) the decision of sharing a tweet, (3) the decision of sharing the content outside Twitter (e.g. news article), and (4) the decision to escalate the information to an emergency organisation. The researcher collected evidence of creating a tweet in all probes except one (probe 8). Evidence of answering to tweets is also provided as part of multiple probes showcasing the bi-directional capabilities of Twitter. Articles published debunking rumours were collected as a source of evidence in the case study and utilised to select decision-makers and probes. Lastly, Virtual Operation Support Team (VOST) workbooks and listening reports for the Hurricane Harvey (HH) and Solar Eclipse (EC) aided to identify probes that were escalated to emergency organisations. The researcher did not have access to these artefacts for the Barcelona Terrorist Attack (BTA); nevertheless, evidence collected through the interviews related to probes 4, 5

and 6 described the escalation process to relevant emergency managers through a phone call.

Case Study	Probe reference		Create a tweet	Reply a Tweet	Create a News article	Escalate to Emergency Organisation	Reference to Evidence collected
BTA	1	Terrorist Level	✓		✓		Image shared in Twitter
	2	Incident vs terrorist attack	✓	✓	✓		Twitter conversation
	3	Number victims	✓	✓	✓		National and International evidence
	4	Bar hostages	✓		✓	✓	A phone call between a VOST member and a Police representative
	5	Interpreters	✓		✓	✓	A phone call between a VOST member and a public information officer
	6	Blood donation	✓		✓	✓	Tweet
EC	11	Electronic devices	✓		✓	✓	Multiple tweets
	7 and 8	Parking			✓	✓	Reported to Twitter and account removed
	9 and 10	Gas Shortage	✓	✓	✓	✓	Meme created as a response
HH	12	Harvey Gas	✓		✓	✓	Tweet
	13	Water drink	✓		✓	✓	News article
	14	Airport Flooded	✓		✓	✓	Tweet
	15	Shark Image	✓		✓		Tweet
	16	People looting	✓		✓	✓	Tweet, news article

Table 4-7 Case study rumours/misinformation probes against identified decisions

Some SMEs were active in more than one case analysed (i.e. Eclipse and Harvey Hurricane). In some scenarios, evidence was gathered of more than one decision-makers individually evaluating the same probe during the emergency selected (e.g. two different VOST members, or a VOST member and a journalist evaluating one probe). To gather further information, all case studies' probes selected were showed to the SMEs

active in each case study, even if no prior proof of a decision was gathered. For each probe, they were asked about their familiarity with the tweet displayed and to evaluate it. All interviewees decisions described in Table 4-7 were made to reduce the uncertainty associated with the misinformation or rumour shared. The description of 75 decision-making processes was documented through the interviews (section 4.6).

In the interviews, SMEs were asked about their role during the case study and the purpose of their activation. All interviewees revealed directly or indirectly their part in debunking rumours and reducing uncertainty levels.

> ***EC6****: They would like to have situational awareness of what people was saying in social media so they could crack the messages in a more meaningful way or see if there was information being shared in social media that they wouldn't know anything about it.*
>
> ***BTA1****: From the beginning, we monitored and published advice, RT of Mossos, Emergencies de Catalunya, of 112, and of course try to identify rumours*

Probes identified aimed to illicit SMEs' knowledge in addressing the identification and debunking of rumours; therefore, all probes selected were acknowledged as a rumour at some stage during the development of the three incidents analysed by at least one interviewee.

The following three sections define the tweets selected for each case study more in detail and the uncertainty implications described by the respondents. Section 4.4.1 focuses on the uncertain information identified in the Barcelona Terrorist attack (BTA). A total of 6 probes were used as part of the Critical Decision Method (CDM) interviews, and they are described in detail. Section 4.4.2 addresses misinformation identified in the Solar Eclipse (EC) in Oregon. Tweets used as a probe are presented to the reader. Lastly, section 4.4.3 summarises the microblogging post used in the interviews with SMEs from the Hurricane Harvey (HH) case study. Each section provides background, the description of the probe, the uncertainty associated with it according to the interviewees and key information dimensions outlined as part of the decision-making process. These findings are further elaborated in section 4.4.4 by cross-comparing the three case studies.

4.4.1. Terrorist attack: uncertainty implications

Uncertainty levels during a terrorist attack are considered high by emergency managers. During the analysis of the data collected, the researcher identified 34 tweets with uncertain information that had prompted a documented decision (e.g. qualified as rumour or misinformation). A selected number of these tweets was used as probes during five Critical Decision Method (CDM) interviews. Five areas of uncertainty were detected through the Barcelona Terrorist Attack case study analysis (section 4.1.4). They were related to the cause of the emergency, the number of injured and casualties, the location of terrorists and hostages, the terrorist alert level declared, and the support available and required to victims and families. This list does not aim to be exhaustive but illustrates uncertain information detected during the analysed case study.

Probe 1: Uncertainty of terrorist level

The first uncertain item used was related to the 2017 terrorist level declared in Spain. The importance of this information resides in the mobilisation of operatives and the emergency measures declared in the country. The tweet selected (Table 4-8) helped to illicit knowledge referent to the evaluation of the source, in addition to the information.

Tweet image	Translation to English
	<<organisation>> No more #false information. The current terrorist level is #NAA 4

Table 4-8 Barcelona Terrorist Attack (BTA) uncertainty Twitter probe 1

As stated by an interviewee, the uncertainty level raises through the form and the content shared:

> ***BTA1**: It is transferred in a way similar to the official source, and people do not verify, and they believe it and send it to all their contacts. And then, everyone believes that we are in maximum alert and something will happen fast. Therefore, from months before the attack and even after the attack, it is required to remind that the emergency level hasn't changed. Excuse me, the antiterrorist level.*

All interviewees in the BTA case study were familiar with the information displayed in this tweet and reported at least one action to debunk this information (e.g. write an article or a tweet). They recommended evaluating this information based on official sources messages and, therefore, on the reputation of the source.

Probe 2: Uncertainty related to the emergency type

In the first few minutes after a terrorist attack, uncertainty associated with the facts was detected. The researcher observed several tweets posted by citizens expressing their fear and asking about the incident and its likelihood of being a terrorist attack. Initially, official sources reported that an incident had taken place; however, this was quickly challenged by mass media and citizens. Evidence was gathered of these moments of uncertainty and the evolution of the facts. As stated by an interviewee:

> ***BTA1**: If the official information does not talk about an attack, if it does not say a terrorist attack… we cannot say a terrorist attack because we will be lying. If the first suspicious is an accident and then it evolves to a terrorist attack, then it is evident that the information is going to evolve.*

Proof of this uncertainty and decision-making outcome was collected through different tweets. For the purpose of the Critical Decision Method (CDM) interviews, a tweet posted by a trusted source and the associated reaction from a citizen (Table 4-9) was used to elicit knowledge from the Subject-Matter Experts (SMEs). This tweet showcases two decisions: the creation of a tweet and the response to a comment. However, evidence of other outcome was registered through the interviews, such as escalation to emergency organisations and publication of a news article.

Tweet image	Translation to English
	<<organisation>> A massive accident just took place in Las Ramblas Barcelona. A person in a van. Do not go near to the zone. *<<citizen>>* An ACCIDENT???? *<<organisation>>* If you follow up the conversation, you'll see that after the official confirmation, we are talking about a terrorist attack.

Table 4-9 Barcelona Terrorist Attack (BTA) uncertainty Twitter probe 2

Key dimensions identified during the evaluation of the information included timeliness, accuracy, completeness, appropriate amount of information, comparability and reputation.

Probe 3: Uncertainty of the number of injured and casualties

The number of injured and casualties was initially unknown and created many tweets related to the victims. Tweets included a request for updates and multiple images/videos of victims. Citizens, mass media and Public Information Officers (PIOs) decided to share or not this content on Twitter and other channels depending on their agenda. It was noted that this type of information shared by citizens could create despair reactions from victims' family and friends. As stated by an interviewee:

> ***BTA2****: I think to know the number of people is not that important. The same with the photos. We are continuously saying it. We do not want to know or see images of people dead or there on the ground because we are aware that there is a family, there is loads of family, friends... we do not want this type of information.*

Without entering into how ethical it is to share images and information of other people on social media, the selected tweet (Table 4-10) focused on illustrating the number of casualties cited by different sources (i.e. press versus official sources). This tweet allowed to evaluate the decision-making process of Public Information Officers (PIOs) (as they cited one casualty); journalists (as they referred to thirteen casualties), and

VOST members as the team created a post and replied to the citizen who used their tweet as a reference.

While the probe focus on the BTA, uncertainty related to the number of casualties, this kind of uncertainty can be observed in different types of incidents, for example, an interviewee described a similar situation in a train derailment which was observed through Twitter:

> ***EC/HH9**: [train track derailment that was in Dupa Washington] Our local news agency stations started to quote each other on the number of fatalities, so the number quickly rose from three to nine and so be able to track down how that number went from 3 to 9 when the official sources were saying 3 was actually to be able to connect the dots and being the news outlets for quoting themselves and not necessarily the official sources. So be able to actually manage that and let the PIOs know and quickly correct that inaccurate number was highly important.*

Therefore, feedback collected from other participants is also relevant to this scenario.

Tweet image	Translation to English
	<<citizen>> While news reports claim 13 casualties, official sources claim just 1. I do not understand it. *<<organisation>>* We have official confirmation from @mossos. Provisional information: 1 dead and 32 injured, 10 of them serious. *<<organisation>>* We do not understand it either <<citizen name>> but, we are relying on the official information. We are waiting for an update.

Table 4-10 Barcelona Terrorist Attack (BTA) uncertainty Twitter probe 3

Key dimensions identified as a potential solution to support decision-making to reduce uncertainty were value-added, accessibility, completeness, timeliness, accuracy, and reputation.

Probe 4: Uncertainty of terrorist location and hostage situation

The fourth uncertainty item used as a CDM probe (Table 4-11) was related to the location of the terrorists. A rumour was shared through Twitter and other mass media channels describing that terrorists held hostages inside a bar (García et al., 2017; Lytvynenko, 2017).

> ***BTA5****: Yes, I remember this because… there was very confusing information concerning which one was the bar. They were talking of 'La Luna de Estambul', then they changed the name a few time, but of course it was always a Turkish restaurant. And they didn't know... of all Turkish restaurant that there are in the area, there are loads of them, and all of them have similar names, which one they were referring to.*

Tweet image	Translation to English
	<<organisation>> Today's false information: someone is inside a bar in downtown holding citizens as hostages… Raise your hand if you said that? STOP false information

Table 4-11 Barcelona Terrorist Attack (BTA) uncertainty Twitter probe 4

Official sources and VOST Twitter accounts debunked this information in due course. The temporality dimension was crucial in this decision-making process as stakeholders knew this information's falseness in advance. Therefore, the decision-making process of different Subject-Matter Experts was cross-examined.

> ***BTA2****: There was a moment where we debunked that there were hostages in a bar, we said 'No'. And we had this information for a long while because we*

> *phoned the police and we said 'listen, is this true?'. They said 'No, but do not say anything yet because…' we have also to respect official forces' efforts too.*

Interviewees referred to different Information Quality (IQ) dimensions to aid the decision-making process, including believability, completeness, comparability and representational consistency.

Probe 5 and 6: Uncertainty of support available and required

The last piece of information used in this case study was related to the support available and requested by official sources. Two tweets were displayed for this category which referred to the requirement of translators in hospitals and the need for blood donations (Table 4-12).

Tweet image	Translation to English
	<<organisation>> French, English and Italian translators are required in the Hospital del Mar, Clinic and Vall d'Hebron. All help is few. IT IS NOT TRUE. FAKE NEWS. FALSE.
	<<organisation>> It has been shared in social media that hospitals are requesting blood donations. There is NO an official request, we repeat there is NO an official request… https://t.co/U1X18aAKX

Table 4-12 Barcelona Terrorist Attack (BTA) uncertainty Twitter probe 5 and 6

Interviewees agreed that people would share this type of information with their best intention. As stated by an interviewee:

> *EC1: Obviously, in an attack with multiple victims, the first thing that people think is blood will be needed in the hospitals. However, if there is not an official request from the blood bank or emergency services… then obviously do not go until you know that it is needed. In fact, blood usually is not required straight away but days afterwards. In an event with a limited number of victims, it is more likely that it is required the days after and not on the attack day.*

Goodwill was reported as a potential problem for emergency managers and volunteer organisations. For instance, the donation of items after hurricanes is a handicap for the effective management of resources as second-hand items must be sorted and stored adequately before distribution delaying the opportunity to support people in need. The evaluation of this information should include Information Quality (IQ) dimensions that refer to objectivity, reputation, accuracy and relevancy.

4.4.2. Solar eclipse: uncertainty implications

The task defined in this incident focuses on decision-making performed before the solar eclipse using Twitter information as the researcher observed a large number of tweets in this phase. Oregon County expected to receive a total of 1 million visitors. The uncertainty for this event was related to unknowns associated with crowd management (number of visitors, traffic requirements, the relationship between supply and demand of essential goods) and health issues (the probability of being impacted by wildfires). Several active fires were in the area days before and during the Eclipse in Oregon; additionally, the weather conditions made it suitable for the start of fires by people camping over the weekend before the eclipse or just by the touch of the exhaust of any car. Other worst-case incidents were also well-thought-out by emergency teams; however, their probability was lower, and while they were considered, they are not included.

Probes 7 and 8: Crowd management uncertainty

The first EC uncertainty considered was the management of a large number of people in the area. As described in section 4.1, numerous out-stated visitors were expected. Uncertainty about the impact of this was amongst the area residents. Hot items included

the increase in demand for petrol, access to critical areas and the ability to accommodate people and vehicles.

The next item reviewed referred to a fake account that claimed that parking was possible in different parts of the city of Salem free of charge (Table 4-13). This tweet was reported using a Virtual Operation Support Team (VOST) listening report, and appropriate actions were performed to remove this account. The researcher did not have access to this account; however, a citizen's reference was identified and showed as a probe. It also demonstrates the ability to use Twitter to request clarification from emergency organisations (targeted question).

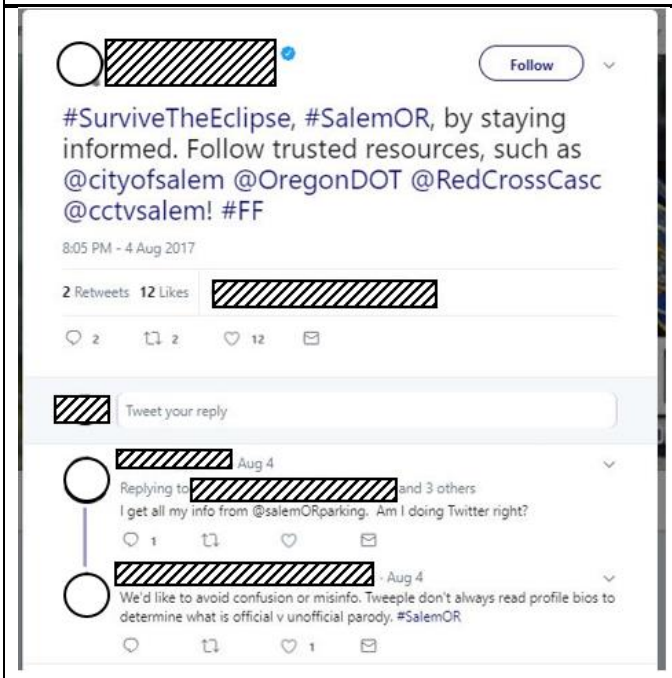
Tweet image	Text
	*<<organisation>>* #SurviveTheEclipse, #SalemOR, by staying informed. Follow trusted resources, such as @cityofsalem @OregonDOT @RedCrossCasc @cctvsalem! #FF Comments: *<<citizen>>* I get all my info from @salemORparking. Am I doing Twitter right? *<<organisation>>* We'd like to avoid confusion or misinfo. Tweeple do not always read profile bios to determine what is official v unofficial parody #SalemOR
In reference to @salemORparking Twitter account (from VOST listening report): One twitter post this morning from a City of Salem "spoof" account (fake account) claimed that the City of Salem was not enforcing city park rules "or any other rules that we normally abide by". The city has been alerted regarding this.	One twitter post this morning from a city of Salem 'spoof' account (fake account) claimed that the City of Salem was not enforcing city park rules ' or any other rules that we normally abide by'. The city has been alerted regarding this.

Table 4-13 Oregon Solar Eclipse (EC) probe 7 and 8

Quality dimensions outlined by interviewees included reputation, believability and representational consistency.

Probes 9 and 10: Fear of access products that covered basic needs

In this case, the fear of accessing essential goods, in this case, diesel (Table 4-14).

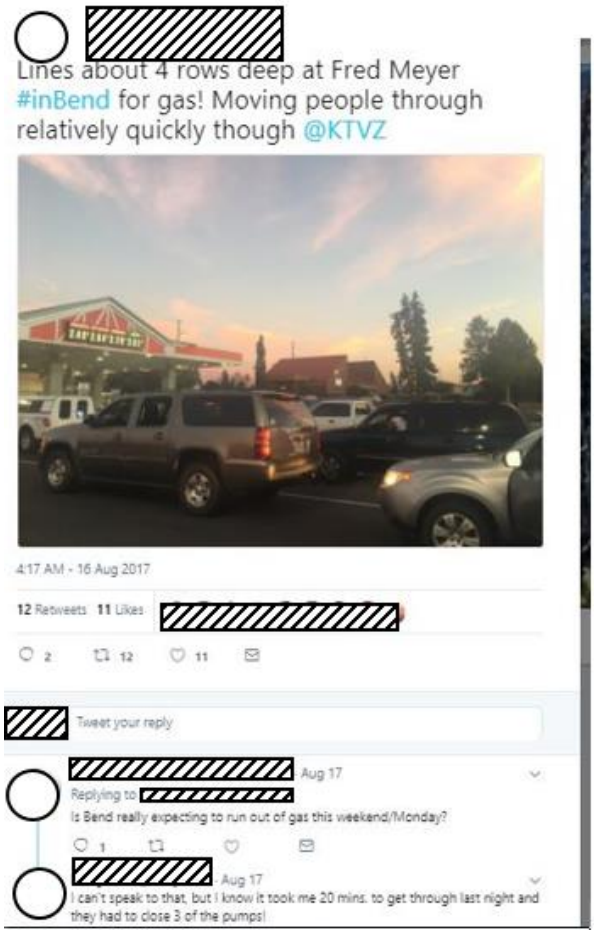
Tweet image	Text
	*<<Journalist>>* Lines about 4 rows deep at Fred Meyer #inBend for gas! Moving people through relatively quickly though @KTVZ Comments *<<citizen>>* Is Bend really expecting to run out of gas this weekend Monday? *<<Journalist>>* I can't speak to that but I know it took me 20 mins to get through last night and they had to close 3 of the pumps!
	<<organisation>> Truth. #OReclipse #Eclipse2017 Image: Do not be that guy! There's enough fuel to go around #OReclipse

Table 4-14 Oregon Solar Eclipse (EC) Probe 9 and probe 10

Several tweets were shared, referring to people queuing to fill their tanks. Additionally, rumours circulated on Twitter about an increase in petrol price up to $5 a gallon (Boyle, 2017). Two tweets were selected to motivate the discussion of this topic. The first one illustrated the problem: an image of people waiting. The second one, a meme shared as a response to palliate the issue by a Public Information Officer (PIO).

Dimensions outlines by respondents included value-added, accuracy, completeness, reputation.

Probe 11: Uncertainty about technological disruption

The third item presented was related to citizens' uncertainty about technological implications of the eclipse in specific to phone devices (Table 4-15).

People were advised not to take back roads. As described by Jennie Demaris, Lincoln County emergency manager:

> '*Cell phones won't be able to access maps because we only have so much bandwidth. Local cellular portals will be overwhelmed and may not be available to you.'*(L. Tobias, 2017)

The tweet selected presented several citizens sending messages asking for information on Twitter. They were directed to @NASA, and while not respondent works for the NASA, these messages were commented on by the VOST members.

Tweet image	Text
	Citizen 1: @NASA is true that we need to turn off our phones when the eclipse happens? *Citizen 2*: @NASA can these cosmic rays really harm our phones tablets etc?! *Citizen 3*: Anyone else get some random warning msg about some cosmic rays tonight that one should turn their mobile phones off for?? #NASA #WORDNews

Table 4-15 Oregon Solar Eclipse (EC) Probe 11

Information Quality (IQ) dimensions remarked included believability, completeness, reputation, comparability and representational consistency.

4.4.3. Hurricane: uncertainty implications

The last five probes presented here refer to the Hurricane Harvey case study. While the scientific community mostly predicts hurricanes in advance, the uncertainty levels are high concerning the impact of hurricanes and associated events. As can be appreciated in the Hurricane Harvey timeline description (see section 4.1.3), a hurricane's evolution can change in a few hours by increasing or decreasing its magnitude from a tropical wave, hurricane or storm. The uncertainty is therefore associated with the phenomenon itself and activities surrounding the response and recovery.

The application of the Critical Decision Method (CDM) to better understand the decision-making process while evaluating tweets after the hurricane was facilitated by the information gathered through the case study, including communication channels (Skype), the information collated in the VOST Workbook and two teams report, observation, tweets analysis and newspaper articles. Five interviews were performed using five probes and evaluating three uncertainty issues that prompted the development of rumours.

Probe 12 and 13: Fear of no access to basic needs products

During Hurricane Harvey, evidence was collected concerning the uncertainty to access products and services to cover basic needs such as water and petrol. The Texas Attorney General's Office reported over 600 complaints related to high-prices for water, petrol, food and accommodation:

> *'Specifically, we've seen $3.50 for gas in Houston, $8.50 for bottles of water and $99 case of water complaints. We also received a complaint about one Houston convenience store charging $20/gallon of gas," spokeswoman Kayleigh Lovvorn said in an email.'* (Young, 2017).

Two probes were selected to evaluate the decision-making process (Table 4-16). The first was a rumour related to access to water. Houston OEM had to belie that the water was being shut off in the area and ensure that it was safe to drink on the 27th of August (Broder Van Dyke et al., 2017; R. F. Graham & Smith, 2017). It was reported that one of

the city's water plants was flooded, and misinformation spread concerning water being contaminated, increasing uncertainty about how safe it was to consume tap water. (Martinez, 2017). On the 31st of August, CNN, (CNN Español, 2017c) reported that the city of Beaumount (Texas) had no access to drinkable water, and citizens had to queue to access water and food.

Like the probe described in the Oregon Eclipse, the second probe referred to citizens' access to petrol. Reports about motorists' queues in petrol stations after a rumour were shared on Twitter (Cantu & Staff, 2017). The tweet selected shows Christi Craddick, chairman of the Texas Railroad Commission, asking Twitter users not to perpetuate rumours, and he ensured that there was no *'gas shortage'* (Kera News, 2017). As one of the interviewees stated:

> ***EC9:*** *I work for state <<removed for confidentiality purposes>> office, so I also know that there wasn't necessarily an actual shortage of gasoline, it was a human cause shortage based on demand.*

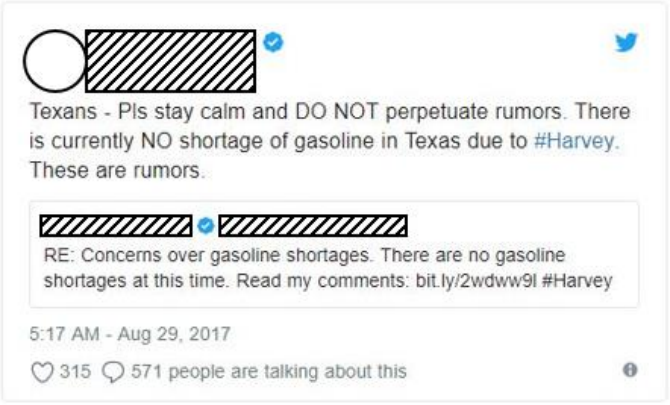
Tweet image	Text
	*<<organisation representative>>* Texans- Pls stay calm and DO NOT perpetuate rumors. There is NO shortage of gasoline in Texas due to #Harvey. These are rumors. RT *<<organisation representative>>* RE: Concerns over gasoline shortages. There are no gasoline shortages at this time. Read my comments: <<link>>
	<<organisation>> RUMOR: @HoustonPWE is NOT Shutting off water. Water is currently safe to drink and meeting 100% of the need. #harvey #houstonflood

Table 4-16 Hurricane Harvey (HH) Probe 12 and Probe 13

Interviewees mentioned checking official sources as their first verification protocol to reduce the uncertainty of this information. They stated that providing accurate

information is "*part of their job"* (**EC9**). Additionally, reference was made to providing timed updates and information that included added value.

Probe 14 and 15: Uncertainty about the magnitude of the emergency and associated events

Uncertainty about the magnitude of an emergency may impact evacuation decisions and activities to protect property. Doubts about official information can endanger lives. The two selected probes are supposed to showcase the devastation of the hurricane through two images. They provide evidence that the unknowns of an emergency can make tampered images more credible. Two examples were selected to gather feedback from decision-makers in order to assess how to decrease the likelihood of falling for this information (Table 4-17). The first tweet selected refers to an image and text making reference to Houston airport being inundated. The second tweet is a recurrent rumour which illustrates a shark swimming in a flooded area. This image had been used in previous disasters, and it is in fact used as a piece of evidence for previous research for a different hurricane (Sandy) in the area of fake content analysis (i.e. Gupta, Lamba, Kumaraguru, & Joshi, 2013a).

> *'Social media sites post a photo claiming there is a shark... and people fall for it. The photo below is not Houston, and the shark was "creatively edited" in'.* (Martinez, 2017)

> ***EC9:*** *It is the same shark. So, it is literally the same image, and they superposed over stuff.*

Tweet image	Text
	<<organisation>> Caution, this picture is not Houston Airport but a fake from an older picture of LaGuardia Airport #Harvey
	<<citizen>> Believe it or not, this is a shark on the freeway in Houston, Texas #HurricaneHarvey

Table 4-17 Hurricane Harvey (HH) Probe 14 and probe 15

Key dimensions termed included representational consistency, amount of information, reputation, and believability.

Probe 16: Crowd management

Also, multiple tweets were seen under the hashtag #HarveyLootCrew describing looting taking place; however, the Houston Police Department stated that very little looting occurred during the first week of flooding (Emery, 2017).

Tweet image	Text
	<<organisation>> Social media rumours are not confirmed. Metrocom Dispatchers report absolutely no confirmed reports of looting anywhere in our city #Harvey

Table 4-18 Hurricane Harvey (HH) Probe 16

4.4.4. Twitter probes cross-analysis

The sixteen probes presented to the Subject-Matter Experts (SMEs) shared commonalities in form and content. All probes bar one were presented to SMEs in the form of a tweet. They highlighted uncertainty elements in the area of crowd management (e.g. probe 3, 7 and 16), access to essential goods (e.g. probe 5, 9 and 13) and the magnitude of the events (e.g. probe 1, 11 and 15).

The researcher defined probes before the analysis was conducted to prevent irrelevant or non-compliant information. In order to improve findings validity, probes were evaluated and classified using the First Draft initiative (Wardle, 2017) seven categories

of disinformation described in Chapter 3 (page 131): (1) false connection, (2) false context, (3) manipulated content, (4) satire or parody, (5) misleading content, (6) imposter content and (7) fabricated content. The proposed categories consider the purpose of the person creating the content and the relationship between the content itself and the truth. The purpose of the person sharing the information was, initially, unknown by the researcher and in some situations just inferred from the evidence; consequently, some probes were categorised in more than one option. Table 4-19 cross-references each probe against the seven categories.

The category with more occurrences, seven probes, was the fabricated content which refers to content created to deceive or harm people. Fabricated content was observed in the three case studies, with content 100% created to deceive people. For example, the rumour of declaring a higher terrorist level (probe 1) or sharing uncertainty about the whereabouts of the terrorist (probe 4 – bar hostages). In some situations, the researcher was initially unsure if the uncertain items were considered misinformation within the fabricated content or false context. For example, probe 6, which refers to the need for blood donations, was declared a rumour. It was unclear if a Twitter's user fabricated the donations' request or official sources (e.g. hospitals/blood bank) had in their Twitter profiles messages encouraging the blood donation before the BTA (e.g. previous morning or days), and this request was taken out of context.

Case Study		Probe reference	False connection	False context	Manipulated content	Satire or Parody	Misleading content	Imposter content	Fabricated content	None
BTA	1	Terrorist Level							✓	
	2	Incident vs terrorist attack								✓
	3	Number victims								✓
	4	Bar hostages							✓	
	5	Interpreters							✓	
	6	Blood donation		✓					✓	
EC	7 and 8	Parking				✓		✓		
	9 and 10	Gas Shortage				✓			✓	
	11	Electronic devices				✓	✓		✓	
HH	12	Harvey Gas		✓			✓			
	13	Contaminated tap Water					✓			
	14	Airport Flooded	✓							
	15	Shark Image				✓			✓	
	16	People looting								✓

Table 4-19 Probes classification according to the type of misinformation identified

As previously stated, in some situations, the researcher could not determine the intention of the content creator or did not have enough contextual knowledge of how that piece of information evolved and became a rumour. Three of the items classified in the fabricated content category were also considered satire or parody. In the EC case study, probe 7 and 8 referred to free parking, and an unofficial Twitter account shared this information. This account was reported to Twitter and consequently removed. Therefore, it was considered as an example of imposter content which refers to the challenge of genuine sources being impersonated. However, during the interviews, one SMEs referred to this situation as the possibility of being a humoristic or satire profile that created content with no intention to deceive, but it still had the potential to fool people. Examples of humoristic content shared in emergencies are not a novelty. For

example, probe 9 uses humour to debunk a rumour related to the gas shortage in the EC case study.

Probe 15 was initially considered fabricated content as the edit of the shark image in the HH was created to deceive people. However, someone can argue that the option of a shark swimming in a motorway is so unlikely that it can be perceived as a parody. In relation to images, probe 14 was categorised as a false connection as the flooded airport was an old picture of a different airport. Therefore, a false connection was created as the visual showed in the tweet analysed did not support the content.

Also, the difference between fabricated content and misleading content was unclear initially in some of the probes used - for example, probe 12 and probe 13 refer to a shortage of diesel and restricted access to tap water. In both scenarios, it is difficult to ascertain if the content is misleading or it was fabricated to deceive. The main reason is that the evolution of HH made that these rumours could be partially true in some affected areas or become a reality with time. Lastly, probe 2 (severity of the emergency) and 3 (number of victims), considered as misinformation at the time, were confirmed by official sources in the BTA. These two examples showcased how information evolves over time and the relevance to information access.

The above table had showcased the analysis of the probes performed by the researcher. This classification allowed the researcher to understand better probes' similarities and differences within the case studies.

During the interviews, SMEs described their familiarity with the probes presented, their decision-making process while evaluating the uncertainty associated with them and their decision outcome. Table 4-20 summarises the reference of Information Quality (IQ) dimensions made by the SMEs while describing and evaluating the probes.

Case Study		Probe reference	Utility	Value-added	Applicability	Timeliness	Reputation	Relevance	Accessibility	Accuracy	Reliability	Objectivity	Believability	Representational	Amount of information	Comparability	Completeness
BTA	1	Terrorist Level	X	X		X	X	X	X		X	X	X	X	X	X	
	2	Incident vs terrorist attack	X	X		X	X	X	X	X	X	X	X	X	X	X	X
	3	Number victims	X	X		X	X							X	X	X	X
	4	Bar hostages	X	X		X	X	X			X	X	X	X	X	X	
	5	Interpreters	X	X		X	X	X			X	X	X	X	X	X	
	6	Blood donation	X			X	X		X					X	X		X
EC	7	Parking	X	X			X	X	X					X	X	X	
	8																
	9	Gas Shortage	X			X	X	X	X	X			X	X	X	X	X
	10																
	11	Electronic devices	X	X			X	X		X				X			
HH	12	Harvey Gas	X			X	X		X				X	X		X	
	13	Water drink	X			X	X							X	X	X	
	14	Airport Flooded	X				X										
	15	Shark Image					X				X	X					
	16	People looting	X	X		X	X	X				X			X	X	

Table 4-20 Alignment of probes with IQ dimensions described by SMEs (RQ2)

Content analysis was performed in each probe to identify the IQ dimensions described by SMEs. Reference was made to value-added, applicability, relevance, timeliness, reputation, accessibility, accuracy, reliability, objectivity, believability, comparability, representational consistency, amount of information and completeness. Depending on the complexity identified by the respondent concerning the probe showcased and their role/experience with it, the description of the decision-making process was more or less extended. For instance, probe 15 (shark image) from the HH did not provide extensive descriptions as emergency stakeholders were familiar with similar images in other hurricanes. The researcher did not find relevant findings for each type of unit of analysis or the types of misinformation described at the beginning of the section. Furthermore, due to the sample size, it is believed that there is not be enough evidence to answer any

hypothesis formulated to cross-compare these groups. Hence, the next section (4.5) provides the findings of this research as a whole and describes the IQ dimensions that prompted a decision, as described in section 4.2.

4.5. Twitter Information Quality (IQ) for emergency decision-making

Interviewees, aided by the naturalistic Critical Decision Method (CDM), identified the use of the following Information Quality (IQ) dimensions to use Twitter as part of the decision-making process. As described in section 3.4.6, the CDM interviews were adapted to suit the use of three case studies and selecting relevant probes and decision-makers. The previous two sections have summarised the implications and rationale of selecting experts in social media emergency management (section 4.3) and specific probes to demonstrate uncertainty within the decision-making process (section 4.4). In turn, this section presents the reader with the findings as interviewees described their decision-making process and how specific Information Quality (IQ) dimensions are relevant to reduce uncertainty. A total of 15 IQ dimensions were identified through the experts' analysis of the probes. While the researcher attempted to describe each dimension as a standing-alone element, from the beginning, it was evident that IQ dimensions are linked to each another, some of them enhancing the perception of IQ while others have a negative correlation between them.

All interviewees agreed that IQ dimensions are not discrete variables and they interact and build upon each other. The following subsections (4.5.1 to 4.5.5) outline interviewees understanding of the dimensions included in their decision-making process and their outlined IQ dimensions' relationships. This section's findings supported the development of the proposed descriptive model, which the researcher describes in section 4.6. Chapter 4 concludes with a summary of the main findings.

4.5.1. Utility: value-added, relevance, and applicability

This section describes the Information Quality (IQ) dimension utility and its relationship with value-added, relevance, and applicability. Interviewees received the task of recalling the decision-making process used while evaluating the information displayed in the tweets (probes). As described in the literature review (section 2.3.3) and by a

Public Information Officer (PIO) decision-making is influenced by the right information, the right people, and the right time.

> ***EC/HH6**: It is to get the right information, to the right people, at the right time so they can make the right decisions*

Therefore, as the task on hand was to perform a decision, remarks were made to the reason of considering the piece of information, including if the tweet added value to the decision, the relevance of the content displayed or the applicability of the information to their final decision.

> ***BTA 4:** It is different… if it is information to be informed or you are someone who is affected. Let's say, if there is a rumour that impacts me directly because I live 100 meters from that bar, then it is different than if I am at home in Girona, and I just want to be informed.*

The utility of the information conditioned the decision of acting. Decision-makers perception of utility was inferred by their opinion of the information's value-added, relevance, and applicability. These four dimensions were directly or indirectly referred to as the starting point and a contextual parameter of the decision of using Twitter.

The decision-making process often evaluates if the information shared adds any value to the situation. This IQ dimension is especially relevant when PIOs decided to create tweets. The decision of creating tweets was based on the premise of meeting the information needs of different emergency management stakeholders.

> ***BTA4**: [We think] what does the citizen need to know? What does the communication channel need to know? What are they expecting when this happens? […] In this decision-making process, when people decide if they should share or not a piece of information, we focus on what people need to know, so basic information needs are met. If the essential information needs are met at least in this space where we cover the basic information, rumours will have more difficulty to enter or at least they will compete with official sources, and that was our biggest worry.*

All PIOs advised that if the information shared was not helping someone, then it should not be shared at all. Three respondents recommended that citizens should not be sharing content (RT) if this was not adding value to the conversation or helping anyone.

> ***BTA1**: And before RT or share, think twice – am I helping anyone or is this information helping anyone?*

While adding value, the decision of producing or consuming information to/from Twitter should also consider the relevance and applicability of the information.

According to all interviewees, information's relevancy played a vital role in deciding to use information from Twitter. If the information was not relevant to the decision-maker, this was discarded and not considered. Evidence of this was vastly gathered during the observation of Virtual Operation Support Team (VOST) interactions in the Eclipse (EC) and Hurricane Harvey (HH) case studies where team members had a predefined objective while searching and reporting information from Twitter. In this decision-making process, six interviewees described Twitter as a tool that supported the identification of relevant information through the search-functionality and the achievement of situation awareness. For instance,

> ***EC6****: So, I would say it [Twitter] help us to achieve these goals because of the fact that we are familiar with it and there was a lot of traffic on Twitter with relevant information.*

In this line, it was outlined that PIOs decide to compose tweets based on the relevancy of the information to be shared. As stated by an interviewee, they share information that can help emergency stakeholders to make decisions.

> ***BTA1****:* There is a waiting period, but if it is not there, then it is not relevant between inverse commas.

It was described that uncertainty could also be reduced by sharing information that applies to the specific emergency. The importance of using specific keywords and hashtags was highlighted by multiple SMEs (70% of interviewees) to support the action of retrieving information from the Twitter universe. As described by a PIO:

> ***EC8****: We schedule everything that seems applicable to, and we have several tweets that we put all the hashtags.*

Therefore, the utility of the information was inferred from the concept of usefulness to make a decision.

> ***HH8****: I mean it is dated information, so some of it still has usefulness.*

> ***HH9**: If you are quoting something that happened three days ago, during an incident's response is kind of… I would just let it go.*

The utility of the information is time-sensitive. Then, information timeliness plays a vital role as incidents evolve quickly.

4.5.2. Timeliness

Timeliness is a vital Information Quality (IQ) dimension in incidents. All interviewees referred to it while evaluating the probes and describing verification protocols. Furthermore, the case studies' timeframes described in section 4.1 demonstrated how incidents evolved over time, particularly hurricanes, which can increase or decrease their strength over a short interval. The challenge resides in creating and consuming information when uncertainty is high such as at the beginning of the incident.

Public Information Officers (PIOs) and journalists alike (60% of the interviewees) described the importance of being the first person reporting an emergency. They mentioned the role of information leadership and how time impacts the establishment of trust and credibility.

> ***BTA4**: Official source must give their information quickly, or the audience will go somewhere else to get their information. […] There is [information] leaderships created not because of being official but because they are the first people giving information, or because they are nearby, or due to the visual content, etc.*

Additionally, on the first moment of a response operative, the information's verification can take longer than when the team is on the ground.

> ***BTA1**: Basically, one of the reasons of why people can believe this [a rumour] is due to the lateness that emergency team can have in disseminate relevant official information.*

> ***BTA4**: Once the machine is fully working, the information, for instance, the police [information] that we were giving in Cambrils is very fast or the maximum quick possible at the time of giving information.*

All interviewees acknowledged the role of Twitter in accelerating the information flow and speed between stakeholders in comparison with other communication channels, such as press releases in the media. The case study analysis showcased that incidents

can evolve faster than information flow, making information quickly out-dated — for example, the number of casualties in the Barcelona Terrorist Attack (BTA). Therefore as described in section 4.2.1., the use of Twitter as a communication tool helps to provide quicker updates, and in turn, it increases the perception of IQ shared on it.

The dimension of time was mentioned through many keywords, including *'lateness, when, before, after'*, and in combination with other dimensions. Timeliness was described as one of the biggest reasons for rumour propagation and uncertainty levels.

> ***BTA1****: Basically, one of the reasons why people can believe this [a rumour] is due to the lateness that emergency team can have in disseminate relevant official information*

Concerning debunking misinformation, 90% of the interviewees also highlighted the importance of time. Six interviewees provided examples of rumours circulating months in advance or present in previous incidents. Then, it was stated that the decision of belaying old rumours could be unproductive as by acknowledging them; these can become relevant again.

Five interviewees expressed that a compromise must exist between timeliness, accuracy and completeness in order to reduce uncertainty. For example, in the BTA, the number of casualties had to be officially verified by the forensic team:

> ***BTA4****: We talked about multiple deceased without given an exact number until we were able to confirm that they were 13, but in this case, there was indeed a delay that we tried to minimise until we were able to give the exact number.*

Besides, conceptually timeliness and these dimensions (completeness and accuracy) are negatively correlated in incidents. The provision of complete and accurate information at the beginning of an emergency is highly unlikely. All decision-makers acknowledged that during incidents (e.g. emergencies), they have access to partial information from multiple sources and create a full picture usually takes time. As well, situations described in the case studies evolved quickly, making information out-dated and changing the full operational image of the incident. Therefore, reducing uncertainty through the evaluation of IQ using Twitter must combine timeliness while working on the assessment of completeness and accuracy.

4.5.3. Reputation, accuracy and accessibility

Reputation is one of the critical dimensions outlined by all interviewees and a key element in the perception of Information Quality (IQ). All interviewees concurred on the importance of the establishment of the source reputation to evaluate IQ. To become a reputable source, several conditions need to be met. Four interviewees volunteered their definitions, including the mention of IQ dimensions, including time, objectivity, accessibility or accuracy, and adverbs related to respectability and ethicality. However, the majority of respondents (six) qualified reputation as official sources. All of them stated that the use of official sources to reduce uncertainty while using Twitter is a must. All interviewees described these sources mostly as governmental agencies, but some (five) included ONGs and Virtual Operation Support Team (VOST) Twitter accounts as accurate information providers.

> ***EC6****: And I will take that information from the VOST report, and I will look at it, and I will think how can I confirm that information so that I know that this information is accurate, so I will find a point of contact that it is the official for this information or somebody that can confirm whether that information is accurate or not.*

It was common the agreement that a good reputation in emergency-related information can be achieved by demonstrating expertise (100% interviewees).

> ***EC/HH7****: someone who actually is an expert.*

All interviewees mentioned the importance of checking official sources for emergency updates. However, the perils of impersonated accounts were discussed (90% of interviewees) as per evidence showcased in section 4.4 from Barcelona Terrorist Attack (BTA) and Eclipse (EC) probes. Even with information that looks from official sources, users must verify the information provenance as they can be mock-ups and false profiles. In the case of information shared by individuals, it is paramount to evaluate the user profile and critically establish their reputation.

> ***EC/HH9****: I personally I would find out who x is because there is no title included. So, that will be my first thing that I would look at, so who is <<name removed>> and why is she speaking in behave of the city of Corpus Christi.*

Moreover, when there is no information available, then emergency stakeholders should request it. As described by all interviewees, official sources and accounts with a high reputation in emergency management (e.g. VOST) have access to expert knowledge and ground operatives. Furthermore, Public Information Officers (PIOs) work together from the operations control room, having access to crucial information in real-time.

> ***EC7****: Yes, I mean the thing about the joint information center is that there is people from <<emergency organisation name removed>> and <<emergency organisation name removed>> and all these people in one room so I can just pick up the phone and talk to somebody there and have it verified.*

In the case studies, PIOs were in contact with ground operatives that could verify specific information — for example, an interviewee ***(EC8)*** suggested that someone could drive to petrol stations to determine if there was a petrol shortage in specific locations (mentioned as an example in the EC case study).

As stated by 50% of the SMEs, journalists and VOST members requested press departments' updates and activating organisations.

> ***EC/HH8****: Usually, it is the source. For instance if when I do the search say I am in Alaska and… it is Police Department for Alaska 511 is the people who do roads closures and accidents so if I am following Alaska 511 information or the state troopers or the police or someone like that I would assume that it is correct and official information.*

> ***BTA1****: In principle, we are in touch with emergency services directly. In VOST we have a group of VOST influencers where we share the official information, and this official information comes directly from the emergency services, therefore, if we detect any information, we ask in that WhatsApp channel for verification.*

Information access was understood as access to accurate information. In this context, sorting inaccuracy on Twitter was perceived as challenging as it is unknown what emergency stakeholders had seen before.

> ***EC/HH6****: here we are talking about Twitter, so there is people on Twitter who are saying this so we need to figure out how we can reach the* people who has *seen the wrong information and let them know that that information is inaccurate.*

An interviewee suggested increasing accuracy by providing concise information on Twitter. So, in the case of detecting a petrol shortage rumour, PIOs could not only post

a debunking tweet but also add evidence by providing useful information such as where to find petrol.

> ***HH9****: Where am I getting that information from? So, a government entity let's says an interstate office or something similar, [if they] actually shared something about an update in the status of gasoline -doing a quote and a tweet saying 'please review this information for accuracy'- or something like that, or- 'I think they had a shortage of gas anticipated with the Hurricane Harvey response'-. So [accuracy can be improved by] sharing the information about where you can find a gas station, where you can find gasoline. So just redirecting the conversation back, so it gets back of that spiral.*

In addition, an interviewee suggested that the perception of accuracy could be reinforced through redundancy. If a more significant number of trustable sources repeated the same message, citizens would perceive an increase in accuracy's levels. This concept is further analysed in section 4.5.5 when the researcher describes IQ dimensions related to comparability.

> ***EC/HH6****: One of the things that have to do with that is where the case of redundancy is 'do it'. We are going to saturate social media and traditional media with that message. […] Redundancy helps people and ensures that people are actually going to see the message and helps reinforce that that message is actually accurate.*

Redundancy would also improve information access as information on Twitter can be shared and linked using hashtags (#) and mentions (@).

Alternatively, when information is not accessible on Twitter (i.e. it was not tweeted or cannot be found), four interviewees advised that citizens could ask for updates directly to official sources through social media channels, including Twitter. Three PIOs mentioned limitations to manage the potential influx of enquiries; however, the BTA case study demonstrated how VOST could support emergency management's risk communication strategy. Compared with the other two case studies (eclipse and hurricane), activated VOSTs in BTA, who are considered reputable sources by their role in previous incidents, produced tweets to manage uncertain items, including creating a two-way dialogue in Twitter (section 4.3.1).

The VOST role in BTA case study demonstrated that information accessibility supports decision-making and increases source reputation. Through the interviews, IQ accessibility was understood from at least two perspectives — access to information and the type of information available.

First, all interviewees inferred that official sources usually have access to reputable sources (e.g. through their network or Information Systems) and, therefore, to higher IQ. However, access to this information does not always translate into the decision of sharing it on Twitter. For instance, in the Barcelona Terrorist Attack, officials knew that terrorists were not in a specific location but did not share that information on Twitter for operational reasons *(**BTA2**)*. In uncertain situations, when information is not accessible to citizens, social media facilitates rumour propagation:

> ***BTA1**: Many times for operational reasons you cannot give this information or because the police are active, and because you cannot give the precise information people starts elaborating or speculating things, and at the moment when someone says something in a tense situation and the minimum rumour extends in a situation that it is very confusing, and someone posts something in a social network then it expands because there is not an official source of that is not happening.*

Second, information accessibility can be challenging as people are not able to receive and understand the information in different ways.

> ***EC6**: We talked about access, and sometimes that can be difficult too because you know because people are not going to be able to receive and process information in many different ways so…*

Three interviewees argued that access through other channels to reputable sources helped them achieve a higher IQ than Twitter. Furthermore, one respondent challenged the validity of using Twitter as the primary communication channel to reduce uncertainty amongst citizens. He referred to the concept of '*digital divide*', providing an example of people without access to smartphones due to financial constraints or inability to use these devices (***BTA3***).

Aside from the relationship between reputation, accuracy and accessibility, seven interviewees mentioned the relation between reputation and other more subjective dimensions such as reliability, objectivity, and believability (section 4.5.4).

4.5.4. Reputation, objectivity, believability and reliability

There are three subjective dimensions related to the perceived reputation associated with official sources. In more than one probe, interviewees agreed that if the source was an official source, they had a better reputation and, therefore, they were perceived as more objective, believable and reliable. However, official sources specifically related to politicians can be considered subjective depending on decision-makers' political associations.

A limited number of references were made directly to the dimension of *'objectivity'* during the interviews while evaluating the presented probes. This concept was not openly mentioned by any interviewee while asked to describe their standard verification protocol. However, five Subject-Matter Experts (SMEs) discussed the concept of subjectivity when the researcher enquired why they believed specific tweets were more shared than others by emergency stakeholders, mostly citizens, without being previously verified (e.g. probes 5 and 6). A Virtual Operation Support Team (VOST) member declared that this is the case with highly emotive messages and those that appeal to citizens' desire to help.

> ***BTA1****: One of the reasons why [rumours extend] there is not an official belied and secondly that people is susceptible and [they] believe anything.*

Another interviewee pointed out that the truth is subjective. Therefore, if it does not come from official sources, then the population should just believe that these tweets are somebody interpretation of the facts.

> ***EC/HH8****: So from people I do not really consider it truthful unless it comes from an official source, I assume that it is somebody impression of what's happening.*

Similarly to objectivity, believability is described as highly related to reputation, and the challenge resides in how an emergency stakeholder could establish it on Twitter. Consequently, four Subject-Matter Experts (SMEs) declared that believability is not only

related to the tweets' content (e.g. images or text), but it is concomitant to the person sharing the information. As stated by an interviewee in her approach to verify the information:

> ***EC/HH9**: I personally I would find out who 'x', is because there is no title included. So, that will be my first thing that I would look at so who is [Twitter name removed for confidential purposes] and why is she speaking in behave of the [HH authority name removed for ethical purposes].*

Additional information can provide further reliability; however, it depends on what type of information. It must be information that adds value (e.g. sharing casualty images do not help anyone) or complements the discourse (e.g. quote from an official source). This brings back the concept of information utility.

> ***EC/HH9**: Yes, so I do not know if she is a representative from a particular part of Texas having that included in there it would be super helpful as an official source or even just sharing… so she just quotes herself. If she quoted a governmental entity saying that there is not a gasoline shortage that would demonstrate more reliability of where she was getting that information.*

In summary, the information source's reputation on Twitter is not only built from their actual activity in this social media but also from decision-makers' perception of the source in terms of objectivity, believability and reliability. All these, in turn, impact the perception of the IQ shared by that Twitter user. Hence, perception can improve through the comparability of the information provided.

4.5.5. Comparability, amount of information, consistency and completeness

All interviewees highlighted the amount of information shared by emergency stakeholders, its representational consistency and the ability to provide decision-makers with sources to compare the information as Information Quality (IQ) dimensions. Remarks were made to the importance of these three dimensions to increase the perception of IQ and, therefore, reduce the uncertainty of using Twitter in major incidents.

70% of the interviewees argued that information that is continuously presented in the same format and it is compatible with data presented previously has a perceived higher quality.

> ***EC/HH6:*** *So if we are doing our jobs right about what is happening and so the public is going to be looking at that tweet, and then, they are also going to be looking at the… when they see that they will be looking at the information from the official sources are sharing and see it matches with that information.*

Seven Subject-Matter Experts (SMEs) instilled that consistency could be achieved intrinsically by the elements within the tweet (e.g. image and text). These Twitter entities (see appendix 2 for a full list of Twitter entities) should be evaluated before using the tweet information as part of the decision-making process.

> ***EC8:*** *If I follow a hashtag, just looking at hashtags sort of accident or something, then I look at peoples' link. If there is a picture I assume and I am stuck in a line of traffic so, I know what the weather is so if I see and I am in an overcast sky, and I see someone said there is some accident and it is very sunny then that is not from today because I know it is not from today because I am sitting here and it is not like it.*

> ***HH9****: That is when you have to do some background checking like if you are not familiar with the area and you see folks making statements about that, you can actually go and do a Google search or any search engine and look at and find out if they actually have a parking department or something like that and if they have a website you can actually see what Twitter account they use so it is going back and verifying information on the searcher side of things as well.*

Externally, other sources could also impact the perception of IQ through consistency. Emergency organisations can achieve this by providing a consistent and redundant message through their network:

> ***EC6****: Consistent, redundant … I will call it socialisation. So that they are multiple partners that are coordinating to ensure that we are communicating in a consistence voice with a consistent message.*

> ***EC7****: The way that we normally do it is we look for an alternate form of an official source. So, it needs to be a governmental source or real scientific body.*

It was noted that redundancy could also be achieved by the amount of information shared. All interviewees referred to the amount of information on Twitter; however, from two different perspectives: first, the amount of information shared by the same source; secondly, the amount of information required to saturate Twitter.

A Public Information Officer (PIO) described that information shared by the same source, even if it is to complement the narrative, enhances the quality of the information required to reduce uncertainty by the decision-makers.

> ***BTA4**: More information you push, more information will be to contrast, and it will make you the leading broadcaster or a reference [broadcaster] one concerning that narrative. If I know that this person will inform me of everything that he can or everything that deserves to be shared, and I receive different information, then I will first verify it there, and if the information is not there so, I will have just the doubt of 'maybe he cannot say it, or maybe they do not have this information yet, etc.*

Other sources can aid in providing the right amount of information by sharing the same message. 70% of interviewees stated that a decision-maker had more opportunities to compare a piece of information if multiple sources shared the same or similar information (message redundancy). All interviewees agreed on the importance of networking with different trusted agents as part of any verification protocol and risk communication strategy for Twitter and outside this platform. As stated by an interviewee:

> ***EC/HH6**: But then, in addition to that, they also should be retweeting their network partners and the other official sources in different areas so they can help to amplify that message. So, let's say for example if [emergency organisation name removed] says 'this is misinformation, this is a fake account, we are the official source, please you do not look into that account, please come to us' they may not have, the [emergency organisation name removed] police department may not have a lot of Twitter followers so they may want to go to the city of Salem, they may want to go to the [USA county removed], they may want to go to the state office of emergency management, they may want to go to all these partners and say 'hey, can you help us to amplify this message in your account, so it is reaching a wider audience'. So, for instance, [emergency organisation name removed] has 200,000 followers in Twitter, so they say 'hey can you help us to share this information, so we are reaching a wider audience that way'. Also, maybe going to the media as well and saying 'we are having this problem, would you mind doing a report about it or putting something out on the local newspaper so the [Local newspaper name removed] – can you put something out on your paper or in your website' or if in [city name removed] you can talk to the TV stations, and you can ask them if they would do a report on it.*

The amplification of the information impacts the Perceived Quality Information (PQI). In turn, if a more significant number of trustable sources repeat the same message, citizens would think this information is more accurate.

> ***EC/HH6**: One of the things that have to do with that is where the case of redundancy is 'do it'. We are going to saturate social media and traditional media with that message. […] Redundancy helps people and ensures that people are actually going to see the message and helps reinforce that that message is actually accurate.*

Two Subject-Matter Experts (SMEs) argued that by saturating the network with verified information from trusted sources, the decision of using Twitter in major incidents decreases uncertainty levels as different messages provide a complete picture and make information more believable and accessible.

Therefore, SMEs with a PIO background (60%) inferred that a coordinated effort between organisations to share the same message on Twitter but from different perspectives would provide a sense of completeness, enhancing believability and accessibility to the information. Besides, information shared by relevant Twitter users would complement each other enhancing the message and providing a complete vision of the evidence. Consequently, the concept of completeness was referred to from the perspective of providing contextual information for situation awareness. As described by a PIO:

> ***BTA4**: There is also this will of providing information that it is not strictly of covering a need, but that completes the vision and the narrative of what is all the organism involved doing.*

Moreover, it was declared that the provision of fractional information improves the PQI of the following messages shared by the same Twitter user.

> ***BTA1**: Therefore, if I receive a piece of information, I can compare it with the small, partial or full and total that this official source is providing.*

> ***BTA3**: Then, citizens know that they will give the information, but they will give it when it is safe to do so, when data has been contrasted and verified, and that is not jeopardising any intervention or operation. However, they tell you from the beginning that they are there, that they know what is happening and that they will update when they can do so.*

Additionally, it was argued by two interviewees that decision-makers should be wary of messages that were too complete from non-official sources. Hence, while completeness is initially perceived to increase IQ, evidence showed that detailed information in major incidents is unlikely; and therefore, decision-makers must evaluate these tweets carefully. For instance, in the Barcelona attack, rumours included the type of gun:

> ***BTA4****: Even in this rumour, people were able to name the bar, the bar was 'La Luna de Estambul' or something similar, and that the person inside had a K47. People were even able to identify the gun that he had. This is one of the multiple rumours circulating in those moments.*

Aside from the textual content included in the tweets, reference (100% of SMEs) was made to other Twitter entities that would provide contextual information such as URL links, hashtags and photos. For instance, the inclusion of links (3 interviewees) would redirect users to additional information allowing further comparability.

> ***EC7****: So, that is something that we may give back to them and say 'can you please put out a post that tells people about retardant' or there may some official sources that we may amplify from forest force publication from the past and without answering that person just put out something and here there is an article to read about fire retardant water supply.*

The importance of using images was also highlighted. Seven SMEs maintained that tweets with images have a higher probability of information propagation. It increases the amount of information created (text and image) and supplements completeness through visual aid. To support the decision-making process, an interviewee (PIO) mentioned that her protocol included creating tweets with images.

> ***EC8****: So, if we post an update, we tweet it and so my protocol, and this is for my team, in particular, I want all the jpeg, I want a date jpeg even if it is a document as a jpeg. […]I try to tell people 'don't post anything in Twitter that it is just a bunch of words, things get shared more when they have pictures' and so, we always try to have a picture so to update but sometimes we put two pictures in the update- a regular picture of the incident and then the .pdf link and we try to .jpeg whatever we can.*

Another strategy to support comparability is a suitable selection of hashtags. This Twitter feature allows to group information and facilitates comparability.

> ***EC8**: We search before we even get to the incident to tell me what has been used by people following this fire. If it is called ABC fire, just start searching hashtags 'emergency fire', or if it is in Durango, Colorado then search Durango, anything that the search will tell me what is the most commonly used hashtag. And then we will stick with that hashtag instead of creating a new one because undoubtedly even if we are the first team in there, somebody has already started talking about the fire. Then somebody has already created a hashtag, so we try to use a hashtag that it is already in use that it is prevalent, and we may use two, they may be two maybe the name of the town and the name of the fire. So, we start comment using whatever hashtag. That is reason one. But if nothing seems prevalent and we have a better one, then we use it, but I don't like to add too many hashtags in the equation so… And then you know every time that we post something in Facebook we also tweet it.*

To conclude, 90% of interviewees established a conceptual correlation between the dimension of completeness, representational consistency and amount of information shared by key emergency stakeholders. Furthermore, comparability could be enhanced by the design of an excellent collaborative communication strategy. It should be based on clear delimitations of emergency organisations competencies and the development of a network to produce and propagate well through information on Twitter. The decision of creating a high IQ would support, in turn, the decision of consuming information from Twitter by reducing uncertainty.

The next section describes the steps used by the decision-makers interviewed. The researcher reports SMEs' conceptual relationship while evaluating information for/from Twitter within a decision-making context in major incidents.

4.6. Steps of naturalistic decision-making in Twitter

The process of decision-making in naturalistic environments using Twitter was interrogated directly and indirectly through the interviews. The researcher used the data collated through the three case studies - Barcelona Terrorist Attack (BTA), Solar Eclipse (EC) and Hurricane Harvey (HH) – to identify ten Subject-Matter Experts (SMEs) in the use of Twitter for Emergency Management (EM). They were presented with a selection of the sixteen probes identified. Those probes represented uncertainty elements acknowledged in the different case studies (section 4.1.4) and which had been previously evaluated by at least one of the SMEs. Probes and Subject-Matter Experts

(SMEs) were used to develop and implement the adapted Critical Decision Method (CDM) described in the methodology section (Chapter 3). Through the CDM interviews, SMEs described their decision-making process while using Twitter to reduce uncertainty in major incidents. Depending on the decision-makers' role in each probe, their description was aligned with the use of Twitter from a production or consumption perspective (section 4.2).

This section describes the decision-making process followed by this research's respondents. First, SMEs were asked to describe their own and their organisation verification protocol (see Appendix 6 for Interview guide). Then, using relevant probes (described in section 4.4) from the three case studies (4.1), decision-makers (4.3) were asked to define their line of thought (mental model), which prompted a decision (4.2). The description of 75 decision-making processes was documented through the interviews. Table 4-21 summarises the probes presented to each interviewee. Five Barcelona Terrorist Attack (BTA) SMEs were showed 6 probes collected in this case study. They defined 30 decision-making processes. Four interviewees evaluated 5 eclipse's (EC) probes providing insight into 20 decision-making processes. These four participants were also active in the Hurricane Harvey (HH) case study, and therefore reviewed probes 11 to 16 (5 additional). The researcher was able to capture information about the impact on their process, depending on the type of emergency analysed. The researcher collected no evidence of a different protocol to evaluate information quality depending on the emergency type. In addition, an interviewee was added in the HH case study to increase the representativeness of the journalists' group as a unit of analysis. A total of 26 decision-making processes were recalled using the HH probes.

Interview ID	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5	Probe 6	Probe 7	Probe 8	Probe 9	Probe 10	Probe 11	Probe 12	Probe 13	Probe 14	Probe 15	Probe 16
BTA1	✓	✓	✓	✓	✓	✓										
BTA2	✓	✓	✓	✓	✓	✓										
BTA3	✓	✓	✓	✓	✓	✓										
BTA4	✓	✓	✓	✓	✓	✓										
BTA5	✓	✓	✓	✓	✓	✓										
EC/HH6							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EC/HH7							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EC/HH8							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EC/HH9							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HH10											✓	✓	✓	✓	✓	✓

Table 4-21 SMEs decision-making process against probes (tweets)

This section reports these findings. Building on those, the researcher proposes a novel descriptive model. In emergency management, a model is understood as a chart that shows theoretical links between different variables or relationships in or among groups (McEntire, 2004), in this case, IQ dimensions.

4.6.1. Description of existing verification protocols

All interviewees provided evidence that Information Quality (IQ) evaluation is a must while using Twitter for decision-making in major incidents (e.g. emergencies). At the beginning of each interview, Subject-Matter Experts (SMEs) were asked to describe their existing verification protocol to evaluate Twitter information in incidents. A limited number of interviewees (n=3) were able to describe the steps followed to verify Twitter's information fully. All respondents referred to their own experience or the ability to ask their network for confirmation or check with official sources.

> ***EC7****: we have someone at the check so I can go directly to him and say' I saw this' and see if you can ask people right there if that was an issue*

When prompted by the situation of not having access to these partners, the majority of SMEs (80%) declared that they did not have a set protocol but that each situation was unique and they made decisions on a case by case basis.

Virtual Operation Support Team (VOST) members and journalists interviewed were more vocal in describing strategies and techniques for verifying information retrieved from Twitter, including:

- Verification of images using reverse search and other tools
- Review Twitter users profiles
- Evaluate previous messages
- Evaluate messages from another source: how many people are saying the same versus who is saying it.
- Check with official sources or trusted agents for confirmation

It was a collective agreement that verification without asking official sources could be highly time-consuming (100% SMEs).

> ***HH7****: But if there is something that looks fishy then we will look it up but generally have to be something like this [referring to the shark probe] before we go looking into it. Part of that, it can be a real-time suck when people have better things to do. So you could... you know… report it in and file it for officials and staff [for verification] or invest an unknown amount of time playing investigator when it is not necessary.*

On the other hand, Public Information Officers (PIOs) described their approach to create tweets and support citizens' decision-making process by providing information.

4.6.2. Naturalistic decision-making steps for Twitter

Using the Critical Decision Method (CDM), research participants were asked to describe their specific decision-making process used to evaluate the selected tweets' information. In this section, the researcher describes their line of thought and identified mental models. Section 4.5 had illustrated interviewees understanding of the Information Quality (IQ) dimensions which are referred to here.

The data analysis showed that the process followed by the decision-maker is conditioned by the individual perception of the Information Quality (IQ). As the date of the interviews, there was not a well-defined Twitter (or social media) verification protocol used by the interviewees' organisations; however, all interviewees used their previous experience to decide on each scenario. Nevertheless, the researcher detected

similarities while analysing the decision-making steps reported. The researcher found resemblances across different interviewees, different probes and different case studies. Section 4.5 described fifteen IQ dimensions mentioned by the interviewees: utility, value-added, applicability, timeliness, reputation, accessibility, accuracy, reliability, objectivity, believability, comparability, representational consistency, an appropriate amount of information and completeness. Subject-Matter Experts (SMEs) defined conceptual relationships between these, demonstrating that correspondences could be extracted during the decision-making process.

Commonalities identified after the analysis of these 75 decision-making processes are used to develop the proposed model. Several differences were also identified and considered in the analysis. They are described as part of this study's limitations and areas for future research (Chapter 5). It is noted that interviewees with further experience (4.3.2) were more assertive, describing the steps followed to verify the information and assess its quality when perceived information was perceived as less certain. All interviewees described their decision-making as an interconnected universe where multiple dimensions were evaluated simultaneously as their positive or negative relation was more or less evident. For instance, the IQ dimension *'time'* has a negative conceptual relation with most dimensions, as during major incidents, events evolve quickly, making information out-of-date. Other examples of these can be found in section 4.5 and throughout this section.

Using these findings, the researcher proposes the four decision-making steps outlined in Figure 4-17. This is the base for developing the microblogging (Twitter) descriptive model to determine the IQ of posts (tweets) for decision-making in major incidents.

In most decision-making processes (90%) and as Figure 4-17 outlines, the evaluation of the information started by reviewing the utility of a given tweet to make a decision. The researcher notes that without this first step, the uncertainty associated with the information for decision-making and to the potential outcome (decision) would be nonexistent.

In order to assess the utility, decision-makers decided if the information was relevant, applicable or added any value to them. Interviewees were familiar with the probes shown to them and could recall each specific situation, including when and where they saw and evaluated a specific piece of information. It is relevant to notice that the context described by SMEs was usually somehow interconnected with another source of information such as mass media channels or a person in their network (online or offline).

> ***BTA5****: When I heard the news, I was leaving work because I was going home and I had to come back. I was listening to the radio and the information at that moment was very confusing [incident probe].*

> ***EC6****: I remember those tweets [petrol probe]. We put together the response. For this one here depending on where we are logistically, we'll have actually someone to drive down there and talk to them about it. […] So after the VOS team send it to the Joint Information Center or the State Emergency Operations Center we can coordinate with our support function partners for an emergency, and they would verify whether the rumour is it true or not.*

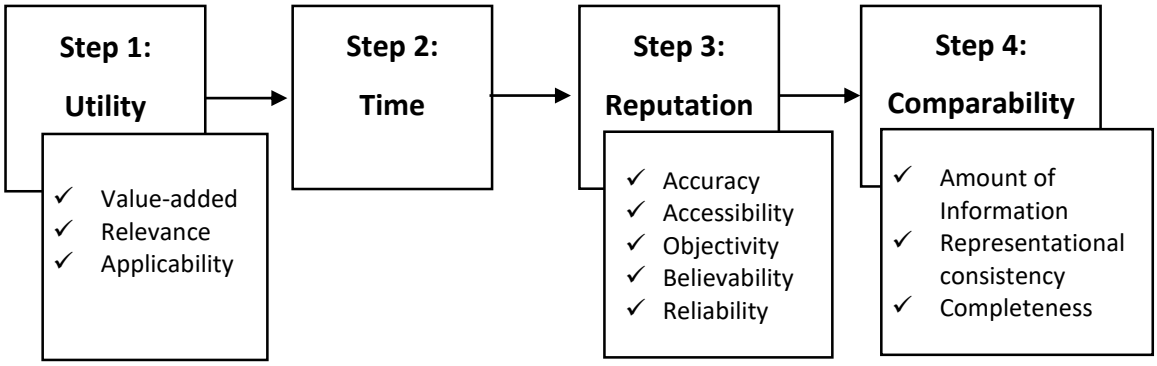


Figure 4-17 Steps for decision-making using Twitter in incidents (RQ3)

The analysis showed that when information from Twitter is deemed to be considered (e.g. it is fit for purpose), decision-makers considered its timeliness (step 2 in Figure 4-17), its reputation (step 3) and comparability (step 4). If the decision-maker perceived these three key dimensions highly, the decision to use Twitter was more likely to take place. For example, VOST in the three case studies had predefined objectives (section 4.3.1). Therefore, their evaluation of Twitter information was linked to the utility of that information to achieve their objective. The assessment of tweets from a utility perspective was also related to decision-makers' previous experience. During the interviews, it was evident that SMEs who had seen before the emergency a piece of

information (e.g. in another emergency or a training session) or had experienced a similar situation invested less time verifying it and achieved a decision quicker. Interviewees referred to recurrent rumours that were disregarded quickly due to the detection of patterns or their previous experience - for instance, the shark probe presented in the Hurricane Harvey (HH) case study or Twitter's users asking for updates of missing people.

> ***BTA5****: In Barcelona, one of the rumours was 'we are looking this girl, she is my friend, please we don't know anything about her', and that photo has been used before in another terrorist attacks such as in Belgium and… even some of these photos were from Mexico. They follow similar patterns, such as the theme or the type of images.*
>
> ***EC4:*** *That shark is showing up I think in every single disaster for as long as I can remember. When Hurricane Sandy came through and flooded part of New York and New Jersey, a shark made its way to New York [but it did not].*
>
> ***HH7****: In the case of people who do VOST and social media in emergency management, they kind of have seen it all. Though we have a good sense of what to look it for and what is believable and what is not when a lot of people here don't.*

If the utility of Twitter information was perceived positively, then a tendency of evaluating the temporality aspect was detected (right time). Time is highly related to the velocity of the information displayed on Twitter, and it is essential for decision-making in emergency management. An interviewee stated that temporality and the type of information conditioned her decision of using Twitter, as other channels could be more suitable for instance, blogs or Facebook.

> ***EC8****: We use a blog to which is one of the other tools that we use. Blogs are good when you have to put something out there that needs to stay up. You know like information about a hotline or where to send donations or the FEMA letter from the governor or the declaration of disaster or how to apply for FEMA assistance. It doesn't work as well in Twitter as it comes and it goes. You know, if you have a busy Twitter feed it can be hard to find it, and in Facebook, things drop in the phone. So when we need something and when we have a lot of information that needs to stay, then we use a blog [but] it is not great for engagement.*

Aside from the platform's temporality, the information age impacted the decision-making process. Decision-makers did not consider tweets with old information.

> ***HH9**: Timing is a key element. If you are quoting something that happened three days ago, during an eme response is kind of… I would just let it go.*

This dimension (timeliness) usually holds an inverse relation with the accuracy and completeness of the information. Many considerations were commented on by interviewees while evaluating these dimensions together. For instance, it was stated that reputable sources usually take time to provide timely updates as information must be compared.

> ***BTA4**: Here, there are two things: comparability and time. Therefore, you can be 100% contrasted and slow; 100% contrasted and quick – that is what we wanted. The information that we were going to provide had to be quick but contrasted. We were not going to provide information, not contrasted or not exact for going quicker. The aim is to manage these two things.*

Therefore, information comparability is negatively related to timeliness. Checking different sources and messages takes time, delaying the response time in an emergency. Nevertheless, tweets shared by official sources were always considered more trustworthy.

> ***BTA2:** For us, it is more valuable… more than the information from 4 people or 60 or 70, it is [the information] from official sources.*

Multiple SMEs stated that providing fast but unverified information is dangerous as if it is wrong; reputation can be damaged quickly, and building a reputation in social media takes time. Therefore, it was advised to use a conservative approach when referring to sensitive information, for instance, the number of casualties. Using this approach, IQ from that source is perceived higher.

> ***BTA5**: The right approach is always for the mass media to wait. And there is like a no-written norm where you must say the lowest number of victims that you have. It is always better when you give a number not to have to belie casualties because it makes things more confusing. Unhappily it is normal that the number of deaths increases in a situation like this, but it would be really strange that first, it was thirteen, then eleven, then fourteen, etc. In this case, always, the official source. If I am at home and I see that the newspaper refers to thirteen mortal victims, and like this tweet… I think what you have to do is to go to the police [Twitter account] and see what's the official count. Nevertheless, when the mass media gives a number of casualties, usually, there are sadly right.*

Consequently, dimensions that help to evaluate the source reputation must be considered. Public Information Officers (PIOs) and VOST members advised that citizens should first consult official sources as their reputation and, therefore, IQ is higher.

> ***EC6****: Our hope for that it is that they are going to be looking at the information of the official sources are sharing.*

> ***HH9****: So, for the general public, I would… my recommendation would be they actually look for the official source through the government entity, I mean right now… news use to be slightly different and now perpetuate some of that rumours so I would just go to the direct source, the local agency and the state agency that are sharing information instead of relying on news media right now.*

Interviewees agreed that the step of checking official sources as part of the citizens' decision-making process was conditioned by the effort made by these sources to become a reference in major incidents during their planning time.

> ***EC6****: The first thing is I go back to what I said before hopefully during their planning time that 95% or more when they are preparing for these situations, they are building up their audience. So, they have a larger following. That way when this misinformation comes out and they can put the right information out to a larger audience and let know that audience that this is misinformation, and if you want the right information you will be coming to the official source witch it is us.*

Accuracy in emergency management is usually driven by the reputation of the information source, which in turn, it has a direct connexion with the accessibility of Twitter's user to the facts.

> ***EC7****: The way that we normally do it is we look for an alternate form of an official source. So, it needs to be a governmental source or real scientific body.*

In addition to accuracy and accessibility, the decision-maker must evaluate the source's objectivity, the level of believability and reliability. While these dimensions are usually associated with official sources, and most interviewees described this step as the main one, evidence exists, than sometimes timely updates are unavailable from emergency organisations.

Therefore, if Information Quality (IQ) is deemed appropriate from a time perspective, but official sources cannot confirm or deny tweets, comparability becomes a critical

component for decision-making using Twitter. By evaluating the amount of information, its representational consistency, and the completeness of the information (i.e. volume and variety), decision-makers in the three case studies created a picture of the situation unfolding.

Interviewees suggested different approaches in their Twitter's risk communication and information searching strategies to support decision-making through comparability. All of them were related to increasing the amount of information available on Twitter, improving representational consistency of the information shared or augmenting the perception of information's completeness. As described in section 4.5.5, comparability can be enhanced by redundancy which can be achieved intrinsically within the content created (Text, hashtags, URL, photos, GPS) and externally through network collaboration (user mentions, RT, likes, conversations). An interviewee described the process as following a breadcrumb trail.

> ***HH9****: We actually do,[we] train our VOST members, we teach them how to do and follow the breadcrumb trails […] Doble check and do a reference check so as to how you will conduct research. So, it is peer review, and so if you are having a hard time figuring out where this information came from then, it may be some red flags - if it doesn't point back to a governmental entity or a reputable non-governmental agency like FEMA or Red Cross or something like that. You may want to do a little of more digging to find out if that it is accurate, if not and it is not just necessarily up to each individual VOST member to decide if it is inaccurate or not but being able to see trends. Also if you are monitoring more than one platform something similar may come up so if you see pop-up more than once or we like to have, I don't know, so when you do a search on Twitter, and you are using Tweetdeck or Hootsuite, it gives you different columns so that's one way you can verify if the hashtag is popular goes viral really really fast.*

To conclude, the researcher has outlined four defined steps based on four information quality dimensions (utility, time, reputation and comparability of information) and supported by eleven additional IQ dimensions (value-added, applicability, accessibility, accuracy, reliability, objectivity, believability, representational consistency, an appropriate amount of information and completeness). As presented in section 4.7, the implementation of these steps is context-specific to the Evaluation of Twitter Information Quality in Incidents (ETIQI model) for decision-making.

4.7. Summary of findings: ETIQI model

Chapter 4 presented the three case studies analysed and the findings to determine the context and requirements of creating a descriptive model to support the Evaluation of Twitter Information Quality Emergencies (ETIQI model) to facilitate stakeholders' decision-making process. The researcher collected evidence of naturalistic decision-making processes using Twitter. The analysis of those illustrated that processes are conditioned by the quality of the information obtained. In fact, Information Quality (IQ) and the perception of the same are impacted by the production (risk communication) and consumption (situation awareness) processes followed by key stakeholders. Through the three case studies, evidence was gathered of the uses of Twitter, and four specific decisions outcomes were documented: the decision of sharing information on Twitter, the decision of engaging with content, the decision of using Twitter information to publish news articles and the decision of escalating tweets to emergency managers. These decisions were selected as they were taken by professionals (subject-matter experts) in the use of social media, especially in the area of Emergency Management (EM).

Understanding the challenges associated with these decisions and the existing solutions applied by relevant stakeholders, social media emergency management experts provided a suitable context and source to identify the linchpin IQ dimensions. To validate these attributes and modify the model parameters as required, the researcher conducted interviews with Subject-Matter Experts (SMEs). The researcher used the data collated through these case studies - Barcelona Terrorist Attack (BTA), Solar Eclipse (EC) and Hurricane Harvey (HH) – to identify ten Subject-Matter Experts (SMEs) in the use of Twitter for emergency management and sixteen probes that represented uncertainty elements. Stakeholders were identified by analysing their role in each case study and after gathering evidence that they were part of a decision-making process with one or multiple probes. Through the Critical Decision Method (CDM) interviews, SMEs described 75 decision-making process while using Twitter to reduce uncertainty. Depending on the decision-maker role in each probe, their description was aligned with the use of Twitter from a risk communication or a situation awareness perspective.

Nevertheless, all interviewees provided evidence that Information Quality (IQ) evaluation is a must while using this mass communication channel.

The analysis of previous research in IQ and the three case studies allowed the researcher to compile a set of IQ dimensions to be considered in the development of the descriptive model. A total of fifteen dimensions were referred to by the interviewees: utility, value-added, applicability, timeliness, reputation, accessibility, accuracy, reliability, objectivity, believability, comparability, representational consistency, an appropriate amount of information and completeness. Of these, four concepts were further elaborated compared to the others: utility, timeliness, reputation and comparability. While an effort was made to describe each of the fifteen dimensions as stand-alone elements, all interviewees described their decision-making as an interconnected universe where multiple dimensions were evaluated at once.

By gathering additional feedback from SMEs, the researcher identified the appropriate dimensions and evaluated their relationship to develop a model that enables emergency stakeholders to make decisions reducing their associated level of uncertainty. The importance of establishing these relationships is that models that do not contemplate the interconnectivity between IQ dimensions fail to support the decision-making process in this context.

Using the information described in Chapter 4 and summarised in the paragraphs above, the researcher proposes the descriptive model outlined in Figure 4-18 (page 298) to facilitate the Evaluation of Twitter Information Quality in Incidents (ETIQI model). The model was developed after answering the three Research Questions (RQs) from this research:

> *'RQ1. How is Twitter used for decision-making in major incidents?'*
>
> *'RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?'*
>
> *'RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?'*

As described in the literature review (Chapter 2) and by one interviewee, the objective of information management can be summarised by the following phrase: *'Getting the right information to the right person at the right place at the right time'* (National Working Group, 2008, p. 3). Therefore, four variables are identified: the right information, the right person, the right place and the right time. The model development departs from the premise that the decision-maker (the right person) is in Twitter (the right place) and information must be evaluated from a timely and rightful perspective (right time and right information). Hence, the model can be implemented by decision-makers using Twitter in an emergency. Figure 4-18 (page 298) summarises the proposed descriptive model and the next paragraphs describe its elements.

While evaluating Twitter information for risk communication or situation awareness (RQ1) in emergencies, the decision-maker must evaluate the Information Quality (IQ). According to Subject-Matter Experts, there are fifteen interconnected IQ dimensions (R2). In the decision-making process, those dimensions have a clear relationship grouped in four steps. The first one is the assessment of the IQ utility. The decision-maker will evaluate if Twitter information adds value, it is relevant, and it is applicable. Using her expertise will then decide to act upon or move to step 2: the evaluation of the information dimension of time. By looking at the freshness of the information, the decision-maker will further infer in the evaluation of the utility of it. Again, the emergency stakeholder will use her expertise to achieve a decision, or she will check the information source reputation (step 3). The evaluation of the IQ through the assessment of source reputation is achieved by analysing source accuracy, information accessibility, objectivity, believability and reliability. Using their own experience, decision-makers can achieve a decision (outcome) or further evaluate the IQ by comparing the information through the amount of information, its representational consistency and its completeness. The analysis of 75 decision-making processes showcased that after considering those four steps with their associated Information Quality (IQ) dimensions, the decision-maker will achieve a decision outcome. In the analysed case studies, those outcomes will be the decision of tweet, RT / engage in Twitter, publish an article with a tweet or escalate a tweet to an emergency organisation (Figure 4-18).

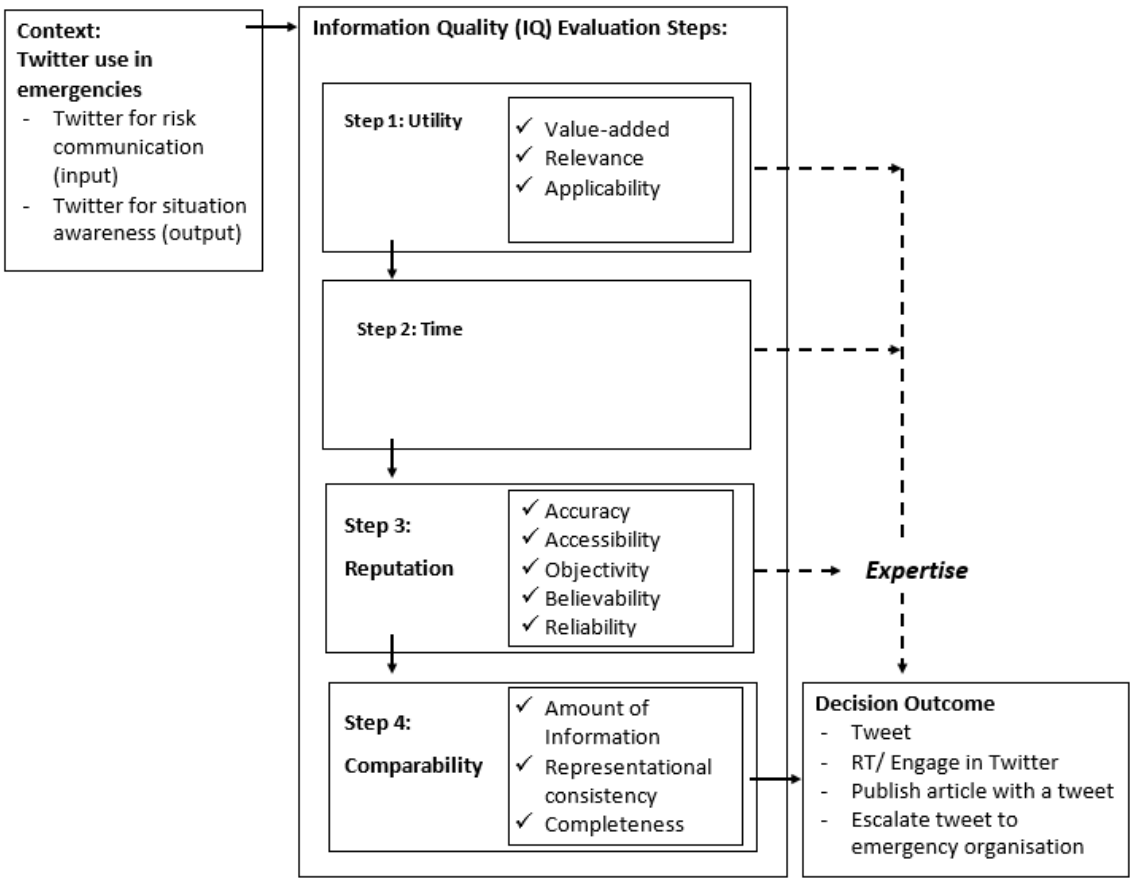


Figure 4-18 Evaluation of Twitter IQ in Emergencies model (ETIQI model)

The proposed model has different connotations in relation to the steps to take depending on the information available from official sources and in Twitter-sphere (reputation and comparability dimensions). It is also argued that even the proposed model is linear (step 1 to step 4), this can be exited as soon as the decision-maker achieves a decision (using their expertise); however, it is recommended to complete it to communicate and achieve better situational awareness.

Chapter 5 further elaborates on this point by summarising this research objective, its associated research questions, outlining key findings, and enumerating limitations and avenues for future research to better support the decision-making process to use Twitter reducing uncertainty through Information Quality (IQ).

Chapter 5. Conclusions

This chapter concludes this research by bringing all its key elements together. First, it evaluates the findings of the study (Chapter 4), including the development a new model that before the research did not exist: the ETIQI model. Secondly, Chapter 5 links the key findings back to the research's objective and questions derived from the literature review (Chapter 2). Thirdly, it evaluates the suitability of the methodology employed (Chapter 3), outlining its limitations. Lastly, the researcher describes the contribution of findings to theory and practice in the area of Information Systems (IS), User-generated content (UGC), Emergency Management (EM) and Naturalistic Decision Making (NDM).

The objective of this research was to:

> ***'To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents.'***

Chapter 5 demonstrates how this objective was achieved through the research by describing the steps to create the ETIQI (Evaluation of Twitter Information Quality in Incidents) model and how emergency stakeholder can implement it. For reference purposes, Figure 5-1 (page 300) illustrates the ETIQI model. It provides the reader with an overview of its principal components referencing the context of the decision-making process, the steps to follow while evaluating uncertain information in incidents, and the four potential outcomes identified in this research.

Figure 5-1 is further described in the next five sections. Section 5.1 summarises this research objective and recapitulates the methodology employed. Hence, it describes how the model was created. This research analysed the requirements "To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents". A novel descriptive model is proposed based on the steps (internal model) followed by Subject-Matter Experts

(SMEs) in decision-making using Twitter in incidents (contextual information) by analysing IQ dimensions and their relationship.

Section 5.2 discusses the research's findings against the gap identified in Chapter 2 (literature review). Furthermore, it assesses whether this research objective was met through the three proposed research questions and describes how to use the ETIQI model (Figure 5-1). Lastly, implications (5.3), limitations (5.4) and recommendations (5.5) for future research are also addressed within this chapter.

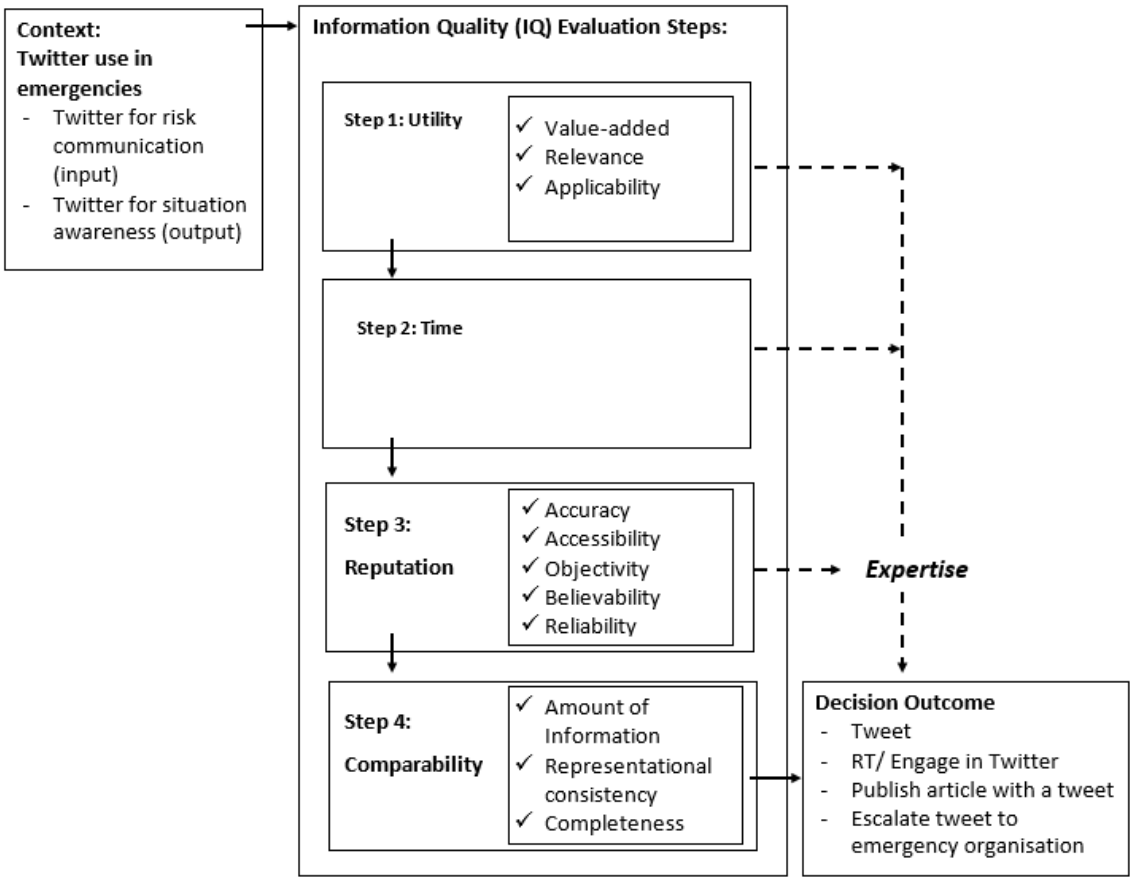


Figure 5-1 ETIQI model

5.1. Research background information: objective and methodology

This section summarises the research background by outlining its objective and the methodology employed. Furthermore, it describes how the novel ETIQI (Evaluation of Twitter Information Quality in Incidents) model was developed, including its rationale and steps. While the existing literature and previous research aided in creating the model, it is relevant to outline that the ETIQI model is an innovative model derived from

Subject-Matter Experts (SME) input and the mapping of their decision-making internal processes.

5.1.1. Research gap and objective

While the use of Twitter for Emergency Management (EM) is still in its infancy, a growing research body points toward the utility of this tool in this context. However, there is limited evidence of the use of Twitter for decision-making in naturalistic environments such as major incidents (e.g. emergencies). Using three case studies, the researcher identified the decision of using Twitter to reduce uncertainty as an exciting avenue to develop. In turn, a gap was identified in the area of evaluating Twitter Information Quality for decision-making in incidents.

As defined in Section 2.1., decision-making involves one or multiple decision-makers evaluating a set of alternatives with different dimensions and states of nature that may have different utility and uncertainty levels associated. While all decisions have a degree of uncertainty associated with them, this increases when using Twitter and other online sources for decision-making in major incidents such as emergencies. To reduce uncertainty, this research created a novel descriptive model to facilitate the Evaluation of Twitter Information Quality in Incidents (ETIQI model) to support decision-making in major incidents (Figure 5-1, page 300).

The literature review (Chapter 2) showcased the evaluation of Information Quality (IQ) as one of the biggest challenges while using Twitter for decision-making in incidents. Chapter 2 described existing research in the area of IQ requirements from an Emergency Management (EM) perspective, and it summarised existing solutions and models derived from Information Systems (IS) research. The researcher identified a gap while trying to use these solutions to implement a decision-making process using Twitter in naturalistic environments such as emergencies. What is more, little is known about the IQ dimensions available on Twitter for emergency management. In turn, three Research Questions (RQs) were proposed:

- ✓ *'RQ1. How is Twitter used for decision-making in major incidents?'*

- ✓ *'RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?'*
- ✓ *'RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?'*

To address these RQs and this research objective, the researcher used a three-stage process to develop the Evaluation of Twitter Information Quality in Incidents model (ETIQI model). The process included:

1) gathering evidence of decision-making using Twitter in incidents;
2) identifying relevant Twitter IQ dimensions for decision-making in non-routine incidents;
3) and evaluating the identified dimensions' conceptual relationship for decision-making in uncertain environments in the analysed context (case studies).

The identification of Twitter information requirements in major incidents for decision-making (RQ1) and their alignment with Twitter IQ dimensions (RQ2) supported this new model's development. Furthermore, RQ1 findings defined the scope to analyse IQ dimensions' conceptual relationship and better understand the steps taken by Subject-Matter Experts (SMEs) to reduce uncertainty in Twitter (RQ3).

By developing a descriptive model using three real-life case studies, the study enhances the theoretical understanding of Naturalistic Decision Making (NDM) using social media and User-Generated Content (UGC). Furthermore, it provides a new model based on experts' knowledge (i.e. journalists, public information officers and virtual operation support team) that can be used by any emergency stakeholder before, during and after a major incident facilitating their decision-making process while using online information.

5.1.2. Methodology summary

The ETIQI model (Figure 5-1, page 300) was developed using a three-phase research protocol designed to achieve the research objective (development of the ETIQI model) and answer its associated Research Questions (RQs outlined on page 302).

Figure 5-2 describes this research protocol which was based on three case studies and included ten adapted Critical Decision Method (CDM) interviews (75 decision-making processes). The three-phased protocol (context development, IQ identification, IQ conceptual relationship) comprised six steps, and findings were described in Chapter 4. This section summarises the methodology employed by outlining its highpoints and shortcomings to achieve this research's objective.

The first phase of this research was designed to collect evidence of the requirements and set up the context for developing the proposed descriptive model. Therefore, it aimed to answer RQ1 (*"How is Twitter used for decision-making in major incidents?"*), and findings contribute to practice through the collection of evidence. The research postulates that findings can be generalised to other existing social media platforms and extended to any type of User-Generated Content (UGC). The selection of Twitter instead of other social media platforms in this research was based, as documented in Chapter 2, on other researchers' findings, the number of users, its easy access with low privacy settings (removing ethical challenges) and the documented preference of Emergency Managers. However, commonalities shared by social media and UGC are such in essence that they suggest the applicability of these research findings to other online platforms. Hence, the use of Twitter mainly fulfils a methodological aspect of this descriptive study while research findings can be expanded to other online sources and applications. This key point is further developed in section 5.5 (page 352).

Findings from Phase 1 were reported through the first two steps of the research protocol and described in sections 4.1 and 4.2.

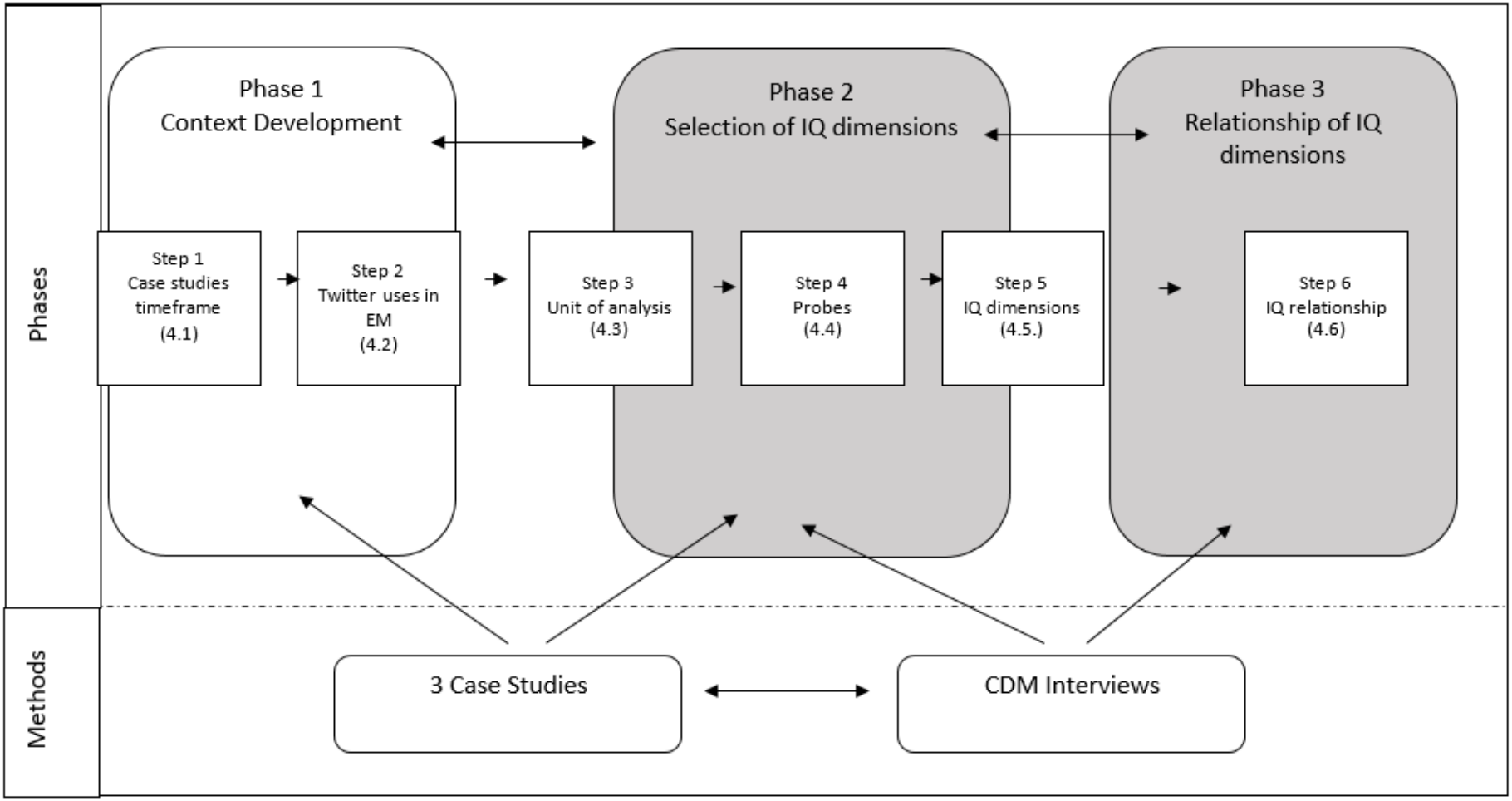


Figure 5-2 Research protocol– phases, steps (findings sections) and methods alignment

- ✓ **Step 1: Definition of case studies' timeframe**
- ✓ **Step 2: Description of observed uses of Twitter for decision-making in major incidents**

Three case studies were opportunistically selected for this research. The use of real situations as case studies, instead of simulated scenarios, is not exempt from challenges: major incidents are rarely predicted, and their potential magnitude is unknown at the beginning. The researcher had the opportunity of observing three incidents in short-time spam. They took place in August 2017 and illustrated the use of Twitter for decision-making in a terrorist attack, a solar eclipse (response planned as an emergency) and a hurricane. The use of real scenarios was aligned with the researcher's belief and the Naturalistic Decision Making School (NDMS). It is believed that reality is a social construction somewhat impacted by the projection of human interpretation and imagination, and conditioned by decision-makers experience. Hence, a high emphasis is placed on the importance of prescriptive knowledge in front of theoretical descriptive knowledge. Furthermore, the use of the Critical Decision Method (CDM), a NDMS qualitative method based on real situations, enabled the researcher to collect expert input within these situations.

Building on the first phase, three steps were defined to support the development of phase 2 and answer RQ2 (*"What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?"*). This second phase (Figure 5-2, page 304) supported the identification of key Information Quality (IQ) dimensions in major incidents while using Twitter for decision-making. In order to achieve this, a three-step approach was followed (steps 3, 4 and 5 from this research):

- ✓ **Step 3: Identification and definition of** Subject-Matter Experts (SMEs) as **the unit of analysis**
- ✓ **Step 4: Identification of probes: tweets that prompted a documented decision related to reducing uncertainty**
- ✓ **Step 5: Identification of Information Quality (IQ) Dimensions**

Ten Subject-Matter Experts (SMEs) were identified through the three case studies. These represented three decision-making profiles: journalists, Public Information Officers (PIOs) and Virtual Operation Support Team (VOST) members (an expert group of volunteers). Evidence was gathered of their role as decision-makers in each analysed case study while acting to reduce Twitter uncertainty using a production (create a tweet, shared) or consumption approach (extract information to escalate to an emergency organisation, debunk information outside Twitter). The analysis sample can be considered small in size; however, they provided insight into 75 decision-making processes. The validity of findings rests on SMEs expertise in the use of social media in major incidents which was corroborated through the case studies and in the interviews. While the participants' selection was driven by the evidence collected, several suitable SMEs were not available to participate in the study. The researcher stopped pursuing additional respondents when no further information was being added.

The use of interviews allowed the collection of detailed descriptions, which were analysed using content analysis. Only one person (the researcher) analysed the content; therefore, measures were put in place to guarantee the findings' validity during the coding process. The researcher transcribed and reviewed twice the information classified in each category, especially the classification of quotes within each IQ dimension. Furthermore, each respondent received a copy of their interview transcript enabling them to verify and clarify their responses as appropriate. All process was documented in order to keep the chain of evidence. In addition, participant observation (action research) allowed the researcher to further understand interviewees' roles and tasks and information collated in the case studies. Findings were reported in sections 4.3, 4.4 and 4.5.

After evaluating the IQ dimensions in RQ2, the researcher appraised the steps followed by the SMEs. This step is aligned with the last phase of this research protocol (see Figure 5-2, page 304), which addressed RQ3 – *'What steps are followed by experts to use Twitter in their decision-making process in major incidents?'* Consequently, the last step (step 6) included developing a descriptive model and findings were described in section 4.6.

- ✓ **Step 6: Model development: conceptual IQ relationship**

Derived from the 75 decision-making processes described by the respondents and the outlined verification protocols and strategies, the model was proposed in section 4.6, and it is discussed in section 5.2.3.

The use of three case studies combined with the Critical Decision Method (CDM) provided the researcher with a pre-defined protocol to follow. This approach enabled the navigation of a large volume of sources of evidence while remaining focused on achieving the main objective. The use of six steps made data triangulation feasible while using real-life situations. Furthermore, it is believed that the use of Naturalistic Decision Making (NDM) theories and methodologies in Information Systems (IS) is beneficial while designing and evaluating expert artefacts and should be further considered in detail by IS researchers. The next section discussed this research's findings by analysing them against the literature review gap (section 2.4).

5.2. Discussion of the findings

Using the methodology outlined in the previous section, the researcher provided answers to the following three research questions (RQs):

- ✓ *'RQ1. How is Twitter used for decision-making in major incidents?'*
- ✓ *'RQ2. What are the Information Quality (IQ) dimensions of Twitter posts in major incidents?'*
- ✓ *'RQ3. What steps are followed by experts to use Twitter in their decision-making process in major incidents?'*

The research's findings related to these RQs, including literature gaps addressed, are discussed in the next three sections. Furthermore, evaluating these findings retrospectively against the ETIQI model, the researcher illustrates the usefulness of this novel model and its potential use to support the Evaluation of Twitter Information Quality in Incidents.

5.2.1. The use of Twitter for decision-making in major incidents

This section discusses the research findings associated with the first research question, *'How is Twitter used for decision-making in major incidents?'*. First, the researcher analyses the proposed classification to categorise the use of Twitter in major incidents using an IS perspective. Then, evaluates the applications identified in special their impact of reducing uncertainty in Twitter for decision-making. Furthermore, the implementation of the proposed model is discussed in this context.

Decision-making in major incidents (e.g. emergencies)

Decision-making in emergencies refers to a mechanism to support each step of the problem-solving process (FEMA Independent Study Program, 2005). The decision-maker, an emergency stakeholder, must evaluate different candidate alternatives considering their control variables and states of nature to achieve an acceptable outcome. The process includes evaluating context-specific decision criteria based on the utility and uncertainty levels perceived by the decision-maker.

Decision-making in naturalistic environments (e.g. major incidents, emergencies and disasters) is intrinsically different from decision-making in other contexts. Several factors, including ill-structured problems, uncertain dynamic environments, time stress, and high stakes, can impact the ability of the decision-maker to achieve a timely and acceptable decision (M. L. Jensen, Lowry, Burgoon, & Nunamaker, 2010). Hence, the quality of the information used and the decision-maker's ability to process it play a vital role within this context. Within uncertain and ever-changing situations, the use of Twitter and other social media platforms has proven useful to receive timely updates from citizens and emergency organisations alike. However, this information system's research in major incidents and its impact on decision-making is still in its infancy.

Due to the peculiarities of decision-making in naturalistic environments such as emergencies, the researcher learned that any proposed IQ model should be context-specific. In this case, the context proposed is the decision-makers' use of Twitter in major incidents.

Classification: The use of Twitter in major incidents from an IS perspective

Scholars and practitioners are demonstrating the usefulness of Twitter in major incidents on an ongoing basis. Over the years, researchers (e.g. Alexander, 2014) proposed classifications based on multiple evidence and experts' input. However, to this researcher's best -knowledge, no previous evaluation of Twitter's use for decision-making in major incidents has been performed. This research addressed this gap by looking into the use of Twitter in incidents for decision-making, in particular, what actions can be done to facilitate the decision-making process. The researcher evaluated Twitter's use from an IS perspective; hence, the proposed classification is based on users' interaction with this social media platform. The researcher outlined Twitter use cases by using the platform's user-tweets entity-relationship.

Figure 5-3 describes this relationship. The researcher found evidence of Twitter use for decision-making from a production and consumption perspective through the three case studies. This classification is similar to the proposed by Kaminska & Rutten (2014), who classified social media use in Emergency Management within three pillars: (1) public information, (2) situational awareness, and (3) monitoring, evaluation and planning. Similarly, the researcher classified Twitter use within three use cases: risk communication, bi-directional communication and information search for situation awareness.

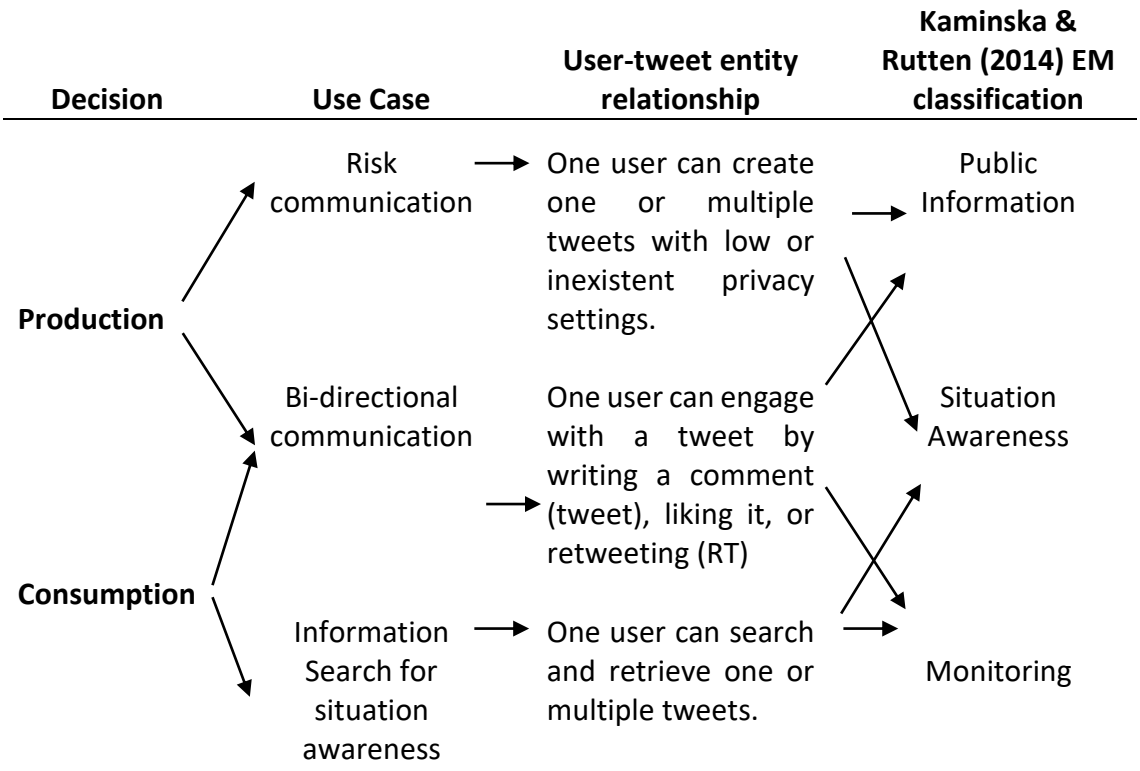


Figure 5-3 Twitter uses classification from an IS perspective

The proposed classification simplified the process of categorising observed uses and enabled the researcher to simplify evaluating the decision-making process related to information evaluation. Nevertheless, and while the researcher focused on gathering evidence of the use of Twitter for decision-making, findings from this research can be used to validate previous classifications (e.g. Alexander, 2014). For instance, case studies' stakeholders partnered with the public by extending emergency response during the rescue operation after Hurricane Harvey or the coordination to collect donations. Whereas these uses mainly focus on individual actions, the researcher grouped them into categories (e.g., creating a tweet or reply to a tweet) to evaluate Twitter's use from a decision-making perspective using the outlined approach.

In summary, the researcher learned that, as outlined by previous researchers, Twitter in major incidents can be used by users to produce and consume information before, during and after an emergency. Hence, the model designed required to consider the information flow between users: production (input) and consumption (output) of Twitter information.

Production: Communication through Twitter to support decision-making in major incidents

As the literature demonstrated (e.g. Veil et al., 2011), Twitter is broadly used by emergency organisations as a risk communication tool. For instance, the effectiveness of Twitter to reach a specific population in an emergency has been analysed in different contexts, such as university students (Snoeijers et al., 2014).

This research's case studies provided examples of Twitter use in the USA and Europe for decision-making in major incidents. Activities to support decision-making through risk communication strategies were extensively observed, including providing advice and updates to the general public and affected population. For instance, essential information was translated into other languages and shared through Twitter to reach tourists during the Barcelona Terrorist Attack. While this tool presents benefits to reach targeted audiences, interviewees indicated that media dependency theory and *'digital divide'* concept - which refers respectively to individual limitations (e.g. Veil et al., 2011) and preferences (Ball-Rokeach & de Fleur, 1976) to where to find information - are relevant to the use of Twitter in major incidents. Furthermore, decision-makers proved that it was also complemented with data from other sources when Twitter information was used. This approach, mostly based on asking for verification to their network, helped them reduce the uncertainty associated with the decision on hand.

Evidence of Twitter network-asking was gathered through the case studies; however, the researcher failed to collect extensive evidence of this practice from Subject-Matter Experts (SMEs) and emergency organisations. Besides, limited evidence was found on the use of Twitter as a bi-directional channel (asking/replying) by emergency organisations. However, actions to engage with content such as retweeting (RT) information were broadly observed. Hence, emergency organisations and citizens alike propagated messages from other official Twitter accounts. Evidential findings support Liu, Liu, & Li 's research. They indicated that *"source trustworthiness, source expertise, source attractiveness, and the number of multimedia have significant effects on the information retweeting. In addition, source expertise moderates the effects of user trustworthiness and content objectivity on the information retweeting in*

microblogging." (2012, p. 1). Furthermore building on Starbird & Palen (2010), evidence was found that retweets (RTs) – which work as a recommendation system- are more likely if the information is authored by local users and contain incidents-related search terms during major incidents.

In summary, the model proposed required to consider the use of Twitter for risk communication, including the decision of creating tweets and engaging with tweets from other sources.

Consumption: Information search on Twitter to support decision-making in major incidents

The research showed that emergency stakeholders (e.g. Public Information Officers, Virtual Operation Teams and journalists) used Twitter as an information source when the information was unknown through other sources. For instance, Virtual Operation Support Team (VOST) was provided with specific mission objectives when gathering intelligence from social media. The use of Twitter to help with an exploratory search task has been previously researched (Evans et al., 2010). For instance, Tim, Pan, Ractham, & Kaewkitipong (2016) analysed the use of Twitter as informational support during the 2011 Thailand flooding disaster. On a bigger scale, numerous publications evaluate the information on Twitter by performing trends analysis. An example of this use is developing a sensor for the detection of target events in tweets, such as the development of an earthquake reporting system in Japan (Sakaki et al., 2010).

Similarly, evidence was gathered of how Twitter can address information needs when access through other means is unavailable (e.g. number of victims after the Barcelona Terrorist Attack). Twitter becomes a valuable resource for information managers as it provides them with a listening mechanism to gather information from citizens. According to the *'Emergency Field Handbook'* (UNICEF, 2005), Information Managers need to gather information about the time and the location of events unfolding; the number of victims; emergency network activities; and the most urgent needs and gaps to save a more significant number of lives. The Twitter data stream can be added to other relevant sources that information managers evaluate as part of their on-going job in an emergency – *i.e. "seek information, question it and, where appropriate, validate*

acquired information" (National Working Group, 2008, p. 6). Likewise, journalists use Twitter to gather situation awareness from a different perspective, such as event unfolding, official confirmation and politicians declarations.

The researcher learned that the model developed needed to address the evaluation of Twitter Information Quality to facilitate situational awareness development. Two decision outcomes were observed in the case studies: the use of tweets in newspapers and the escalation of Twitter information to emergency organisations.

Twitter for decision-making in major incidents: risk communication and situation awareness

This research focused on identifying the uses of Twitter to support decision-making in major incidents such as emergencies. After the analysis and as described above, the researcher postulated that the use of Twitter for decision-making is impacted by emergency stakeholders' decision of using Twitter both from a consumption and production perspective.

The four decisions observed (decisions outcomes) are related to the production of information through risk communication and the consumption of information to create better situational awareness:

1) the decision of creating tweets,
2) the decision of sharing information,
3) the decision of escalating Twitter information to emergency organisations,
4) and the decision of using tweets posts to provide an update outside Twitter (e.g. news article).

This list does not aim to be exhaustive, but it illustrates decisions made by Subject-Matter Experts (SMEs) to address information requirements and uncertain information detected during the three case studies. The researcher proposes the ETIQI model with these four decision outcomes in mind, but it believes that its usage can be extended to other decisions outcomes.

Findings of this research contribute to support previous research findings in the area of risk communication, information propagation in Twitter, individual information search, Twitter as an information source for trend analysis (Table 5-1).

	Research area	Decision-making outcome of reducing uncertainty	Description	Sample of previous research
Risk Communication	Mass communication	Create a tweet	A user creates a tweet to support decision-making	(B. F. Liu, Fraustino, & Jin, 2015; St. Denis et al., 2014)
	Information Propagation	Engage with other tweets	An information-sharing behaviour is identified to propagate a tweet (RT)	(Starbird & Palen, 2010; Sutton et al., 2015; Wukich & Mergel, 2016)
Situation Awareness	Individual information search -And- Trend analysis	Use Twitter to document news articles	Information-Seeking behaviour is recorded to provide evidence of a new	(Diakopoulos et al., 2012; Hermida, 2012)
		Escalate Twitter information to emergency organisations	A tweet is escalated to an emergency organisation	(Fathi & Fiedrich, 2019; Fathi et al., 2019; St. Denis et al., 2012; Susaeta et al., 2017)

Table 5-1 Alignment of RQ1 findings with previous research

As Table 5-1 illustrates, previous research had been performed in the individual aspects of the four decisions (outcome) evaluated. However, the approach for assessing these actions together from a decision-making perspective and with the aim of reducing uncertainty is a novelty of this research. Furthermore, the researcher postulates that the use of Twitter for decision-making in emergencies could be improved by addressing Information Quality (IQ) pro-actively from a production perspective through risk communication and re-actively from a consumption perspective through addressing misinformation and improving information seeking and processing mechanisms.

While this research's findings can contribute to each of these areas (mass communication, information propagation, individual information search and trend analysis), it merges the four research areas from a decision-making perspective. In conclusion, the use of Twitter to reduce uncertainty depended on the type of emergency

stakeholder. However, in all situations, strategies implemented were part of risk communication and information-seeking mechanism. The research focused on evaluating the information flow between different stakeholders and their actions to address Twitter Information Quality (IQ) challenges in naturalistic environments, such as major incidents.

Naturalistic decision-making, uncertainty and Information Quality (IQ)

Within the Emergency Management (EM) context, decision-making is defined as *"a mechanism for making choices at each step of the problem-solving process"* (FEMA Independent Study Program, 2005, p. 2.1). Therefore, by definition, any model developed to aid decision-making had to support the problem-solving process through multiple steps.

A decision includes several components, including the concepts of utility and uncertainty. It is understood that all decisions have a level of uncertainty associated with them as the implications of the outcome are unknown at the moment of making the decision. However, this level of uncertainty increases in naturalistic environments where decision-makers have to address dynamically complex situations such as emergencies (Aldunate et al., 2005; Comfort, 1999; Danielsson & Ohlsson, 1999; Kapucu & Garayev, 2011; Moynihan, 2008). In emergencies, uncertainty levels make *"responders and citizens vulnerable to injury, death, disruption and other adverse effects"* (McEntire, 2004, p. 17).

Twitter, as a User-Generated Content channel, is prone to increase uncertainty in naturalistic environments. Multiple challenges previously outlined in the Chapter 2 literature review (e.g. big noise, information shift, misinformation) were confirmed by Subject-Matter Experts (SMEs) through the interviews. All of these challenges complicate the decision-making process by increasing information uncertainty associated with this social media platform (uncertainty about information provenance, reliability…). Consequently, the researcher observed how Twitter is used to address these challenges, particularly how Twitter is used by SMEs decision-makers in major incidents to reduce uncertainty. Besides, the researcher noted that all decisions

evaluated aimed to address Information Quality (IQ) by increasing the utility of the data while decreasing the uncertainty level associated with the use of Twitter.

5.2.2. Information Quality (IQ) dimensions of Twitter posts in major incidents

The previous section highlighted how Twitter is used in major incidents to enhance decision-making through risk communication and situational awareness. Building on the previous findings; the author discusses what is understood by Information Quality (IQ) in this given context. The analysis of information requirements in the emergency management context against existing IQ models showcased a misalignment between these. The researcher approached Subject-Matter Experts (SMEs) to question *'what are the relevant IQ dimensions of Twitter posts in major incidents?'*. Key findings discussed in this section refer to the definition of Information Quality (IQ) and the dimensions associated with it.

Information Quality (IQ) definition

The researcher provided different definitions of Information Quality (IQ) in Chapter 2. IQ is defined by most researchers based on information's *'fitness for use'* which relies on the concept of meeting end-users' requirements and expectations (Kahn et al., 2002; Y. W. Lee, 2003; Y. W. Lee et al., 2004; R. Y. Wang & Strong, 1996; Zhu & Wu, 2011).

By reviewing Information Systems (IS) and emergency management literature, the author encountered more than thirty Information Quality (IQ) dimensions that could be relevant within the analysed context. IQ dimensions included accuracy, accessibility, amount of information, applicability, availability, believability, concise representation, clarity, comparability, completeness, comprehensiveness, conciseness, consistency, context awareness, convenience, correctness, currency, interactivity, interpretability, location, quantity, objectivity, relevancy, reliability, reputation, security, speed, traceability, timeliness, understandability, usability, validation, and value-added.

In addition to previous research, findings from this study allow the researcher to infer in the idea that any Information Quality (IQ) definition is context-specific. Hence, the proposed model would apply to this given context (until tested in other situations). Furthermore, essential dimensions included as part of the IQ definition would vary in

their importance depending on the applicability to the research area. Hence, from these findings, the researcher proposes the following Twitter IQ definition for naturalistic environments for decision-making:

> Twitter Information Quality (IQ) in major incidents refers to the quality of a tweet based on the utility for decision-making, the timeliness of the tweet, the source reputation and the information comparability.

As the above definition demonstrates, not all IQ dimensions are highly relevant to the analysed context: decision-making using Twitter information in incidents. It was pointed out that Information Quality (IQ) in Twitter increases by improving the quality of the content shared. Consequently, a higher IQ would reduce uncertainty for decision-making. An interviewee advocated that Twitter IQ improves by analysing emergency stakeholders' information needs before, during and after an emergency. This premise had been previously explored by Kenneth a. Lachlan et al., (2014, p556), who indicated that Twitter becomes a *'good barometer for evaluating the needs of those affected'*. Chapter 2 (literature review) referred to Dimensions, and this research's findings are next discussed.

Relevant Information Quality (IQ) dimensions in Twitter's post in major incidents

Through data triangulation from case studies sources in combination with SMEs input, IQ dimensions pertinent to the use of Twitter for decision-making in major incidents were identified. Probes prompted the mention of these dimensions shown in the context of using Twitter for decision-making in incidents. Findings addressed RQ2, and they are discussed in the following paragraphs.

The literature reviewed in the area of Information Quality (IQ) in Information Systems and Emergency Management allowed the researcher to identify misalignment between dimensions mentioned in both research areas (Chapter 2).

Table 5-2 illustrates Information Quality (IQ) dimensions mentioned in the Information Systems and emergency management literature review (LR), comparing them against research findings (RF). As shown in this cross-comparison table, not all IQ dimensions encountered in this research's literature review (section 2.3) were mentioned by

interviewees as they were not be seen as relevant to the context discussed. In fact, fifteen dimensions were referred to by SMEs: utility, value-added, applicability, timeliness, reputation, accessibility, accuracy, reliability, objectivity, believability, comparability representational consistency, an appropriate amount of information and completeness.

Findings demonstrate that information utility IQ dimensions (i.e. value-added, applicability, relevance) impact IQ Twitter posts within this context. Decision-making is based on the decision-makers' perception of information utility and its quality. Consequently, information dimensions related to the attributed utility of a tweet were considered relevant. However, respondents stated that tweets relevant to one person may not be relevant for another one. This belief is aligned with interpretivism, which believes that reality is a subjective social construction somewhat impacted by the projection of human interpretation. Furthermore, tweets' information can be defined, explained and justified using a large variety of subjective premises, all depending on users' interpretation and expertise.

While information utility can be interpreted from a different perspective, SMEs agreed that if a tweet's information does not add value to any decision-maker, this should not be shared as a tweet or retweeted (RT). By minimising the volume of low utility information published, the Information Quality (IQ) of the remaining tweets would be perceived as higher. This approach will also positively impact the *'big data'* volume challenge created by user-generated content (UGC).

		EM IQ Dimensions	IS Information Quality (IQ) Dimensions																
			Objectivity	Believability	Accessibility	Accuracy	Amount of Information	Completeness	Concise representation	Reputation	Reliability	Timeliness	Value-added	Interactivity	Interpretability	Relevancy	Security	Understandability	Usability
IS IQ Dimensions			RF	RF														LR	LR
EM Information Quality (IQ) Requirements	Comparability	RF																	
	Applicability	RF																	
	Accessibility				LR/RF														
	Accuracy					LR/RF													
	Quantity						LR/RF												
	Completeness							LR/RF											
	Conciseness								LR/RF										
	Reputation									LR/RF									
	Reliability										LR/RF								
	Timely											LR/RF							
	Value-added												LR/RF						
	Interactivity													LR					
	Interpretability														LR				
	Relevance															LR			
	Security																LR		
	Applicability	LR																	

	EM IQ Dimensions	IS Information Quality (IQ) Dimensions																
		Objectivity	Believability	Accessibility	Accuracy	Amount of Information	Completeness	Concise representation	Reputation	Reliability	Timeliness	Value-added	Interactivity	Interpretability	Relevancy	Security	Understandability	Usability
Comparability	LR																	
Availability	LR																	
Comprehensiveness	LR																	
Clarity	LR																	
Consistency	LR																	
Context awareness	LR																	
Convenience	LR																	
Correctness	LR																	
Currency	LR																	
Location	LR																	
Speed	LR																	
Traceability	LR																	
Validation	LR																	

Table 5-2 IQ dimensions literature review (LR) and research findings (RF) comparison (Information Systems and emergency management)

Time is also an important Information Quality (IQ) dimension for emergencies, decision-making and Twitter. First, in emergencies, there is a need for immediate action. Secondly, decisions are achieved by providing the right information to the right person at the right time. However, information can be quickly out-dated, complicating the decision-making process. Lastly, time is a relevant dimension of the Twitter platform as its features allow producing and consuming tweet at high velocity. For instance, the limit in the number of tweet characters impacts the time dimension as it reduces the time required to produce content. Furthermore, Vosoughi, Mohsenvand, & Roy (2017) demonstrated that rumours are temporal in nature (i.e. the tweets that make up a rumour are tweeted at different times).

All interviews agreed that time is an essential dimension for using Twitter for decision-making in incidents. It was also stated that time could be a key element while establishing information leadership, which would impact sources' reputation.

Reputation was mentioned while evaluating all probes presented to the Subject-Matter Experts (SMEs). Reference to official sources and their role as reputable and trusted entities inferred that all content posted by them in Twitter inherited their quality perception by extension. Interviewees highlighted the difficulty of maintaining one's reputation online and especially on Twitter. It was outlined that a simple mistake or the wrong wording of a Tweet can impact the perception of a user's reputation in front of a broad audience. The Twitter platform allows information to be spread speedily for good and for wicked. Multiple researchers studied online reputation in different areas but mostly concentrated in communication research (e.g. Ott & Theunissen, 2015). Studies demonstrate with empirical evidence the difficulty of maintaining reputation levels when this is damaged in a crisis.

In the case of reputable official sources, it is believed that they have access to higher Information Quality (IQ) through their online and offline network. Accessibility to information is perceived as a relevant quality dimension in all defined contexts. It is understood that access to first-hand information (e.g. through witnesses or CCTV) provides a better understanding of any given event. In major incidents, official sources collaborate by providing information to a joint operations centre, which increases the

emergency's situation awareness. Twitter also increases access to emergency-related information as victims and witnesses can share information in real-time. Information access is a relevant dimension for decision-making; however, evidence collected through the case studies demonstrates that in specific major incidents such as terrorist attacks, information access can difficult the operational response of the police. For example, in multiple terrorist attacks in Europe, accessibility to information through Twitter was tempered by promoting Tweets' creation that included cat images. The aim was to difficult information access to terrorist who could be using Twitter for their own decision-making process.

Information accuracy is directly related to Information Quality (IQ); however, accuracy in major incidents is difficult as uncertainty levels are high. This dimension is related to others. For example, providing an exact number of casualties in the Barcelona Terrorist Attack required confirmation from the emergency response and forensic team that needed access to the bodies and time to certify their death officially. Adherence to this process made information reliable. One interviewee mentioned reliability, and it referred to the provenance of the information.

A factual description of the emergency unfolding was observed in the three case studies. However, a public information officer empathised with the importance of meeting information needs but also providing information that supported the narrative of the events (e.g. appreciation messages to emergency teams). Twitter has been used in multiple research to evaluate the sentiment analysis for specific topics (Gaspar, Pedro, Panagiotopoulos, & Seibt, 2016; Y.-R. Lin & Margolin, 2014). Therefore, subjectivity must be considered while evaluating information retrieved from Twitter. Furthermore, a VOST member outlined that any information shared by others other than official sources should be perceived as the user's perception of the truth.

Related to the decision-maker perception is the next Information Quality (IQ) dimension: believability. This dimension can be applied to tweet (i.e. the likelihood of information authenticity) and source believability. Hence, tweets entities related to content (i.e. text, link, image) and users profiles (i.e. biography, followers/followees, profile creation date) are relevant to perform an informed assessment.

While users' actions impact IQ perception, it is also influenced by external and complementary elements such as other users' tweets and interactions. Multiple interviewees discussed the comparability dimension by developing the dimensions of representational consistency, amount of information and completeness. Feedback collected included references to tweets evidence but also to the concept of a Twitter network and information redundancy.

Representational consistency was referred to as an essential dimension to support risk communication narrative and portray an image of a legit information source. Tweet consistency can be achieved intrinsically by effectively using Twitter post creation capabilities (e.g. text, images, timestamp, location, hashtag) to increase Information Quality (IQ). This approach also enhances the completeness dimension. Externally, representational consistency can be achieved by sharing similar messages through stakeholders' network. Similar findings were described by Sheppard, Janoske, and Liu (2012, p. 11) *"Empirical studies have shown that to be effective in prompting risk-reduction behaviors, preparedness information must come from multiple sources (Basolo, Steinberg, Burby, Levine, Cruz, & Huang, 2009; Mileti & Fitzpatrick, 1992), be communicated over multiple channels (Rogers, 1985; Smarick, 2010; Turner, Paz, & Young, 1981), and be frequently repeated (Mikami & Ikeda, 1985; Mileti & O'Brian, 1992; Turner, Nigg, Paz, & Young, 1979)."*

It was highlighted that redundancy achieved through the amount of information shared by a Twitter user and its network directly impacted the perception of IQ. The principle of saturation described by interviewees aligns with the idea of seeking information and the satisficing principle described in the Recognition-Primed Decisions (RDP) model (see section 2.1.). According to Simon (1959), the notion of satiation can adjust to the attainable. Therefore, tweets redundancy would make information more attainable and support decision-making.

Lastly, emergency awareness increases through information completeness, making this a relevant dimension while assessing IQ on Twitter. Completeness is achieved by emergency organisations through reported information to join operations centres.

Similarly, access to different Twitter accounts can increase the completeness of the data collected as it is provided from different perspectives.

IQ dimensions conceptual relationship

In conclusion, 15 dimensions were referred to by the interviewees and are included in the ETIQI model: utility, value-added, applicability, timeliness, reputation, accessibility, accuracy, reliability, objectivity, believability, comparability, representational consistency, an appropriate amount of information and completeness. Interviewees described their decision-making as an interconnected process where multiple dimensions were evaluated at once through their decision-making process. Therefore, the results highlighted the importance of analysing the relationship between these dimensions to understand further the steps followed by emergency Subject-Matter Experts (SMEs). In turn, RQ3 and Phase 3 are extremely important to fulfil the objective of this research. Those are discussed in the next section.

5.2.3. Steps for tweets to be used for decisions in major incidents

While the previous sections focused on the Information Quality (IQ) dimensions, here, the researcher discusses the decision-making process followed by experts to assess tweets quality in emergencies. Outlined steps include references to the Recognition-Primed Decisions (RPD) model and to the situation awareness theory as described as follows.

Recognition-Primed Decision (RPD) and experience

Decision-making in major incidents is inherently different from decision-making in other contexts. This research showed evidence that decisions made using Twitter data within naturalistic environments follow similar patterns identified by previous research in situations of stress and uncertainty.

In 1985, Gary Klein proposed the Recognition-Primed Decision-making (RPD) model, which summarises how people actually made decisions, and it highlights how decision-makers search cues and identify patterns instead of comparing options. Evidence of the three complexity levels -simple match, developing a course of action, and complex RPD strategy/progressive deepening - were found in this research. Depending on the

decision-maker's familiarity with the probe showed to elicit their knowledge, decision-makers further elaborated the steps followed to use Twitter information for the decision on-hand. For example, the tweet's image of a shark in Harvey Hurricane was quickly described as fake (simple match) by all interviewees based on the images cues (image reflection) and the appearance of the same image type in previous hurricanes (previous experience). Other probes with a higher level of uncertainty, and therefore unfamiliar situation, required a more complex RPD strategy where the situation was reassessed, and decision-makers searched for additional information. For example, the need for translators in hospitals after the Barcelona terrorist attack or the shortage of petrol in the eclipse and hurricane case studies had to be consulted with relevant stakeholders by multiple interviewees.

It is understood that independently of information's provenance, experience and intuition become a key factor in the decision-making process in major incidents. The challenge resides in enhancing both when people are not experts. Hence, the descriptive model includes the concept of experience while still guiding other users through the decision-making process.

This research indicates that risk communication and information verification protocols become more relevant for novice decision-makers (non-experts in the use of Twitter in major incidents). Interviewees highlighted that by designing an effective risk communication strategy based on verified content and networking, citizens' decision-making could be enhanced during the information gathering process. In turn, this is aligned with key contributions proposed by the situation awareness theory.

Situational Awareness (SA) theory and User Generated Content (UGC)

The situational awareness theory refers to how in complex and dynamic environments, decisions are not made using isolated cues but through decision-makers' ongoing situation awareness. This research's findings support the SA theory by illustrating how decision-makers used other data sources to complement UGC retrieved from or generated for Twitter. Initially, interviewees found it difficult to itemise specific steps to follow while describing their decision-making process. This difficulty illustrates that information processing was performed by interpreting the data presented as a whole.

In turn, it presents the challenge of accepting any model based on a linear workflow as multiple IQ dimensions can be processed and utilised to create mental models at once. While the researcher acknowledges this difficulty, the proposed model is derived from steps described by Subject-Matter Experts (SMEs). It is believed that this descriptive model would benefit novice decision-makers and people with low access to additional information sources (i.e. low situation awareness level). Further research would be required to prove its effectiveness.

Decision-making steps

Using 75 decision-making processes, the researcher mapped and grouped IQ dimensions in four steps. As described in Figure 5-4, the first step refers to the utility of the tweet information. This IQ dimension is informed by the perception of value-added, relevance and applicability of the information. The second step is the evaluation of time. This is followed by step 3, which refers to the assessment of reputation source concerning perceived accuracy, accessibility, objectivity, believability and reliability of the Twitter user posting the information online. Lastly, the last step refers to comparing the information (tweet) intrinsically and extrinsically in relation to the amount of information, its representational consistency and completeness. All these steps are further discussed in the next paragraphs, and they include strategies outlined by Subject-Matter Experts (SMEs) to perform the evaluation.

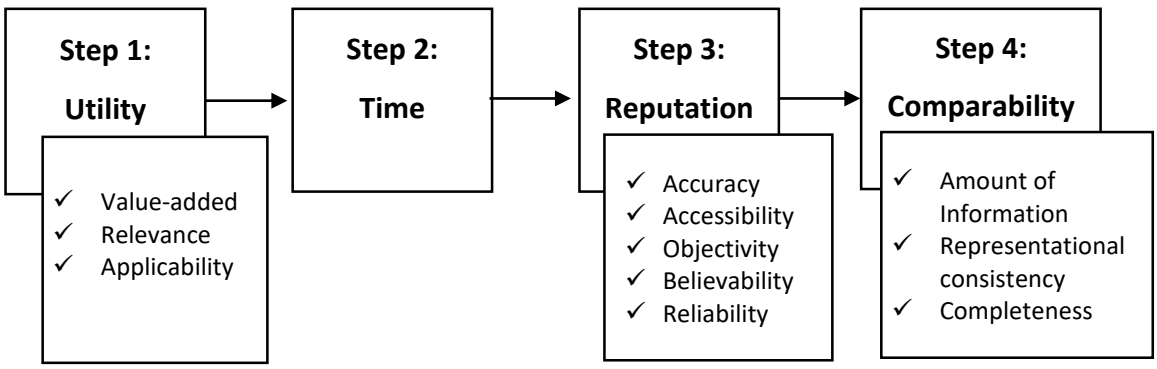


Figure 5-4 Steps for decision-making using Twitter in incidents (RQ3)

Step 1: Tweets' utility in major incidents

This research showcased that in major incidents, the information from Twitter is only considered for decision-making if it fits the requirements of the decision-makers' task. Hence, the decision-maker evaluates the utility of the information obtained or created for Twitter. As described in section 2.1.1, the utility is used to identify the scalar measure of relative contribution to a decision's success, and it may be done subjectively, intuitively or implicitly (Lifson, 1972). The importance of information utility was already pointed by Imran et al. (2015, p. 6), who outlined: *"the information any individual, group, or organisation finds useful and seeks out in a disaster will depend upon their goals".* The utility dimension also aligns with the concept of fitness for use presented in the Information Quality definition outlined in section 2.3.1 from Chapter 2 (Literature review).

In major incidents, three Information Quality (IQ) dimensions aid in evaluating the utility of a tweet: (1) value-added, (2) relevance and (3) applicability. In the decision-making process, decision-makers must respond positively at least to one of the following questions:

- Does this tweet add any value?
- Is the tweet's information relevant?
- Is this tweet applicable to the situation?
- Can the tweet information be utilised to make a decision?

It was mentioned that in order to reduce the uncertainty of consuming Twitter data, users could facilitate the retrieval of information by only producing information that addresses at least one of these dimensions. Therefore, several strategies were mentioned by interviewees to reduce Twitter uncertainty through the enhancement of Information Quality (IQ) based on increasing tweets' utility (Table 5-3).

Twitter Feature	Utility
Text	Only tweet based on utility
URL	Provide links to static content
Photos	Do not tweet images of victims or police movements
Share (RT)	Only verified information based on utility
Profiles	Report accounts that impersonate official sources
Keywords (#hashtags)	Standardise hashtags to facilitate retrieval

Table 5-3 Utility IQ dimension: Strategies to reduce uncertainty in Twitter

Table 5-3 summarises strategies to reduce uncertainty mentioned by interviewees. Some of them were already captured in the literature review (section 2.3.4). For example, the utility of the information through content analysis was researched to classify content (A. Kumar, Prakash, Yogesh, & Nripendra, 2020).

In the table above, the strategies proposed had been mapped against Twitter features to facilitate its implementation. Subject-Matter Experts (SMEs) suggested only to create tweets (text) or share information (RT) based on its utility. The proposed approach would reduce the challenge of volume and big noise associated with Twitter by reducing the amount of information shared. Hence, images that can create despair reactions should be avoided (photos). In addition, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) proposed to standardise hashtags to facilitate information retrieval based on adding Global Positioning System (GPS) location and using disaster name, public reporting and emergency response hashtags (R. Moore & Verity, 2014).

Reactive strategies, such as reporting accounts that impersonate official sources or misleading content, would also improve the overall emergency stakeholders' decision-making process by eliminating irrelevant content. The role of social media organisations (Twitter, Facebook) has been a theme of discussion in the last few years, where it has been advocated that they should play an active role in eliminating fake profiles and minimising the impact of misinformation (e.g. El Mundo, 2018).

Step 2: Tweets' timeliness in major incidents

Time is a highly important consideration in any emergency. Situations can evolve fast, making information quickly outdated. In addition, Twitter is a fast-paced environment where information displayed in feeds moves at high speed. This is due to the velocity and volume of information contained in this platform.

The provision of timely updates is one of the biggest challenges in emergency management. Subject matter experts described timeliness with an inverse relation to information comparability and reputation. The provision of timely updates is difficult if stakeholders need to compare the information using other Twitter data or other sources of information as it is a slow process. In turn, the provision of wrong information can damage the reputation of the source. In order to protect their reputation, users can be slow providing updates until they had the time to compare the information. Despite this, decision-makers would perform decisions with the information available at the time.

Interviewees highlighted four main strategies to use time in the decision-making process. They refer to the text, timestamp, image analysis, and keywords use in major incidents (Table 5-4).

Twitter Feature	Timeliness Strategies
Text	Prepare tweets in advance. Let know the audience that official sources are aware and will inform when it is safe or has been confirmed.
Timestamp	Use only fresh information (Starbird & Palen, 2010)
Photos	Observe time elements such as the position of the sun against the location and time (Faure, 2019)
Keywords (#hashtags)	Identify the hashtags used before creating content.

Table 5-4 Timeliness IQ dimension: Strategies to reduce uncertainty in Twitter

Subject matter experts emphasised the importance of using only fresh and actual information in the decision-making process. Hence looking at when the tweet was posted should be part of the steps followed. When old information is identified, it should be discarded, and an update should be searched. It was also recommended to enhance risk communication strategies by preparing tweets in advance that can be tailored to the unfolding situation. By analysing information needs, the speed of creating tweets could be highly improved. The requirement of having a Twitter library was also noted by

the S-HELP project in 2016. This project developed a risk communication tool within its decision-support system that allowed multiple organisations to use pre-approved tweets (S-HELP, 2016). In addition, searching hashtags that citizens had already used in the emergency unfolding would positively impact making tweets easier to retrieve. While it is difficult for emergency organisations to be the first ones to report in an emergency situation on Twitter, efforts must be made to become leaders in communication and avoid organisation silence.

Step 3: Tweets' reputation in major incidents

Reputation was mentioned by all stakeholders while explaining the process of verifying the information. It is a collective agreement that Twitter accounts from official sources inherit their reputation, and they are perceived as objective, reliable and believable. This perception is due to their supposed access to higher information accuracy through their operatives' network in join operations centres. If information provenience is from other sources (e.g. citizens), decision-makers must evaluate all the termed dimensions: objectivity, believability, reliability, accuracy and accessibility. The analysis of a user reputation online is not exempt from challenges, and some of the IQ dimensions related depend on the perception of the decision-maker. Subject-Matter Experts (SMEs) and previous researchers suggested different strategies to evaluate Twitter users' reputation based on the analysis of different Twitter features. Verma & Sofat (2014) summarised different techniques (algorithms) employed in research papers to identify spammers on Twitter. They classified these studies according to four categories of features for detecting spam profiles: user-based, content-based, mix of both and other features like graphical distance or graph connectivity. The use of these features was also outlined by Subject-Matter Experts (SMEs) in this research but from a more individualistic approach (Table 5-5).

Twitter Feature	Reputation
Timestamp	Check when the profile was created (Gupta et al., 2013a)
Text	Check previous profile tweets Be careful with wording
URL	Link to official sources
Photos	Add images to provide evidence
People (user tags /user mentions)	Network. Check followers and followees
Share (RT)	Only share information from reputable sources (Diakopoulos et al., 2012)
Profiles	Check source bio Check official sources

Table 5-5 Reputation IQ dimension: Strategies to reduce uncertainty in Twitter

Strategies used to assess source reputation included checking when the profile was created, evaluating previous tweets, checking links provided, looking at user's network, being critical evaluating images, and comparing the information with official sources.

Step 4: Tweets' comparability in major incidents

Previous research validates the approach of evaluating reputation in front of comparability. It has been demonstrated that *"the 'wisdom of the crowd' is not really wisdom at all and it is better to rank evidence from Twitter in order of the most trusted and credible sources"* (Middleton, 2015, p. 1). However, when official information is not available, decision-makers may need to compare different tweets / online information to achieve situational awareness.

In order to do so, steps need to be performed to compare the information intrinsically and extrinsically. The analysis should be performed by evaluating the amount of information provided, its representational consistency and completeness. Table 5-7 summarises strategies to reduce uncertainty mentioned by interviewees. It includes evaluating Twitter features from different perspectives and mostly using additional information such as other tweets, features or external information sources. Comparability and its associated IQ dimensions enable decision-makers to perform a confirmation step that is highly related to the contextual information available to the emergency stakeholder.

Twitter Feature	Comparability
Timestamp	Compare information with the events' timeline
Keywords (#hashtags)	Create and search incident-related hashtags Be specific and descriptive (e.g. name, location and/or type of emergency)
URL	Provide links to support the evidence
Photos	Add images to increase the probability of sharing content Do image inverse search
People (user tags /user mentions)	Mention relevant stakeholders to increase tweets credibility
Add new post	Ask for clarification
Share (RT)	Amplify network tweets

Table 5-6 Comparability IQ dimension: Strategies to reduce uncertainty in Twitter

This section has described different strategies suggested by interviewees and included references to previous research. Table 5-7 provides a summary of all the mentioned strategies grouped by Twitter feature and IQ dimension. Other researchers had partially validated the findings of this research in their own studies.

A recent publication (J. Yang, Yu, Qin, Lu, & Yang, 2019) used Hurricane Harvey Twitter data to test a credibility framework based on a 3-factor hierarchy (Twitter text, URL, and retweet/RT) combined with a scoring system to extract reliable situation awareness events. They indicated "*that higher credibility score indicates that there are more tweets, more linked URLs, and more retweets mentioning this event"* (p.2). This three-factor framework includes features associated with the utility, reputation and comparability IQ dimensions proposed in this research.

Twitter Feature	Description	Strategy to reduce uncertainty			
		Utility	Timeliness	Reputation	Comparability
Timestamp	Time when a tweet was posted		Use only fresh information (Starbird & Palen, 2010)	Check when the profile was created (Gupta et al., 2013a)	
Text	Words and phrases (Limited to 140 characters and extended to 280 in November 2017)	Only tweet based on utility	Prepare tweets in advance	Check previous profile tweets Be careful with wording	
Keywords (#hashtags)	Any word or phrase immediately preceded by the # symbol. Convert content in a clickable link.	Standardise hashtags to facilitate retrieval (R. Moore & Verity, 2014)	Identify hashtags used before creating content		Create and search incident-related hashtags Be specific and descriptive (e.g. name, location and/or type of emergency)
URL	Link to external content 'http: //www.'	Provide links to static content			Provide links to support the evidence
Photos	Pictures	Do not tweet images of victims or police movements	Check temporal and Geolocation elements such as the sun position (Faure, 2019)	Add images to provide evidence	Add images to increase the probability of sharing content Do image inverse search

Twitter Feature	Description	Strategy to reduce uncertainty			
		Utility	Timeliness	Reputation	Comparability
People (user tags /user mentions)	Mention another user and create a link to their profile (@username)			Network	Mention relevant stakeholders to increase the credibility
Add new post	Allows to publish multiple posts interlinked				Ask for clarification
Share (RT)	Retweet (RT) messages with network	Only verified information based on utility		Only share information from reputable sources (Diakopoulos et al., 2012)	Amplify network tweets
Profiles		Report accounts that impersonate official sources		Check source bio Check official sources	

Table 5-7 Strategies for uncertainty reduction in Twitter (Source: created by the researcher unless it is stated)

By comparing research findings with strategies from previous publications, the researcher is able to enhance the proposed solution. Surprisingly no mention of the location feature was made by SMEs. Tweets had been considered in research as *"a spatiotemporal signal (geolocation and timestamp of tweet) with a semantic information layer (content of tweet message)"* (Steiger et al., 2015, p. 2). Even though geolocation information is not always available in all tweets, it is a feature that researchers and journalists consider to facilitate event's detection on Twitter and verify its accuracy. Its use is also recommended by OCHA, the United Nations Office for the Coordination of Humanitarian Affairs (R. Moore & Verity, 2014).

In this research, journalists' input showcased how emergency managers can benefit from acquiring best practices from that profession while verifying and cross-checking facts online. The researcher took part in the *'Collaboration against disinformation'* workshop[41] organised by First Draft Initiative and funded by Google in Germany (2019), where some of the outlined strategies were discussed. For instance, strategies discussed in the area of verifying images through the identification of eyewitness location by reviewing landmarks against other parameters such as the position of the sun on a specific date through the webpage Suncal (Faure, 2019). Using a more broad approach, investigation techniques such as gap analysis can be implemented to verify information in special images (Nixintel, 2019). Hence, the researcher suggests strengthening further collaboration between journalists and emergency managers in the advent of an emergency.

It is postulated that by developing training material based on the development of experts' verification protocols, any emergency stakeholder can improve their decision-making skills. They can become proficient in and use Recognition-Primed Decisions (RPD) and situation awareness approach to decision-making. Therefore, instead of generating a range of options, comparing them and selecting the best one at a specific decision point, they would depend on their own experience and mix situation awareness

[41] The First Draft organisation hosted three identical disinformation workshops (in Brussels, Frankfurt and Milan) bringing together journalists, researchers, analysts and innovators from Europe. The researcher was invited to attend as a participant to the event hosted in Frankfurt (Germany) on March 14th to 16th of 2019. During the event strategies to verify online information were discussed. Website: https://firstdraftnews.org

with mental simulation. Therefore, decision-makers will focus on the situation as opposed to analytically comparing all available options. By focusing on the situation awareness, especially assessing available goals, cues, expectancies and actions in Twitter, decisions of how to verify the information would be taken depending on the different levels of complexity. For each IQ dimension, different strategies can be used while evaluating the cues hosted on Twitter features.

5.2.4. How to use the ETIQI model?

The ETIQI model was designed to support the Evaluation of Twitter Information Quality in Incidents for decision-making. During the assessment of existing research in the use of Twitter for decision-making in major incidents, the researcher identified the assessment of Information Quality (IQ) as a challenge unaddressed from a user perspective. The findings from this research described in the above sections supported the development of this model. This section focus on describing how to use the model and discusses its key elements.

The objective of this research was:

> ***'To develop a descriptive microblogging (Twitter) model to determine the Information Quality (IQ) of posts (tweets) for decision-making in major incidents.'***

Hence, this descriptive model assists any decision-maker, independent of their experience, to determine the IQ of tweets in major incidents such as emergencies. The ETIQI model (Figure 5-5, page 337) includes the concept of experience while still guiding other users through the decision-making process. ETIQI is a decision-making model: a mechanism that outlines steps to support the problem-solving process.

As outlined in the literature review (Chapter 2) and by this research's findings, decision-making in major incidents (e.g. emergencies) is conditioned by the characteristics of these naturalistic environments (uncertainty, ill-defined problems…). The definition of Information Quality (IQ) depends on the information requirements of each specific research area. Therefore, the ETIQI model should be used in the context that it was

designed for as it is context-specific (until tested in other contexts). In this case, the context proposed is the decision-makers' use of Twitter in major incidents.

Twitter is used to produce and consume information related to before, during and after a major incident. Hence, this descriptive model (Figure 5-5) can assist the production (input) and consumption (output) of Twitter information incidents.

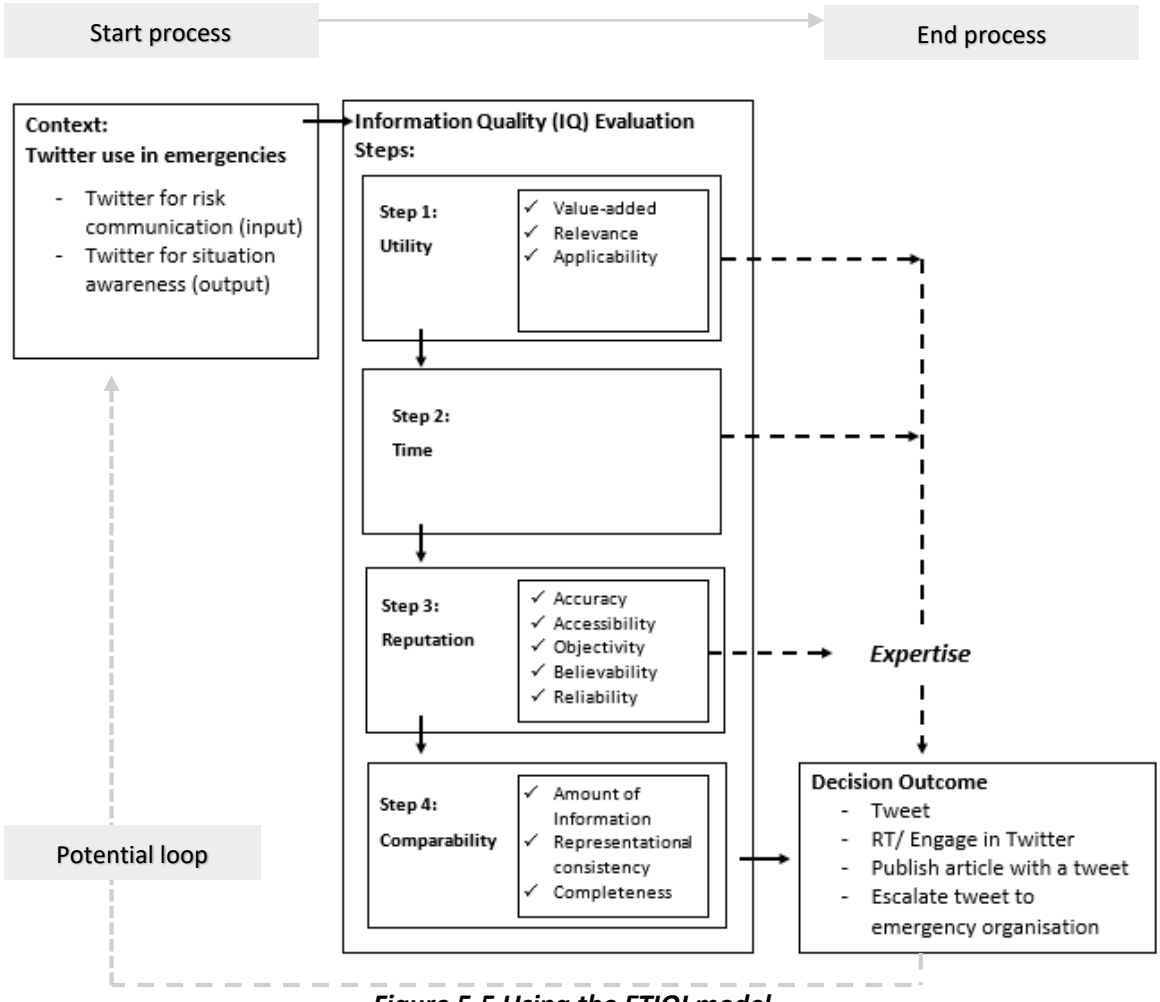


Figure 5-5 Using the ETIQI model

As Figure 5-5 describes, the model is designed to aid emergency stakeholders in the use of Twitter for risk communication and facilitate the development of situational awareness (context box in the ETIQI model – start process). Hence initially, it enables four decision outcomes (end of the decision-making process in the ETIQI model). Those represent the four decisions observed in the three case studies analysed:

1) the decision of creating tweets,
2) the decision of sharing information (RT/Engage in Twitter),
3) the decision of publishing an article with a tweet,
4) and the decision of escalating tweets to emergency organisations

The four decisions outcomes (end of the process in the ETIQI model) were performed in the three case studies by Subject-Matter Experts (SMEs) to reduce uncertainty through increasing information utility and, therefore, Information Quality (IQ). Hence, the outlined decisions outcomes can enhance the use of Twitter as part of risk communication and situational awareness, creating a potential loop in the ETIQI model.

For instance, a public information officer can start the process by gathering situational awareness from Twitter. Each tweet would be evaluated concerning its utility, timeliness, reputation and comparability. At the end of the verification process, the public information officer will have generated a mental picture of the events unfolding and decide to create a tweet to update citizens (end of the first decision-making process). The public information officer will then use Twitter as a risk communication tool (start of the second process) and compose the tweet looking into its utility, timeliness, ensuring source reputation, and creating comparable content (confirmation step). The outcome of the second process will be a tweet that will help the decision-making process of other emergency stakeholders who can use the model on a third iteration. This potential loop showcases how the evolution of thinking evolves with decision-makers' internal models and the contextual information available to them.

One example from the case studies illustrates perfectly this dynamic (ETIQI model loop) and how one decision-making process can lead to the next one. It refers to probe 8 and 9 in the eclipse case study (see Table 4-14, page 259). Before the eclipse, the Oregon

Virtual Operation Support Team (VOST) was activated. Using Twitter for situation awareness, they identified several tweets reporting large queues to access petrol (probe 8). After assessing this information, they decided to escalate the information to their activating emergency organisation (decision outcome 1). In turn, the Public Information Officer (PIOs) evaluated this information and decided to create a tweet (probe 9 – decision outcome 2). Hence, the use of Twitter for information awareness from VOST (with decision outcome 1 – i.e. escalation) was transformed by the PIO to the use of Twitter for risk communication (decision outcome 2 – i.e. create a tweet), which enabled situation awareness for citizens.

Figure 5-5 illustrates that between the start of the process (context) and the end of the process (decision outcome), the decision-maker will evaluate the Information Quality (IQ). Influenced by the RPD model, the ETIQI model departs from the premise based on a four-step process that can be exited based on the decision-maker experience at any point to achieve a decision (outcome). In the context analysed, the decision-maker's experience is a key factor in the decision-making process.

The proposed model includes four IQ dimensions -utility, time, reputation and comparability- which are complemented and enhanced by eleven interconnected dimensions -value-added, applicability, relevance, accessibility, accuracy, reliability, objectivity, believability, representational consistency, an appropriate amount of information and completeness-. The comparability IQ dimension enables decision-makers to confirm their internal model using contextual information and verify their decision-making process (confirmation step). While the researcher proposed a high-level linear decision-making process, the inclusion of eleven interconnected dimensions enables decision-makers to evaluate the information using different approaches depending on observed cues, stimulus, signals, and perception. Strategies utilised by Subject-Matter Experts and previous research findings were outlined in the previous section (see Table 5-7, page 334). Those strategies can be included in any potential training designed to implement the ETIQI model. The use of this descriptive model has multiple implications for decision-making in major incidents and Information Systems (IS).

5.3. Implications for decision-making in incidents and IS

This research contributes to the decision-making theory and practice, in particular to decision-making in naturalistic environments. It illustrates the importance of online information quality for decision-making in this context. Findings suggest that decision-makers evaluate information quality using internal models that are constantly adapted to their experience and the contextual information available. This result provides evidence of how thinking evolves as part of the decision-making process in major incidents. Interviews showcased that those internal models were not previously documented as part of any interviewees training or protocol. Hence, this research contributes to reducing uncertainty by providing an artifact (process) to evaluate online information for decision-making in major incidents. Furthermore, it provides an operational Information Quality definition based on its dimensions and the conceptual relationship of these for decision-making. It showcases the relevance of information quality dimensions as part of each step in the decision-making process. Besides, it illustrates the relevance of including the workflow between dimensions within the Information Quality model.

In turn, this research's findings have significant implications for Information Quality (IQ), experts' system design, and User-Generated Content (UGC) research and Emergency Management (EM) practice. This section describes implications for theory and practice in these fields.

5.3.1. Implications for theory

The outlined findings have theoretical implications in different research areas, including Naturalistic Decision Making (NDM) and Information Systems (IS). It contributes to the prime recognition model, situational awareness theory, and differs from existing Information Quality (IQ) models by identifying the relevant workflow for decision-making in naturalistic environments. Furthermore, IS theory benefits from the implications of producing and consuming user-generated content in online environments, particularly Twitter.

Information Quality (IQ): Models and definition

Chapter 2 (section 2.3) highlighted that there is limited knowledge of the IQ requirements for the use of Twitter information during decision-making in major incidents. The findings highlight that not all Information Quality (IQ) dimensions have the same importance while evaluating Twitter posts for decision-making in this type of naturalistic environment. Hence, this study infers that IQ is context-specific.

This research contributes by defining Information Quality (IQ) in the defined context. In major incidents, the data analysed suggested four main dimensions to support the decision-making process using User-Generated Content (UGC): utility, timeliness, reputation, and comparability. While further research is required to analyse the statistical correlation between these, the researcher derived a conceptual relationship between fifteen IQ dimensions and developed a descriptive model based on respondents' internal models (Figure 5-5, page 337). The steps followed by Subject-Matter Experts (SMEs) indicated that any model developed to support decision-making benefits of including a workflow for its implementation. This is a novelty in the IQ research area as previous models do not outline the relationship between their dimensions. Hence this descriptive Information Quality (IQ) model contributes to theory by highlighting the dimensions mentioned above and a suitable workflow between them to reduce uncertainty in decision-making.

Naturalistic Decision Making

This study contributes to the naturalistic decision making research by evaluating the Prime-Recognition Model (PRM) and the Situational Awareness (SA) theory concerning Information Systems (IS) in specific social media and Twitter. The Naturalistic Decision Making School (NDMS) showcases that decisions are different in naturalistic environments. Following this line of though, this research's findings argue that the impact of these environments' characteristics can be reduced through the appropriate management of risk communication and information management in decision-making. Hence, any decision-making's uncertainty can be minimised through bi-directional channels with coding and decoding messages based on utility, timeliness, reputation, and comparability (ETIQI model).

Prime-Recognition Model (PRM)

Findings illustrated how the PRM is applied in the area of User-Generated Content (UGC), specificallu Twitter, in major incidents. The PRM specified three models (simple match, developing a course of action and complex RPD strategy) related to the different levels of complexity. Evidence of how the complexity of Twitter information impacted the decision-making process was found when the Subject-Matter Experts (SMEs) evaluated different probes (tweets). Previous experience was relevant to identify some probes as fake information (e.g. shark swimming in the motorway) using a simple match approach. Other probes, where decision-makers were less familiar with relevant cues, required further analysis before reaching a course of action. It is paramount that the complexity level identified was dependent on each decision-maker's experience. Hence, PRM impacts how any workflow implementation of an IQ model in emergencies should be implemented as decision-makers may choose to exit the decision-making process before the last IQ dimension proposed is considered. This implication is observed in the ETIQI model as each step provide the opportunity to reach a decision outcome based on the decision-maker's experience (Figure 5-5, page 337).

Situational Awareness (SA) theory

The Naturalistic Decision Making School (NDMS) has contributed to the Emergency Management (EM) field by proposing the Situational Awareness (SA) theory. In the discussed context, SA refers to the ongoing awareness of decision-maker's environment. Evidence of this was also found within the research. Subject-Matter Experts (SMEs) emphasised the idea of an interconnected universe where signals and stimulus do not live only in social media but work in combination with other data sources (online and offline). Hence, the proposal of any Information Quality (IQ) model for emergencies related tasks must be considered within the lens of the situational awareness theory as the decision-making process not only depend on experience but also on the perception of elements in a current situation, the comprehension of that situation and the projection of any future status. The proposed model (Figure 5-5, page 337) guides the decision-maker through four steps, but within each step, several IQ dimensions are included without particular order. Furthermore, the last step (comparability) advocates verifying the information by evaluating other sources and available resources.

Risk communication: social media and User Generated Content

This study contributes to communication theory by encouraging the creation of messages on their utility instead of the agenda-setting theory. The ETIQI model is based on supporting decision-making instead of influencing people alignment with one or other parties. It also includes the idea that communication must evolve at the same speed as facts and showcases that "nothing is older than yesterday's newspaper". As part of the risk communication decision-making process, the timeliness dimension imposes the evaluation of the information with a temporality perspective. This approach contributes to practice to support managing the information shift challenge of big data present in User Generated Content. Furthermore, findings pinpoint how communication leadership is developed in social media in a major incident. It highlights how leadership is impacted by information access and delivery speed, but also how reputation can suffer from small mistakes online. Therefore, implementing the ETIQI model contributes to minimising big data challenges (big noise, information velocity, variety of data) when implemented by multiple risk communication stakeholders.

5.3.2. Contribution to practice

This research is rich in data sources, enabling the researcher to evaluate the decision-making process in major incidents (e.g. emergencies, disasters) using Twitter from different perspectives. The model was designed based on the decision-making process with four well-defined outcomes: 1) create a tweet, 2) RT/Engage in Twitter, 3) use Twitter information to document a news article and 4) escalate tweet to an emergency organisation (Figure 5-5, page 337). Therefore, practitioners who perform these incident-related tasks can benefit from the use of the ETIQI model. Table 5-8 summarises the model's implications and research contributions to practice, in particular for public information officers and journalists but also for other emergency stakeholders such as citizens.

Model Decision Outcome	Model Implication / Contribution to practice	Example
Tweet	- Support the task of composing a tweet - Make risk communication messages more effective by reducing uncertainty (sender) - Speed up the process of communicating with the press and sharing press release information - Communicate directly with citizens - Facilitate decision-making process (receiver)	During a terrorist attack, PIO can use the model to create tweets sharing operational information from the police to protect citizens and reduce uncertainty. The information would be included based on its utility, the right time without impacting the success of the operation, increasing the reputation of the source and including comparable information.
RT / Engage with tweet	- Increase the network reach of key risk communication messages (sender / receiver) - Facilitate the decision-making process for endorsing messages (sender) - Facilitate decision-making process (receiver)	Before a mass gathering event (i.e. solar eclipse, political demonstration), emergency organizations can use the model to assess tweets from other sources, including other emergency organisation and decide what tweets to RT based on the utility, timeliness, reputation and comparability of the information shared enhancing their message.
Use tweet to document news article	- Provide evidence of official messages - A process to validate risk communication messages - Facilitate decision-making process (receiver)	Journalists can use the model to evaluate their social media sources while using tweets to illustrate and provide evidence for their news articles.

Model Decision Outcome	Model Implication / Contribution to practice	Example
Escalate tweet information to an emergency organisation	- Provide a process to evaluate information from online sources for situational awareness - Facilitate decision-making process (receiver)	Virtual operation support members can use the model to assess the online information to evaluate it before escalating it to relevant emergency organisations to support situational awareness.

Table 5-8 Summary of contribution to practice

Hence, practical lessons learned can be applied to emergency practitioners, risk communication, information management, and to develop Information Quality (IQ) training material for the use of the ETIQI model.

The importance of Information Quality (IQ) within the decision-making process is undeniable. Twitter enables emergency stakeholders to collect information from multiple sources and share it with them (bidirectional communication). It is paramount to develop mechanisms and protocols to enable decision-makers to use Twitter information by minimising the risk associated with this platform in emergencies and major incidents. Access to these tools becomes the difference between using and not using this information source when other means are unavailable. The proposed descriptive model (Figure 5-5, page 337) can, indeed, benefit multiple emergency stakeholders (e.g. public information officers, journalists, volunteers, citizens) by providing them with guidance while evaluating User Generated Content as part of their decision-making process (i.e. creating messages, sharing it and acting on the information). The model supports reducing uncertainty in the creation (system input) and consumption (system output) step for sender and receiver. Furthermore, it can enhance risk communication strategies and facilitate decision-making.

- Journalists

The use of social media to identify breaking news is part of journalists' ongoing activities. Social media provides them with information from witnesses in major incidents and allows them to capture official sources' reactions. Examples of these were gathered through this research's case studies. The challenge highlighted is the evaluation of this information and its verification process. The ETIQI model benefits this collective by guiding key elements to review before using social media information to document news articles. In addition, it provides them with guidelines to create social media content to promote their writing.

- Emergency Managers and Public Information Officers

The use of the ETIQI can improve the information flow between emergency organizations as senders and information consumers (e.g. journalists, volunteers and

citizens). Risk messages can be distributed quicker by creating targeted messages received by journalists and citizens alike. This approach increases the information delivery speed that traditionally was lower as press release distribution takes more time. Furthermore, it allows emergency stakeholders to have direct conversations with citizens and address the quicker information needs of different stakeholders. The use of the ETIQI model can facilitate the development of information leadership when most needed and identify key players and experts in the relevant matter or events unfolding. The use of the ETIQI model in conjunction with the identification of information needs reduces multiple social media information quality challenges such as big noise (focus on utility), information shift (timely updates) and information uncertainty (reputation and comparability).

- Volunteers

Before and after any incident, the role of volunteers is very relevant when official respondents are overwhelmed by a lack of resources or the incidents' magnitude. However, a lack of training and integration with emergency organizations can endanger lives and create further disruption. The use of the ETIQI model will enhance communication between different stakeholders and allow volunteers to support communities and individuals affected. Through the coding and decoding of messages based on its utility, timeliness, source reputation and information comparability, volunteers can action multiple activities while reducing information uncertainty

- Citizens

The ETIQI model was developed with the expert input of journalists, emergency management's public information officers and virtual volunteers. Contributions to their practice are easily appreciated through this research's findings (Chapter 4). However, the model can be used by any social media user independently of their role in an emergency.

This research contributes by providing citizens with a tool designed by social media users who are also experts in managing information in major incidents. It is advocated that citizens' benefit from lessons learned and shared by experts, and everyone can be trained to use this model. Therefore, uncertainty in their decision-making can be

minimized by using the ETIQI model before, during and after any major incident in particular independently of their role using Twitter and other social media platforms.

Role using Twitter and other social media platforms

This research facilitates the use of Twitter information for decision-making by reducing the multiple challenges related to Information Quality (IQ) and information uncertainty associated with this platform in particular and with User Generated Content (UGC) in general. It is achieved through the proposed ETIQI model. It contributes to the practice of creating and processing messages and, therefore, supporting the role of sender and receiver alike. Hence, it contributes to risk communication and information management for situation awareness from a practical perspective.

- Sender: Risk Communication

This research postulates that UGC Information Quality (IQ) can be improved from a production perspective for risk communication. While actions to improve citizens' content generation are challenging to implement, initiatives based on critical thinking development before sharing content demonstrate their value in naturalistic environments. Experts suggested that to reduce decision-making uncertainty, Twitter UGC should be minimized, so information shared is based on its utility for decision-making. Moreover, if emergency organisations create content based on meeting users' needs concerning utility and timeliness, the likelihood of the propagation of rumours decreases as their reputation and network make the content shared trustable and comparable. Hence, emergency organisations have the power to improve Information Quality (IQ) on Twitter by creating risk communication strategies based on the actions suggested in this research.

- Receiver: Information Management for Situation Awareness

An effective risk communication strategy would facilitate citizens' information management strategies. Information search and processing are less cognitively demanding when information is redundant or complementary. While this expert's suggestion improves the decision-making process's speed, UGC may inevitably differ from the official version. In this scenario, the proposed model supports the reduction of uncertainty from a consumption perspective. It has been proven that IQ is context-

dependent. In the area of decision-making in emergencies using Twitter, four key IQ dimensions were highlighted: utility, timeliness, reputation and comparability. The proposal of a descriptive model (Figure 5-5, page 337) based on a reduced number of dimensions has positive implications in emergency management practice as it facilitates the decision-making process. Besides, its simplicity enables its usage with a limited need for training.

Training

While the researcher postulates that the model's simplicity facilitates its implementation with reduced training, it is paramount to highlight that the model's validity resides on the Naturalistic Decision Making (NDM) methodology. The method applied enables learning from experts and identifying best practices. The ETIQI model is based on Subject-Matter Experts (SMEs) input and can be used by any emergency stakeholder independently of their experience in the use of Twitter in major incidents.

This research provides three examples of how Twitter is used for decision-making in major incidents: a terrorist attack, a mass gathering event (eclipse) and a hurricane. Those examples can be integrated into any training material prepared, including the examples of uncertain messages shared online used as probes in this research.

5.4. Limitations of the study

This section outlines the main limitations of the study and also comments on its validity and generalizability.

Philosophical grounding and ethical considerations

By aligning the research with the Naturalistic Decision Making school, the researcher developed the study using real case scenarios and away from a lab setting. This approach limits the number of variables that can be modified in order to evaluate the hypothesis and relies on the researcher's ability to identify Subject-Matter Experts (SMEs) and relevant probes. Therefore, the study is based on an opportunistic method while selecting case studies and interviewees.

Analysis of decision-making

The analysis of decision-making in naturalistic environments presents multiple challenges concerning data collection and research scope definition. Difficulties in recording the decision-making process and decision-makers profiling complicate the ability to generalise any research findings on the area. However, through the selected method, these limitations were minimised, and questions in the interview guide were included to increase the validity and logical generalisation of their responses.

Methodology selected

Three case studies were used in combination with the Critical Decision Method (CDM) interviews. Multiple sources of evidence were used to gather relevant information. Mediated observations were performed using online channels (i.e. Skype, Twitter), which allowed the researcher to observe decision-makers. It can be argued that this is not a direct observation as the researcher was not in the same location as the subjects studied. However, this information provided contextual evidence to correctly identify the right decision-makers and gather their input to develop a descriptive model.

Sources of evidence

Multiple sources of evidence were used as part of the three case studies. This approach supported the triangulation of the data and enabled the researcher to understand better the incidents analysed. While an effort was made to obtain the same type of sources of evidence, organisational differences between Virtual Operation Support Teams (VOST) complicated information access. Two case studies benefited from the access to artefacts produced by VOST Subject-Matter Experts (SMEs). Due to the Barcelona Terrorist Attack's sensitivity and timeliness, the researcher did not have access to artefacts created by the activated VOST group. However, this team had an active Twitter account and increased social media information quality by debunking rumours.

Despite this difference, in the three case studies, the interviewees' selection was driven by a documented outcome/probes (researcher had access to a recorded decision made using Twitter). Several Subject-Matter Experts (SMEs) were not included as a not documented decision was found. While their input is not presented in the research

findings, it cannot be denied the impact on the researcher understanding on the matter and its influence in the conclusion section. The information collated was included as part of the case studies evidence.

It can also be suggested that findings are just limited to the three case studies that were opportunistically selected. This approach can be considered reactive (McEntire, 2004) as it is based on the Naturalistic Decision Making School (NDMS), which beliefs in the analysis of decision-making in real situations. To minimise the impact of this limitation and allow logical generalisation of the findings, the researcher included two questions to evaluate the impact of this constraint. Subject-Matter Experts (SMEs) were asked to list previous emergencies where they were active using Twitter, and to outline their verification protocol or process before showing them any probe. Responses collected showcased a reduced potential impact on these research findings.

Due to the infancy of this topic, statistical generalisation was not the intent. However, it is fair to acknowledge that this could not be achieved with the number of case studies selected and interviews performed. The sample is very small compared with the number of emergency stakeholders impacted in an emergency. Therefore, it is not possible to demonstrate that these research findings are statistically representative of the whole population. Nevertheless, the methodology selected and case studies used allows logical generalisation (Siggelkow, 2007). SMEs were interrogated about their experience aside from the three case studies analysed to evaluate and minimise this potential shortcoming. All respondents had experience in multiple and different types of naturalistic incidents. Hence, using a logical approach, research's findings and the ETIQI model can be applied to multiple emergency types and other potential decisions outcomes aside from those included in the model (Figure 5-5, page 337): the decision to tweet, retweet, escalate tweet to an emergency organisation and use tweet as part of a news article.

Dimensions Relationship

This is an exploratory study; therefore, the relationship and interdependency of the IQ dimensions are based on the subjects qualitative input and not on statistical evidence. All references to a relationship (positive and negative) are done from a conceptual

approach, and therefore, there is the limitation of understanding the strength of their relationship. A similar challenge had been faced by previous research in IQ. As described in Chapter 2 section 2.3, establishing quality dimensions' importance and their relationship strength is challenging to prove. Nevertheless, the outlined relationships illustrate commonalities on the internal models described by Subject Matter Experts when evaluating Information Quality (IQ) for decision-making.

Applicability and usefulness of the proposed model

Interviewees and previous research highlighted that not all emergency stakeholders use Twitter or social media. The existence of a digital divide where citizens do not access (by choice) or do not have access (lack of means, e.g. financially or technologically) to Twitter limits the usefulness of the model proposed. On the other hand, it has been highlighted that people using Twitter are very passionate about it. In turn, it becomes their *'place to go'* for updates. This finding contributes to the media dependency theory demonstrated in previous studies (e.g. Lachlan, Spence, Lin, & Del Greco, 2014), highlighting the idea of loyalty to specific communication channels.

To conclude, recommendations for future research are outlined.

5.5. Recommendations for future research

This study presents numerous avenues for further research. The most obvious one is evaluating the proposed model using a larger Subject-Matter Experts (SMEs) population and in different incident types (e.g. a pandemic). A survey can be attempted to understand better and evaluate the relationship strengths between the Information Quality (IQ) dimensions. In addition, the fitness of the model can be evaluated in different decisions or using different social media platforms.

Building on the present findings, several new research questions could be evaluated. For example, using Knowledge Audit Method (KAM) differences between novice and experts while analysing the credibility of content posted on Twitter could be used identified, or using Goal-directed Task Analysis (GDTA) research can be developed to evaluate goals and sub-goals achieved while using Twitter information.

Additionally, findings can be used to develop a list of emergency management software requirements to support risk communications and information management during non-routine incidents.

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Appendix

Appendix 1 Twitter front-end description

Login

Twitter's brand colour is blue, and this is translated to the full website visual and their app. The front-end website (Figure Appendix 1-1) has a login/account access on the right top, search option on the left, a horizontal navigation menu, and two content-based displays. On the left side, users can find a list of key terms, and on the middle/right, full tweets are displayed.

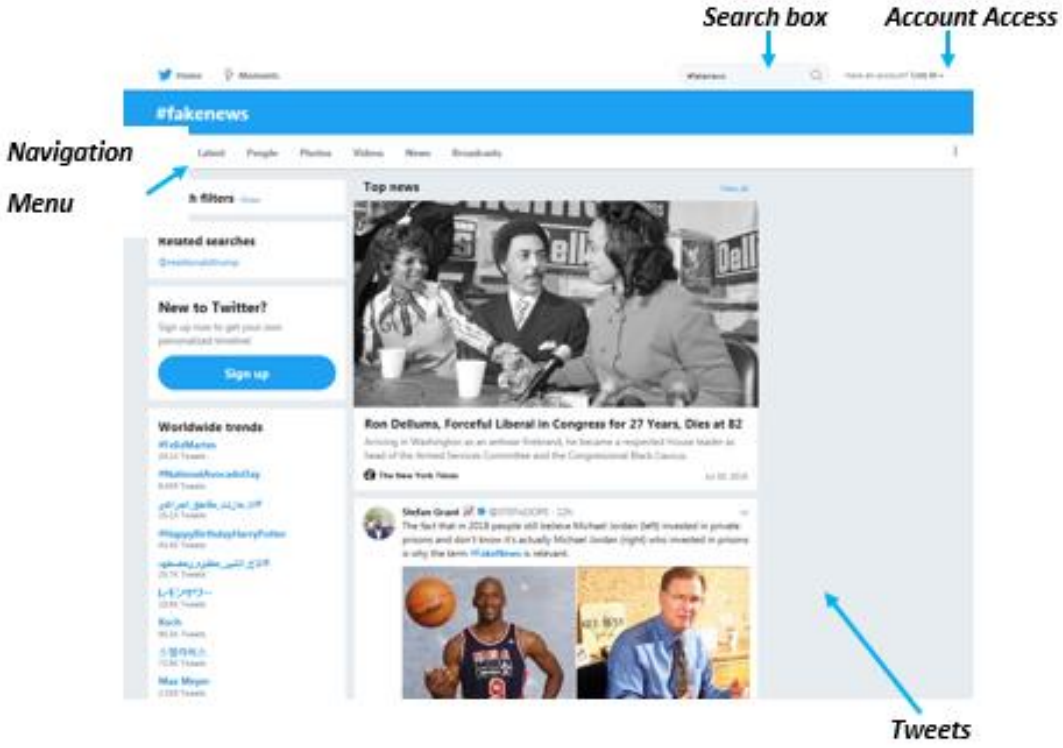


Figure Appendix 1-1 Twitter navigation

User registration

Twitter allows any Internet user to find information without registering; however, to compose tweets and establish a network, users must create a profile. Registering is relatively easy, and it is required the selection of a unique username (@), and the provision of a unique e-mail account or a phone number. Therefore, it is not possible to create multiple accounts using one e-mail address. While creating the account, users are asked to identify their interests and accordingly, users to follow are suggested by the platform. Profiles allow users to include a description, a profile image and a background

image. As described in Figure Appendix 1-2, it is possible to include websites URL, date of birth and the account holder location (Twitter, 2016a).

Figure Appendix 1-2 Example of a Twitter profile

Accounts that deemed as public interest can request a blue verified badge to showcase this status. This symbol appears next to the account's username in the profile and search results.

Content Generation: tweets

Twitter uses tweets or 140-character messages (Twitter, 2016a). Recently, in November 2018, the number of characters allowed increased to 280 (Rosen, 2017; Rosen & Ihara, 2017). Figure Appendix 1-3 shows the features allowed while composing a tweet on Twitter: This platform allows users to share text, images, short videos, URL links, polls, audio and much more. It is possible to observe (Figure Appendix 1-3) that Twitter post creation functionality present a larger area for text input and provide additional features at the bottom left area. The submission button is located on the right side.

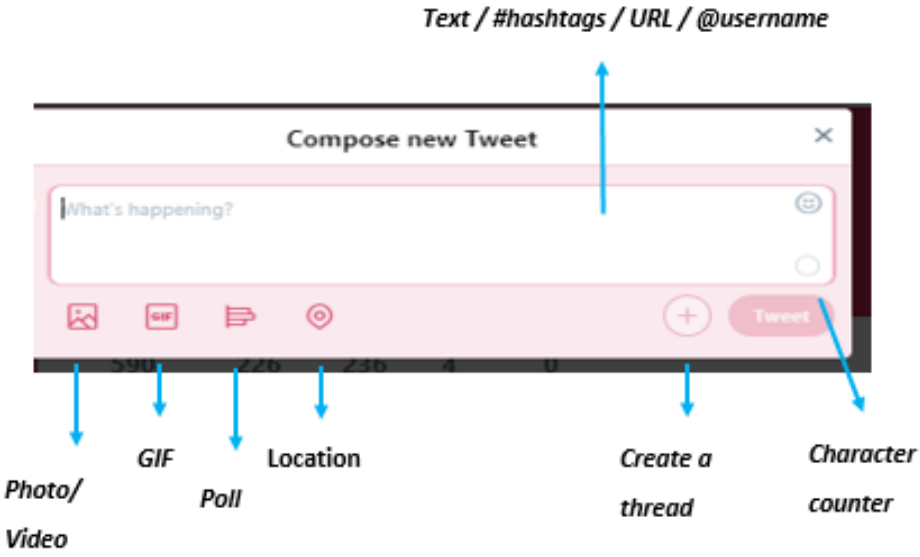


Figure Appendix 1-3 Twitter post creation functionality (Tweets Anatomy)

Search information

Twitter provides users with the functionality to search for queries in their database. A search box is located at the top right of Twitter's interface and allow searches of up to 84 characters. Queries can be sentences, hashtags, words, usernames or profile names. Further search parameters can be accessed through the Advanced Search webpage (https://Twitter.com/search-advanced). Additional parameters can be defined in this webpage, including keywords, users, locations, and dates (Figure Appendix 1-4).

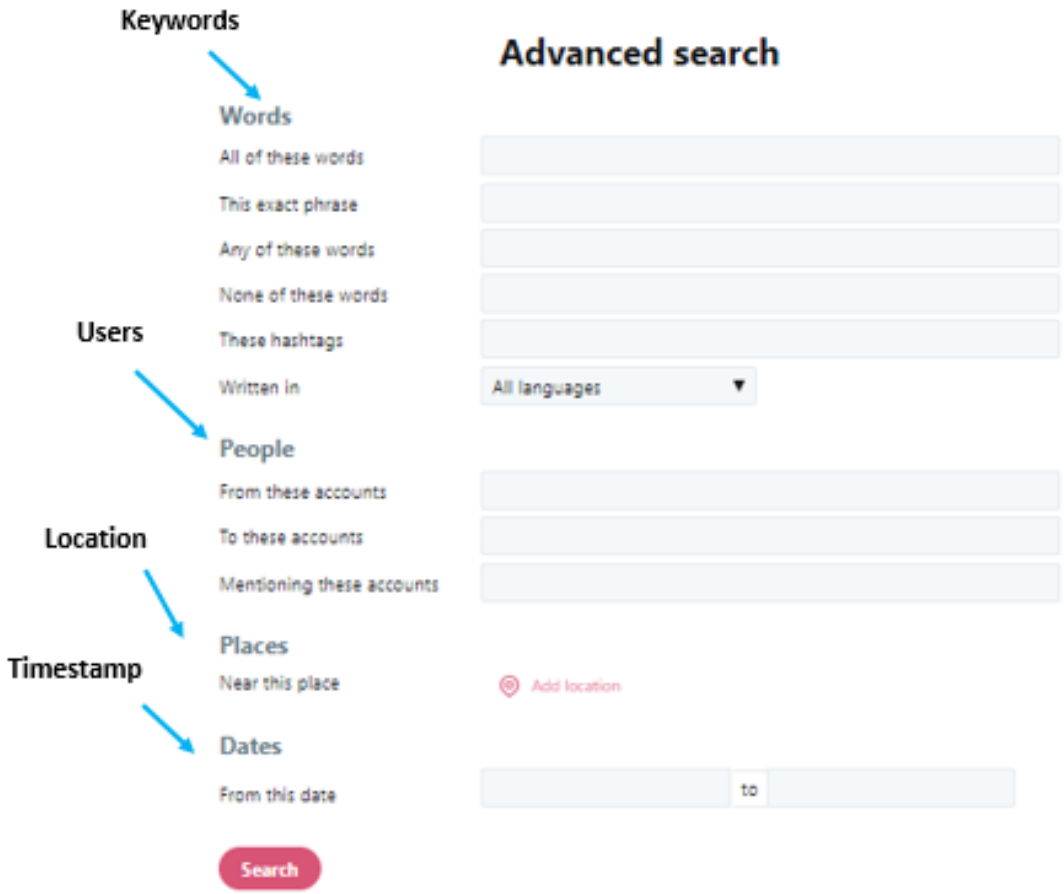


Figure Appendix 1-4 Twitter advanced search screenshot

Appendix 2 The back end of Twitter

Twitter data as a whole is considered big data which can be structured, semi-structured or unstructured. A new breed of databases has been developed to host this data which does not follow the typical structure of a relational database with rows and columns. Examples are Neo4j, Voldemort, Cassandra, and Mongo DB. These new type of databases are being used by social media businesses such as Facebook and Twitter. The selection of one or another database is motivated by the type of user-generated data created and stored.

Twitter provides an API which facilitates the extraction of relevant information from its database. Using Twitter API, metadata from different users and for unique users can be accessed. However, there is a temporal limitation to restrict the access to historical data (Twitter, 2018). Tweets use JSON-encoded (JavaScript Object Notation) objects and attributes which belong to four data dictionaries: Users, Entities, Extended Entities and Places all 'child' objects of the 'parent' object Tweet. Table Appendix 2-1 presents a summary of Twitter entities accessible through Twitter's API. This information can be used while coding to access to Twitter's data.

Object	Description	Attributes
Tweet object	Tweets are the basic atomic building block of all things Twitter. Tweets are also known as *"status updates."* The Tweet object has a long list of 'root-level' attributes and they are also the 'parent' object to several child objects.	id, id_str, text, source, truncated, in_reply_to_status_id, in_reply_to_status_id_str, in_reply_to_user_id, in_reply_to_user_id_str, in_reply_to_screen_name, user, coordinates, place, quoted_status_id, quoted_status_id_str, is_quote_status, quoted_status, retweeted_status, quote_count, reply_count, retweet_count, favorite_count, entities, extended_entities, favorited, retweeted, possibly_sensitive, filter_level, lang, matching_rules, current_user_retweet, scopes, withheld_copyright, withheld_in_countries, withheld_scope
User object	The User object contains public Twitter account metadata and describes the Tweet. Users can be anyone or anything. They Tweet, Retweet, add Quotes to Tweets, follow others, create lists, have a home timeline, can be mentioned, and can be looked up in bulk.	Id, id_str, name, screen_name, location, url, description, derived, protected, verified, followers_count, friends_count, listed_count, favourites_count, statuses_count, created_at, utc_offset, time_zone, geo_enabled, lang, contributors_enabled, profile_background_color, profile_background, profile_background_, profile_background_tile, profile_banner_url, profile_image_url, profile_image_url_https, profile_link_color, profile_sidebar_border_color, profile_sidebar_fill_color, profile_text_color, profile_use_background_image, default_profile, default_profile_image, withheld_in_countries, withheld_scope
Geo object	Tweets can be associated with a location, generating a Tweet that has been 'geo-tagged.' Tweet locations can be an exact 'point' location or a Twitter Place with a 'bounding box' that describes a larger area ranging from a venue to an entire region.	• **Place object**: id, URL, place_type, name, full_name, country_code, country, bounding_box, attributes • **Bounding box**: coordinates, type • **Coordinates object**: coordinates, type

Object	Description	Attributes
Entities Object	Entities provide metadata and additional contextual information about content posted on Twitter. The entities object is a holder of arrays of other entity sub-objects.	Hashtags, media, urls, user_mentions, symbols, polls • Hashtag object: indices, text • Media object: display_url, expanded_url, id, id_str, indices, media_url, media_url_https, sizes, source_status_id, source_status_id_str, type, url • Media size object: thumb, large, medium, small • Size object: w, h, resize • URL object: display_url, expanded_url, indices, url, status, title, description • User mention object: id, id_str, indices, name, screen_name • Symbol object: indices, text • Poll object: options, end_datetime, duration_minutes
Extended Entities	Extended entities are used to host native media (shared with the Tweet user-interface as opposed via a link to elsewhere). All Tweets with attached photos, videos and animated GIFs will include an extended_entities JSON object.	Single media array of media objects: • Media object: display_url, expanded_url, id, id_str, indices, media_url, media_url_https, sizes, source_status_id, source_status_id_str, type, url • Media size object: thumb, large, medium, small • Size object: w, h, resize

***Table Appendix 2-1 Summary of Twitter entities accessible through Twitter API* (Twitter, n.d.)**

Appendix 3 Sample News Python Script

```
# -*- coding: utf-8 -*-
"""
@author: Silvia Planella
"""
title = []
Newspaper = []
link= []
Summary=[]

try:
   from urllib.parse import urlparse, parse_qs
except ImportError:
    from urlparse import urlparse, parse_qs

from urllib import urlencode

from lxml.html import fromstring
from requests import get


url="https://www.google.com/search?q=Oregon+Eclipse+hoax+Twitter&tbs=cd
r:1,cd_min:8/15/2017,cd_max:8/22/2017&tbm=nws&ei=zav1WvqeMMj0Usn4
okg&start=20&sa=N&biw=1366&bih=637&dpr=1"
raw = get(url).text
page = fromstring(raw)

#print title
for i in page.cssselect("div.g h3.r a"):
   title.append(i.text_content())
   print (i.text_content())

for i in page.cssselect("div.slp span.f"):
   Newspaper.append(i.text_content())
   print (i.text_content())
#print url
for result in page.cssselect(".r a"):
   url = result.get("href")
   if url.startswith("/url?"):
      url = parse_qs(urlparse(url).query)['q']
   link.append(url[0])
   print(url[0])

for i in page.cssselect("div.st"):
   Summary.append(i.text_content())
   print (i.text_content())
```

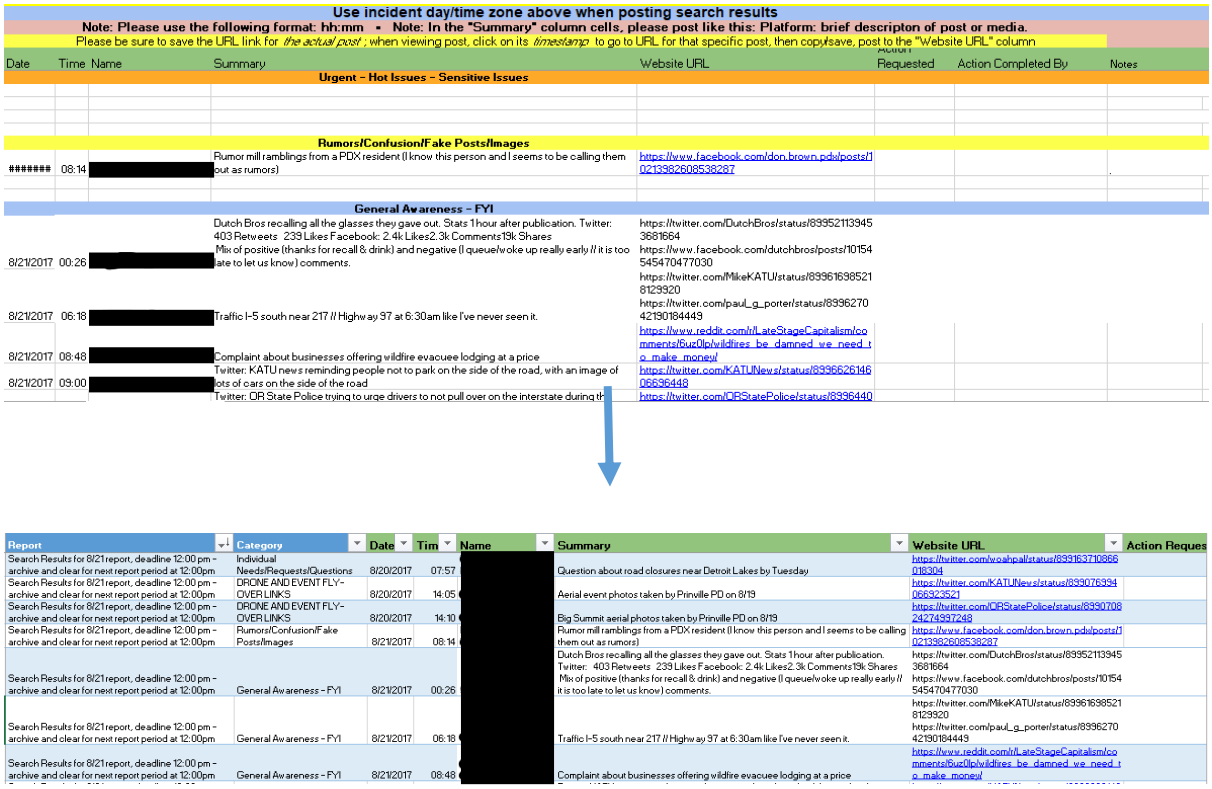
```
import pandas as pd

df=pd.DataFrame(title,columns=['Title'])
df['Newspaper']=Newspaper
df['Link']=link
df['Summary'] = Summary

result.to_csv('ORNews.csv', encoding='utf-8')
```

Appendix 4 VOST Workbook data manipulation example

Each entry in the dataset is qualified, including Date, Time, Name, Summary, Website URL, Action Requested, Action Completed By, and Notes. The format used is not suitable for the analysis required; therefore it has been transferred to an excel dataset where each entry was qualified referring to report included, date, category, content, Website URL (Figure Appendix 4-1).



Use incident day/time zone above when posting search results							
Note: Please use the following format: hh:mm • Note: In the "Summary" column cells, please post like this: Platform: brief descripton of post or media.							
Please be sure to save the URL link for *the actual post* ; when viewing post, click on its *timestamp* to go to URL for that specific post, then copy/save, post to the "Website URL" column							
Date	Time	Name	Summary	Website URL	Action Requested	Action Completed By	Notes
Urgent – Hot Issues – Sensitive Issues							
Rumors/Confusion/Fake Posts/Images							
########	08:14	[redacted]	Rumor mill ramblings from a PDX resident (I know this person and I seems to be calling them out as rumors)	https://www.facebook.com/don.brown.pdx/posts/10213982608538287			
General Awareness – FYI							
8/21/2017	00:26	[redacted]	Dutch Bros recalling all the glasses they gave out. Stats 1hour after publication. Twitter: 403 Retweets 239 Likes Facebook: 2.4k Likes2.3k Comments19k Shares Mix of positive (thanks for recall & drink) and negative (I queue/woke up really early // it is too late to let us know) comments.	https://twitter.com/DutchBros/status/893952113945681664 https://www.facebook.com/dutchbros/posts/10154545470477030			
8/21/2017	06:18	[redacted]	Traffic I-5 south near 217 // Highway 97 at 6:30am like I've never seen it.	https://twitter.com/MikeKATU/status/899616985218123920 https://twitter.com/paul_g_porter/status/899627042190184449			
8/21/2017	08:48	[redacted]	Complaint about businesses offering wildfire evacuee lodging at a price	https://www.reddit.com/r/LateStageCapitalism/comments/6uz0lp/wildfires_be_damned_we_need_to_make_money/			
8/21/2017	09:00	[redacted]	Twitter: KATU news reminding people not to park on the side of the road, with an image of lots of cars on the side of the road	https://twitter.com/KATUNews/status/899662614606696448			
			Twitter: OR State Police trying to urge drivers to not pull over on the interstate during th	https://twitter.com/ORStatePolice/status/899644			

Report	Category	Date	Tim	Name	Summary	Website URL	Action Reques
Search Results for 8/21 report, deadline 12:00 pm – archive and clear for next report period at 12:00pm	Individual Needs/Requests/Questions	8/20/2017	07:57	[redacted]	Question about road closures near Detroit Lakes by Tuesday	https://twitter.com/woahpall/status/899163710866018304	
Search Results for 8/21 report, deadline 12:00 pm – archive and clear for next report period at 12:00pm	DRONE AND EVENT FLY-OVER LINKS	8/20/2017	14:05	[redacted]	Aerial event photos taken by Prinville PD on 8/19	https://twitter.com/KATUNews/status/899076994066923521	
Search Results for 8/21 report, deadline 12:00 pm – archive and clear for next report period at 12:00pm	DRONE AND EVENT FLY-OVER LINKS	8/20/2017	14:10	[redacted]	Big Summit aerial photos taken by Prinville PD on 8/19	https://twitter.com/ORStatePolice/status/899070824274937249	
Search Results for 8/21 report, deadline 12:00 pm – archive and clear for next report period at 12:00pm	Rumors/Confusion/Fake Posts/Images	8/21/2017	08:14	[redacted]	Rumor mill ramblings from a PDX resident (I know this person and I seems to be calling them out as rumors)	https://www.facebook.com/don.brown.pdx/posts/10213982608538287	
Search Results for 8/21 report, deadline 12:00 pm – archive and clear for next report period at 12:00pm	General Awareness – FYI	8/21/2017	00:26	[redacted]	Dutch Bros recalling all the glasses they gave out. Stats 1hour after publication. Twitter: 403 Retweets 239 Likes Facebook: 2.4k Likes2.3k Comments19k Shares Mix of positive (thanks for recall & drink) and negative (I queue/woke up really early // it is too late to let us know) comments.	https://twitter.com/DutchBros/status/893952113945681664 https://www.facebook.com/dutchbros/posts/10154545470477030	
Search Results for 8/21 report, deadline 12:00 pm – archive and clear for next report period at 12:00pm	General Awareness – FYI	8/21/2017	06:18	[redacted]	Traffic I-5 south near 217 // Highway 97 at 6:30am like I've never seen it.	https://twitter.com/MikeKATU/status/899616985218123920 https://twitter.com/paul_g_porter/status/899627042190184449	
Search Results for 8/21 report, deadline 12:00 pm – archive and clear for next report period at 12:00pm	General Awareness – FYI	8/21/2017	08:48	[redacted]	Complaint about businesses offering wildfire evacuee lodging at a price	https://www.reddit.com/r/LateStageCapitalism/comments/6uz0lp/wildfires_be_damned_we_need_to_make_money/	

Figure Appendix 4-1 EC- search tab data preparation example

Appendix 5 Interview Introduction / Data collection consentment

My name is Silvia Planella and I'm a current PhD student at the University College of Cork (Ireland). For my PhD dissertation I am researching the use of social media (Twitter) for decision-making in emergencies. I am currently interviewing experts in the area and after your participation in <<case study / reference to probe>>.

The interview will require approximately 30 minutes to complete. There is no compensation for responding nor is there any known risk. In order to ensure that all information will remain confidential, all answers will be anonymised. Data collected will be shared with only my PhD supervisors and myself.

If you choose to participate in this research, please answer all questions as accurate as possible. With your permission, all answers will be audio recorded and transcribed. Those will be password protected for security purposes. Participation is strictly voluntary and you may refuse to participate at any time.

Thank you for taking the time to assist me in my research. The data collected will provide useful information regarding the importance of information quality in decision-making in emergencies using Twitter. If you would like a copy of your interview transcript, please feel free to contact me anytime via the email address below. Selecting the "Accept" button will indicate your willingness to participate in this study. If you require additional information or have any questions, please contact myself, or my supervisor at the email or phone number listed below.

Yours sincerely,

Silvia Planella
111223484@ucc.ie

Appendix 6 Interview guide

Section	Description	Objective	Question
Participant Profiling	Experience	*Establish participant experience in emergencies*	Describe to us what your experience in emergencies is? Can you list what emergencies/disaster have you witness or responded to? (years)
Participant Profiling	Experience en social media emergency management	*Establish if the participant has organisation support and existing resources available to them*	Social media is a relatively new tool used in emergency management. Are you aware if ***<<participant organisation>>*** use Twitter during emergencies? Can you describe how it is used? What type of resources has your organisation available to support the use of Twitter for emergency management? Guidelines Training programs Information Systems In your opinion, what are the strengths and weaknesses of using Twitter during emergencies?
Participant Profiling	Team activation	*Make participant think about his/her experience & the benefits/weaknesses of Twitter*	As part of your experience using Twitter during emergencies, you were active in <<case study reference>>, can you recall how your team was activated?
Participant Profiling	Goal of activation		What was the purpose of the activation? How did Twitter help you to achieve these goals? Sharing information Obtaining information Can you describe your role in the team?

Section	Description	Objective	Question
Verification Protocol	Decision-making process	Objective: *Discover the decision-making process for: (1) sharing information in Twitter, and (2) take action using information from Twitter*	What steps would you follow before retweeting a message on Twitter to verify the information? Does your organization have a standard protocol? If so, can you describe it? What steps would you follow to verify the information of a tweet before sharing it with the organization that activated your team? Does your organization have a standard protocol? If so, can you describe it?
Probes	Critical Decision Making	*Discover the decision-making process for: (1) sharing information in Twitter, and (2) take action using information from Twitter*	I am going to show you now a number of Twitter post (probes) retrieved from different sources related to the eclipse. I would like you to look at them and try to describe the rationale behind, and steps are taken to qualify them as rumours or miss information. <u>Probes</u> - Can you read the tweet for a moment and explain to me your interpretation of it? (Context) - Have you seen this message before? Yes / No - <u>if yes ask in which circumstances</u> - How would you evaluate the information contained in it? - Of the following dimensions (show them) which ones do you think they are relevant to this post? - Which, if any, should be considered to evaluate the information?

Section	Description	Objective	Question
Other comments		*Learn the quality information dimensions (control variables) that are more relevant for: (1) sharing information in Twitter, and (2) take an action using information from Twitter.*	To finalize, here is a list of dimensions related to information quality extracted from the literature. Can you sort them according to their importance in relation to: How important is for you for risk communication / situation awareness? *List: Accuracy, Consistency, Objectivity, Timeliness, comparability, Accessibility, Comparability, Believability, Dimensions, Completeness, Understandability, Relevancy, Reputation, Verifiability, Amount of Data, Interpretability, Rep. Conciseness, Rep. Consistency, Twitter Response Time, Twitter Security* Is there any other variable that you think it should be considered?

Towards an online information quality model for major incidents:
A naturalistic decision-making study

Interview Guide Part Four - Coding

INTERVIEW REF NO.:	Date:

This evaluation form is to be completed after each interview.

Profiling

Experience in Emergency Management

Type of Stakeholder / decision maker:

Type of emergencies:

Organization use of social media during emergencies

Organization use

Guidelines:

Training programs:

Information Systems used:

Twitter Strengths

Twitter Weakness

SMEM

Participant use of Twitter during emergencies

Personal use of Twitter: Yes / No

Purpose use: Share information / Obtain information

Outcome:

Decision-making process

Steps described by interviewee: <<list>>

Decision-making steps when decision = retweet:

➔ Standard protocol: Yes /No

Decision-making steps when decision = offline action:

➔ Standard protocol: Yes /No

Control Variables

Dimension	Input	Output
Believability		
Value-added		
Relevancy		
Accuracy		
Interpretability		
Ease of understanding		
Accessibility		
Objectivity		
Timeliness		
Completeness		
Reputation		
Representational Consistency		
Ease of operation		
Concise representation		
Appropriate Amount of Information		

Appendix 7 Certificate of Appreciation

A certificate of appreciation was given to each volunteer, including the researcher (Figure Appendix 7-1).

Figure Appendix 7-1 Hurricane Harvey Certificate of Appreciation VOST